Sustainable Mobility System and Human Wellbeing: Design Enquiry and Case Study of Bhutan

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Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or processional qualification except as specified. All the literature sources are fully cited in the main text and provided as a reference list at the end.

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Executive summary

Applying research through design methodology this study enquires mobility as a complete system, which is cybernetically oriented and contextual. For the mobility system to remain sustainable in future and to enable better quality of life is a systemic challenge. Therefore, the system enquiry has the potential to add substantial knowledge in science by defining systemic problem situation, which is often complex and is invisible to the researcher. Therefore, list of variables that potentially define rough image of mobility as a system is identified, which is negotiable keeping in mind the original cybernetic rather than reducing it to simplified object. The complete mobility system is defined by network of variables influencing effect called as effect system and their associated feedback effects are identified for further research work. Therefore, the variables influencing effects are considered as semantic building block of mobility system, which may be used as multiple research problem identification. 22 different global variables are identified for further analysis to describe mobility as a system and its image projection with the help of Vester Sensitivity Model and scenario logic for future decision support. The scenarios in this study are normative value proposition, which is used to position the contextual mobility system problem situation for policy design and innovative exploitation of the system in addressing sustainable development. To support the normative description of the mobility system, empirical re-conformation is further analysed by conducting the case study referring to historical and current mobility development trend of Bhutan, which is shown as an explorative system and its description in addressing the transition to sustainable system in future horizon. The detail analysis of system cybernetic and case study of Bhutan shows, behaviour correction of user and system re-orientation is necessary condition for sustainable development, which is very complex owing to multiple uncertainties. The current analysis recommends the service-oriented market development from the image projection of mobility system is more appropriate than product-oriented market growth for sustainable mobility system design.

There are 7 main chapters and an annex list covering the detail mobility system enquiry. The first chapter is a comprehensive summary concerning mobility system problem situation that introduces the systemic complexity. The second chapter deals with theoretical conception of complex system based on literature sources and the methodological shortfall for complex system research. The same chapter introduces the mobility system in current situation based on existing literature sources, which is used as building block for mobility system variable definition in chapter 3. Since the variables that are introduced for mobility system description is complex and context dependent even though it is the intention of the observer to design sustainable system in future, the literature sources are generalized and a list of 22 different global variables is identified in chapter 3. The case study of Bhutan is introduced in chapter 4 to augment the defined set of variables list and influence factors. These variables are subject to further refinement in cybernetic pattern for decision support. In chapter 5the variables are further examined with the help of Vester Sensitivity Model software tool to visualize the

potential network of influence factors called as effect system and the feedback effect. Chapters 3, 4&5are the major contribution from this study as it leads to further research problem definition and multiple research problem situations, which can be found also in annex list at the end. Chapter 6 introduces the mobility system vision definition, which is based on system analysis and identified critical variables for the design of robust system scenarios resulting from the defined vision and goal for strategy formulation. The future scenarios, uncertainty condition, strategies and case study of Bhutan are reflected in chapter 6. Chapter 7 summarizes the normative descriptive values of mobility system and provides comprehensive research finding. The context and magnitude concerning how far can the system be sustainable is examined considering the case study of Bhutan, where statistical data is used to quantify the normative description of mobility system image. Thus, the chapters are highly interconnected that each topic is often referenced to previous chapter and the following chapters in iterative order.

Note:

Although the system enquire has to be in a participatory format and is a core for mobility system image projection, there is some limitation pertaining to stakeholder participation. The expert stakeholder consultation is still pending due to pandemic situation, which will have to be carried out in future. However, the variable validation process and system negotiation was conducted alternatively with international students in the form of workshop and by using online questionnaire. The workshop is conducted with the support of Vester Sensitivity Model addressing real time system enquiry supported by the online stakeholder data input. Therefore, this study can be used as an introductory baseline concerning the mobility system design for policy recommendation by additionally involving the expert group on a contextual basis internationally. The major guiding question for the design of sustainable mobility system is on how to optimize mobility as a service industry with the inclusion of hard and soft factors listed while defining the mobility system variable. Furthermore, the effect system quantification is additional research endeavour for future researcher.

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List of abbreviations

ADB	Asian Development Bank
AFT	Aviation Transport Fuel
APS	Analysis Projection Synthesis
AS	Active Sum
ASI	Avoid Shift Improve
BEA	Bhutan Engineering Service, Bhutan
BEUC	The European consumers Organization
BPC	Bhutan Power Corporation
BRT	Bus Rapid Transit
CH_4	Methane gas
CO	Carbon Monoxide
DC	Direct current
DGPC	Druk Green Power Corporation, Bhutan
DoR	Department of Road, Bhutan
DRE	Department of Renewable Energy, Bhutan
DRT	Demand Responsive Transportation
ET	Economic Times, Delhi
EU	European Union
EV	Electric Vehicle
GCF	Green Climate Fund
GDP	Goss Domestic Product
GHG	Green House Gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJ	Gigajoule
GMA	General Morphological Analysis
GNH	Gross National Happiness
GNHC	Gross National Happiness Commission
HSU	Hartridge Smoke Unit
HV	Heavy Vehicle
ICT	Information and Communication Technology
IDB	Inter-American Development Bank
IEA	International Energy Agency
IEEE	Institute of Electric and Electronic Engineering
IEGS	Institute for Global Environmental Strategies, Japan
IFAD	International Fund for Agricultural Development
IMPRO-car	Environmental Improvement of Passenger car
IPCC	Intergovernmental Panel on Climate Change
IPT	Intermediate Public Transport

IRU	International Road Transport Union
ITDP	Institute for Transportation and Development policy, Chennai
ITF	International Transport Forum
JICA	Japan International Cooperation Agency
KL	Kiloliters
km	Kilometer
KV	kilovolt
KVA	kilovolt-ampere
L	Liter
LCA	Life Cycle Assessment
LRT	light-rail Rapid Transit
LV	Light Vehicle
MDGs	Millennium Development Goals
MoEA	Ministry of Economic Affairs, Bhutan
MoIC	Ministry of Information and Communication, Bhutan
MoWHS	Ministry of Works and Human Settlement, Bhutan
MT	Million Tons
MV	Medium Vehicle
MW	Megawatt
MWh	Megawatt hours
N_2O	Nitrous oxide
NC	National Council of Bhutan
NCV	Net Calorific Value
NEA	Nuclear Energy Agency
NEC	National Environment Commission of Bhutan
NMVOC	Non-Methane Volatile Organic Compounds
NO_2	Nitrogen dioxide
NSB	National Statistics Bureau, Bhutan
NTGMP	National Transmission Grid Master Plan of Bhutan
Nu.	Ngultrum, Bhutan currency
OECD	Organization for Economic Cooperation and Development
P	Product
PKT	Passenger km Travelled
PM	Particulate Matters
PNHW	Primary National Highway, Bhutan
PS	Passive Sum
PWD	Public Work Department, Bhutan
Q	Quotient
reFINE	Research for Future infrastructure in Europe
RNG	Renewable Natural Gas
RoW	Right of Way
RSTA	Road Safety and Transport Authority, Bhutan
SAM	Shared Autonomous Mobility

SCR	Selective Catalytic Reduction
SDGs	Sustainable Development Goals
SIM	Seamless Integrated Mobility
SMR	Steam Methane Reforming
SNHW	Secondary National Highway, Bhutan
SO_2	Sulfur dioxide
SPSS	Statistical Package for the Social Sciences
SUV	Sport and utility vehicles
tCO_{2e}	Ton Carbon dioxide equivalent
TJ	Terajoule
TV	Television
TW	Two wheelers
UN	United Nations
UNCRD	United Nations Centre for Regional Development
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VGS	volunteered Geographic Information System
WB	World Bank
WHO	World Health Organization

1 Introduction

When the *Limits to Growth* model was defined for the global system transition to sustainable development, the idea of explorative and multiple future alternatives was identified critical, which is a basic requirement for the growth limits enforcement mechanism [1]. Therefore, interdisciplinarity is main driver for the change rather than focusing on linear and specific research problem to find sustainable solutions. The publication of *World Commission on Environment and Development: Our Common Future*, defines sustainable development as *development model that ensures the needs of the present without compromising the ability of future generations to meet their own needs* [2]. De-growth strategy became the leverage point to define sustainable development, which is based on de-coupling economic growth from socio-environment for the desired development model and the design of healthy socio-ecological system [1]. As soon as the desired development model is introduced, multiple future alternatives become an integral part of any system. Different concepts and theories have been emerging to address these global challenges especially on how to slow down the growth through systemic intervention. The publication of Club of Rome *stewarding sustainable transformation* lately identifies, interdependency, interdisciplinary and dynamism are necessary conditions to deal with the systems and their complex nature and are often time disposed with criticality of uncertain future [3]. All together these scenarios curtailed for the need to redefine 8 Millennium Development Goals (MDGs) [4] to 17 Sustainable Development Goals (SDGs), which are humanitarian global systems and our common future [5]. The ambitious targets and objectives of SDGs are heavily dependent on transport and logistics system at various levels for the control of growth and de-growth. Sustainable transport and logistics system sometimes known as sustainable mobility is itself a complex system which is built within different external and internal factors of almost every SD goal [6].

Designing mobility as a system, which is sustainable is therefore very necessary. Assigning right vision, mission, goal and objectives to mobility system can only be possible after understanding the properties of mobility as a complete system that ensures the global vision of 17 SDGs. This would mean transforming current transport and logistics system to sustainable mobility system will need complete set of transport and logistics sub-system modification. Transport and logistics system is composed of infrastructure, technology, people, economy, environment and aesthetics of human life style [6]. This combination altogether makes mobility system to be identified as complex system, whose functioning has strong influence on human-wellbeing. Altogether their transition is very unpredictable and irreducible to single isolated system owing to complex interdependency [7]–[11].

Current transport and logistics system metabolism combined with unplanned infrastructure is too much material and energy intensive to cater sustainable socio-economic progress [12]–[14]. In such a system, de-coupling economic growth from socio-environment to achieve human-wellbeing is near to impossible. Decisively such a system transforms the product design and technology change, strongly promoting consumerism instead of sustainable mobility system development [15]–[18]. Sustainability has also to do with *pricing and psychology of consumption* [19]. Therefore, leveraging alternative mobility system development is heavily dependent on modification of the system as a whole, where the lesson learned from the experience of the past, present and exploration of alternative future with the inclusion of ecological wellbeing in fair and free conditions are pre-requisite [10], [11], [20]. Thus, the detail analysis of current mobility system and projection of alternative future scenario is necessary for the development of sustainable system, which is inclusive in terms of safety, environment friendliness, efficient, affordable and convenient, that stabilises human wellbeing by cross-cutting other global systems [6].

The twin challenges of resource scarcity and growing demand for better quality of life further disposes with the challenge to redefine mobility system as self-sustainable in terms of infrastructure, technology and fuel source instead of pushing too much towards consumerism [15]–[18]. Therefore, the alternative mobility system should inclusively integrate the human behaviour pattern and their reactions to the alternative availability. They are highly unpredictable, uncertain and are with greater degree of complexity. All together these aspects are also placing agenda and debate on climate change, which has significant impact on sustainable socio-economic development [5]. Therefore, there is no straightforward and easy way to address the current problematic mobility system development as they are interconnected within different mobility system variables.

System thinking and design thinking have contributed the epistemological world view to address such problem complex [21]–[24]. Ulrich et al.[21], suggest that the successful system design has to be as much holistic and practical, that the system boundary keeps increasing for the design to be deployed. The avoid-shift-improve strategy as a measure to solve the urban mobility is already realised very pragmatic [25]. However, for the success of sustainable mobility system design, extension of its system boundary and epistemology of their development in the future scenarios are critical. Thus, the design of sustainable mobility system envisions much wider mobility goal that will value the well-being of people, environment and economy addressing both urban and rural dynamics.

To understand the complex dynamics of mobility system and their design criteria, identification of right variables that define the system and leverage their transition to sustainable mobility system is necessary. Therefore, this study seeks to answer the questions: Which variables sufficiently define the mobility as a system in the present situation? What are the possible leverage points for the transition to sustainable mobility system development in the future? To what magnitude can it be sustainable? And what are the challenges and opportunities for such transition in terms of socio-ecological change? Therefore, the study will potentially contribute to the ontology and epistemology of future sustainable development scenarios for designing mobility system vision, goals and objective that will support policy and planning decision internationally [26].

2 Characteristics of complex system

The complex system, because of the interdependent nature of its constituent agent and dynamic pattern of their behaviour is characterized by the contextual conditions, involving the aggregated terms such as emergence, self-regulation, cooperation, specialization, inclusion and embedding [27]. The constituent agent of a complex system resembles the cells in an organism or atomic particles of an object, which define the ontology of the system as it exists [8]. On the other hand the knowledge of this complex reality is reduced epistemologically, which defines how the complexity cannot be controlled by the human's limited knowledge of the system [21]–[24].The aggregated terms define the behaviour pattern established by the agent in the system, which includes both the ontology and epistemology [11]. Ontology is the nature of reality whereas the epistemology is how the reality is known [26]. Therefore, the complex system definition cannot follow the practice of reductionism [27]. Furthermore, the behaviour patterns established by the agent of the system cannot be simply reduced to single agent to understand its emergence owing to their interdependency [27]. Thus, observation of complex system in contrast to reductionist approach will be totally different from that of emergentism [27]. Emergentism is a concept that defines matter, energy and space, which evolve through agent interaction to form an object but exclusive of human behaviour patterns involved in it. With the inclusion of social behaviour pattern, the system's complexity tends to grow, which appear to be very difficult agent of the system [21]–[24]. Thus, complex system in general term is non-reducible heterogeneous object whose behaviour pattern is determined by the agent interaction and their interdependency [8]. System disintegration is mostly seen if the interacting link between the human agents and object or form of that system is weakened. While the problem of disorderliness by means of reductionism exists in the physical and biological system in which single cell or atomic particle cannot fully define the functioning of an organism or shape of an object, it is also true in the science of man-made complex system, the science of society or social sciences in which singularity judgment does not define the system fully [8]. The economy, social network, transport system, internet network, cultural divergence of society are some commonly known examples of complex system in social science that has emerged from the simply non-reducible original entropy or disorderliness over the time, which can be viewed metaphorically as the evolution of a living organism or shape of an object [8].

The complex systems are therefore subject to methodological drawbacks for identifying their disorderliness or disorientation [8], [9], [11], [28], [29]. The methodical shift from the ontological world view to ontological and epistemological worldview is notably significant for assessing the degree of entropy/system disorderliness measurement in man-made system, the governing principles for the system robustness and plurality [24]. Whereas the ontological worldview adheres to the singularity vision mostly the predefined single goal of the reality, the epistemological worldview is much broader way of defining the vision which is future oriented with multiple possible options as alternative futures to co-exist with the reality [30]. The alternative futures therefore provide the insight into planning and policy design decision support of disoriented system to more robust and optional system. Furthermore, the cybernetics of the system in which autonomy for the observed and the observer is also applicable for complex system analysis [31]. Whereas the observed system indicates the purpose of the system called as the first order cybernetic and that of the observer views the system for its own contextual need, which is called as the second order cybernetics. First order cybernetics deals with the system as it is and second order cybernetics deals with the contextual need and the perspectives of the observer, the system as it ought to be [11]. Both approaches are useful for understanding the complex system. Hence positioning the observer in the system adds the autonomy and plurality in judgement. For this reason, the ontological and epistemological world view is necessary. The ontological world view defines system as it is and the epistemological world views allow for negotiable future scenarios [11].

In social system, the tangible and intangible objects such as the physical enabling support condition and emotional aspect the behaviour makes the system to be observed as a complex system [32]. Therefore, it is often seen in system literature the terms like critical system thinking, critical system heuristics, critical holism, total system intervention, executive type problem, overall system performance, operational research practice and systemic approach [21]–[24].Critical system thinking introduces the idea of plurality of system, critical heuristics define the boundary conditions, and critical holism, total system intervention and overall system performance reflect the systemic approach in dealing with the specified goal [21]–[24]. The boundary conditions are those aspects of the system that influences the stakeholder involvement for the negotiation and are often referred to as participatory process. Operational research and executive type problem draw the attention of what exists in the system in the current situation, the ontology and how system alteration are made, the epistemology, which determine the system's future scenario [26].These terms altogether curtail the need of methodology that can adequately define complex system. With the inclusion of social, economical and environmental aspects, the systemic thinking or thinking in systems as an alternative approach to observe system is vital for the analysis of a complex system [8], [10], [11]. Thus, understanding the complex system has dual challenge of irreducibility and methodical shortfall in most of the research findings.

2.1 Morphology of a complex system

Although different modelling techniques are available, morphology/study of form offers much wider spectrum for the analysis of complex system rather than all those available general theory of model [28], [29], [33]. Morphology is defined by the set of configurations of an object/form represented by it [33]. The morphology of complex system from the aggregated terminology is characterized by the heterogeneity, non-linear and complex non-causal relationship among the agents that form an object/component [27]. The system therefore is model relationship represented as an object/component defined by its actuating variables [8]. Design of this object can significantly influence the system's behaviour pattern and the variable sets that define the morphology of a system and their enquiring criteria. Both ontology and epistemology defined by the observer's position (inside and outside) in the system determine the image of the system [11].

The design of a complex system is dependent on the identification of appropriate set of variables that will define the system and the variables obey complex cross-impact non-causal relation rather than linear/non-linear causality [8], [34]. The ontological and epistemological worldview implies that every system model is inseparable from the intentions of the modeler. Therefore, the probabilistic theory (stochastic)/deterministic approach are relatively useless for the analysis of the logical future of multi-layered cause-effect scenario field in a given problem complex [8], [10], [11], [28]–[30], [33]. Thus, future prediction of the complex system is practically meaningless. Further the "emergent" behaviour pattern of complex system depends on collective interaction of the agent/component from the present, past and the future [35]. With the evolution of multi-layered agent/component, system's complexity has increased and therefore their behaviour cannot be treated in an isolation anymore like in the past [8], [30]. Their understanding altogether depends on specialized area of scientific discipline "system thinking" or thinking through and in system, which tend to include ontology and epistemology for the research paradigm, which is mostly missing in normal research practice [9], [11], [18]. "System thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours in the present situation with the input of present, past and future consequences, and devising modifications to them in order to produce desired effects" [36]. These skills work together for the design of system's morphology ontologically and epistemologically.

2.1.1 The need of alternative methodology for system enquiry

The non-causal problem complex of complex system faces methodological constraints, so called the problem of control and the problem of prediction [11]. In this contextual purpose, the design is embedded in system thinking with creative act, which attempts to estimate the alternative sets of behaviour patterns that would serve specified sets of goals definition [37]. So the design captures the objective of total set of variables interaction and plurality goal definition, that is represented by the design of an object or a form as model system and their interaction as explained in section 2 and 2.1.Therefore, the design contribution to complex system observation based on research through (with/by) design approach, the three-phase methodology *Analysis – Projection – Synthesis(APS)* is in a way meta-method to address such problem complex [9]–[11]. In APS approach the system is negotiable where the observer's observation from different position determines the contextual purpose, which is the representation of the system as it is, the ontological world view and negotiation with the stakeholder the epistemological world view [8]. Based on the observation made in the current situation, the research through design practice addresses the situation/scenario management and key factor assessment that will influence the identification of future uncertainties and agreement with the stakeholders for the design of a complex system, leading to plurality futures, the epistemology of the system [30]. Therefore mediation between 'is' and 'ought to be' will play critical role for the design criteria [21]–[24]. Essentially then the general morphological analysis or the design of a form as it is, finds its space methodologically to identify and investigate the total set of possible relationships or “configurations” contained in a given problem complex [28], [29], [33]. Morphology of the product, the design-semantic [38] and morphology of the system the design-cybernetics [8] are some commonly known terminologies used in the design methodology. Both aspect of research through design the semantic and the cybernetics offer identification of plurality goal and multiple future alternatives to be visualised by the observer, which is debatable with the stakeholder [8], [9], [11]. Furthermore, the software-based system enquiry like Vester Sensitivity Modelling tools is also used to analyse the system-cybernetics to cover the *Analysis* phase of APS in design method [8], [11], [39].For the system design, Vester sensitivity and cybernetic approach are very pragmatic as it covers holistically the total set of variables configuration and their cross-influencing strength in an interactive approach, which defines the ontological and epistemological world view in a participatory format [8], [9], [11].

2.1.2 The design of a system: The cybernetics

The behaviour manifested by the manmade mobility system model resembles very closely the biological system in which the system model can be metaphorically viewed as an organism and the subsystems its organs [8]. The functioning of mobility system is influenced by its subsystem as an organ in an organism [8], [27]. The ontology of mobility system model observation with the inclusion of possible subsystems, expressed as global variables of the system that will influence the whole system behaviour, analysed in the matrix based cross-impact assessment is called the bio-cybernetic effect system, according to Vester for any system enquiry [8]. Understanding the cybernetics of the variables and the degree of influence factors are the first steps modelling framework for the design of a system [8]. The cybernetic pattern of variables and their influence factors exerted on the system are in most cases omitted for the design of policy and or for the planning purposes, which is the first mistake of decision-making process [8], [27]. The more robust system enquiry however depends on the ontological and epistemological world view by means of first and second order cybernetics with the inclusion of observer position in the system, which will provide an opportunity to visualise the system in its complete shape [8], [11], [21]–[24], [28], [29], [33]. The complete system visualization is often time accompanied with multiple options on a contextual basis for analytical decision support. Thus, it is obvious to have high degree of wrong decision when system is viewed as a linear object [8], [27]. The system theory and cybernetics of the system therefore finds its root in the non-linear natural system, where self-regulation and auto correction options exist as a system in its original form or in its original cybernetics pattern [8]. The stability of natural system is based on its tendency to self-regulate through cybernetic feedback effect [8]. However the self-regulation or auto-correction options in manmade systems fundamentally depends on ontological and epistemological world view, which is also applicable for the purpose of mobility system design, as strong influencing factor involved in it is human agency for their transformation and it requires participatory approach in addressing the need of system re-orientation(both thinking process and system management) to enquire the mobility as a complete system with regard to research methodology paradigm shift [8], [11], [21]–[24], [28], [29], [33]. Roughly correct orientation is only possible if mobility system is considered in its original cybernetic pattern, which is only possible if epistemology of the mobility system is known. Therefore, the enquiry of mobility system in cybernetics pattern for holistic decision support is realisable through design as an alternative methodology in contrast to the main stream scientific methodology, which is mostly oriented to only ontological aspect. Design method supported by APS approach as explained in section 2.1.1 by integrating ontological and epistemological world view to enquire the system is therefore more meaningful for system enquiry [8], [11], [21]–[24], [28], [29], [33].

Sensitivity Modelling software tool [39], which is developed based on the theory of Vester's system cybernetics effect system has adequately contributed to *Analysis* phase of the design of a system[11]. Vester's Sensitivity Model tool is an excellent system analysis tool for negotiating the system's future vision/image with the involved stakeholders [7], [8], [40], [41]. Vester's30 years of experience on the bio-cybernetic effect system is based on the theory of self-regulation and feedback effect, the cybernetics [8]. The idea is used in numerous scientific papers such as S*ustainability Indicators for Tourism Destinations* [41], *Strategies for the Future of Transport, a Systemic Inquiry* (translated from German) [7], *Methodology to Understand the Role of Knowledge Management in Logistic Companies* [40] etc. Vester's own work of *Art of Interconnected System Thinking* is accepted as Club of Rome report and currently used as standard software tools for analysis of system and bio-cybernetic feedback effect [8], [39]. Therefore, this tool will also be extensively used in this study in the later part. The analysis of a system follows 9 different steps. They are 1) system boundary description, 2) variable definition, 3) fulfilling system criteria matrix, 4) developing variable influence matrix of consensus, 5) understanding systemic role of the variables, 6) developing effect system, 7) partial scenario development, 8) simulation of the system and 9) checking 8 cybernetic rules [8]. The system analysis is semi-quantitative measurement in which the quantitative and qualitative assessments are reduced to influence matrix and the effect system, where the feedback effects are analysed. The feedback effects determine the multiple scenario condition for policy test and provide efficient analytic decision support. The *Analysis* phase of *Analysis-Projection-Synthesis* (APS) is fully covered by the Vester's sensitivity tool [11]. The Causal Layered Analysis [42] and identification of leverage points [43] are best established by the matrix-based assessment technique and cybernetic effect system in the Vester sensitivity tool. Therefore, in the Sensitivity Modelling especially the analysis phase, system's variables are screened and validated and their critical scenario can be projected for the design of desired system's multiple future for analytical decision support [8].

2.1.3 Design consideration of mobility as sustainable system

As of now very vague image of "sustainable mobility as a system" and its complex behaviour pattern imaged [44]. This also indicates the need for the design of mobility as a system providing service and study their cybernetic behaviour to support policy and planning for their transition to sustainable system [45]. Instead, more focus on automobile technology development is often prioritized [46]. This is where the mobility system tends to follow motorization and technology development and less on the systemic innovation, clearly excluding the idea of mobility as an inclusive system although technology development is necessary condition [12]–[14], [25]. So, the identification of mobility as inclusive system can be picked-up from the trajectory of problematic growth, which will have to be strongly influenced by strategy that intend to de-couple motorization trend and influence behaviour pattern alignment to the intended service orientated strategy rather than too much intervention on technology invention [12]–[14], [25]. Therefore, it is very clear that mobility as a system is lacking for policy and planning decision. For example, in urban mobility, which represent currently the larger share of mobility system, the mobility trend is recognized as an organized system with its complex dynamic [47].This refers to epistemological aspects of mobility system design. The epistemology of mobility system is characterized by heterogeneity, coherent local interactions, irreducibility, and persistent disequilibrium [47], which may be referred to as ontology of mobility system defined by its agents, call the variables of the system and their cybernetics effects [8]. Current urban mobility system falls under this category of epistemological and ontological consideration, where technologies tend to dominate the problem space [46]. However, from the system and design perspective, ontology of mobility system is already seen as mal-functional system due to technology dominating the problem space that influences the consumerism behaviour [19]. Technology based consumerism behaviour trend can also be observed when mobility is viewed to serve duality functional goal; the transport as a derived demand and lately as valued activities [48]. Therefore the whole purpose has now been deviated from normal movement / transport activities to also expressing emotional pleasure as leisure time activities. The fundamental problem of mobility is the lack of systemic visualization with clear vision, goal and objectives. For this reason, designing sustainable mobility will require system reorientation, which is again the need for systemic change especially for research paradigm shift from ontological world view to ontological and epistemological worldview [11]. Hence understanding the reality of current problematic motorization trend established on the basis of technology innovation requires much deeper investigation for sustainable solution based on systemic innovation potential for example the mobility as service [45]. That would mean less of the need of new invention, where technology development will dominate the goal and purpose definition, but more of redesign of existing system by systemic innovation by involving cybernetic of variables influencing system innovation potential. The challenge of systemic innovation requires ontological and epistemological world view consideration by engaging mobility system user and planner for the shift from ownership to service orientation [45].This would mean redefinition of current profit oriented mobility system growth model to value oriented growth model. At least now in Germany the German Partnership for Sustainable mobility is formed that can inform the sole purpose of mobility and its aesthetics [49]. However, system as a complete picture is still vague. With the naming convention of transport to mobility and sustainable transport to sustainable mobility, the transport and logistics system should have been already renamed as sustainable mobility system instead of sustainable transport system. It is arguable that the focus on sustainable transport already existed, but the driver of sustainable transport rest on the justification, that the higher proportion of next generation population will be occupying urban space, further promoting the dual goal, the design of exclusive urban infrastructure and promoting the technology invention, rather than sustainable mobility as complete system design [46]. In a way this approach is an organized systemic failure further pushing constricted urban growth that will promote motorization trend supported by technology invention dominating the mobility system problem space [46]. If we observe closely the Western model of mobility system development, the system resiliency depends on centralized growth model and on motorized-infrastructure [50]. Considering the urban bio-capacity and the development trend of urbanization, the Western model is already seen as unsustainable [50].Therefore, the design criteria of transport system are still not clear for the sustainability paradigm shift. This is where the design of mobility as a system defined by all its variables needs to address the de-centralization and regionalization of economy. Therefore, sustainable mobility has to be observed as a part of larger economic system as a complete system instead of part of it serving the urbanization, even if the technology invention attempts to solve the mobility system problem in urban area through for example autonomous driving car [46].

Designing mobility system to sustainable mobility system will need paradigmatic design approach to re-orient the problem of technology-oriented problem solving attitude to systemic innovation [45]. In the first place the design of mobility as a sustainable system requires integration of influencing factors of the system, which will be referred to as variables of the system in the later part of this study. Research through design methodology, which is based on three phase approach *Analysis-Projection-Synthesis* (APS) is more meaningful to study the characteristics of mobility system [7], [8], [10], [11], [28]–[30], [33]. APS approach combines Vester's Sensitivity Modelling the *Analysis* [8] and scenario technique the *Projection* [30] to enquiry the system. The *Analysis* phase is covered by Vester's theory of cross-impact assessment and the *Projection* of critical leveraging variables through scenario process [30]. The strategic consideration of either of the method leads to the *Synthesis* phase [11]. Therefore both ontological and epistemological world views are necessary condition for the design of desired mobility system, which is captured in APS for the system to be sustainable [7], [8], [10], [11], [28]–[30], [33].

2.2 System paradigmatic: goal and purpose

Design of any system will depend on its functional goal and the target vision [51]. Goals are those strategies that enable development of target vision of the system [52]. The vision represents the desired future image of the system [52]. Whereas the goals are short term strategy with multiple options, vision is a clear system's future image [52]. Goal and vision formulation depends on understanding ontology and epistemology of the system under investigation [51]. In the case of mobility system, primary functional requirement is movement function for both people and goods, which can be eased with the help of smart, affordable and eco-friendly mobility services to achieve the desired vision of collective wellbeing of human-being and the surrounding environment.

Any system's paradigm is characterised by globalization, liberalization, dematerialization, and technological revolution [53]. Mobility system, which is primarily responsible for movement function leveraging the access, transaction and connection defined within space, time and distance face the same consequences of globalization, liberalization, dematerialization and technology revolution. It has emerged from localized order to globalized variety, the paradigm shift from non-motorization to meta-motorization. Therefore, the goal and purpose definition of mobility system will be influenced by the global set of variables and their interdependency, which are interconnected [8]. The review of United Nations (UN) reports on 8 millennium development goals and 17 sustainable development goals identifies mobility as an important development indicator for sustainable growth [4], [5], [54], [55]. Sustainable transport (mobility) has been included in seven of the 17 goals and is directly covered by five targets and indirectly by seven targets [6]. As part of the global transport narrative, four possible goals are considered important. They are Access for all, Efficiency, Safety, and Climate respect [6].

Further the space constraint, congestion and localized pollution in urban environment are seen vital [55]. As urbanization continues to grow with the limited physical space, these challenges continue to grow. Hence the mobility planning and management is further linked with the indirect influence of rural-urban demographic disorder and national urban settlement policy which is again recently acknowledged vital for sustainable development [54]. Thus, sustainable mobility plays a vital role in global development agenda in terms of mobility technology, infrastructure planning and human habitat disorientation.

Mobility (transport) and climate change is an important area to focus as transport alone accounts for about a quarter of global energy-related carbon emissions [56]. In addition to the visible aspect of mobility, there are intangible aspects concerning mobility related pollution and health impacts. They include noise, air quality and safety as outlined in International Council on Clean Transportation & WHO publication [57], [58]. Therefore, the agglomeration of access, safety and security, congestion and pollution, health and welfare and efficiency in technology advancement all together becomes the baseline for the mobility system identification considering them as the global mobility system variables.

2.2.1 System infrastructure: Inclusive physical conditions

While intervention on mobility itself is vital, "fast-growing metropolises need both expansions in infrastructure that supports automobile transportation and planning that supports alternatives to the automobile" [59]. Thus, infrastructure planning should include all forms of services that people need. Lumbera et al. (2016), identifies inclusive infrastructure as an alternative to providing all kinds of services to pro-poor demography in both rural and urban design [60]. Various key aspects include the accessibility needs for disability, nearness to health care facilities, and alternative options for settlement [60].

The inclusive and sustainable infrastructure is defined in different region and country differently depending on the geography. For Latin America and the Caribbean, infrastructure is a synonym of competitiveness, development, economic boost, and integration [61]. They include access to electricity, clean drinking water, hospital, and good network of surface and air transport connectivity. Sustainable infrastructure is defined slightly different in Asia as infrastructure that is in harmony with the continuation of economic and environmental sustainability [62]. Therefore, the transport infrastructure is envisioned to be eco-efficient, which is in line with the economic and geographical situation in Asia [62]. For European Union the sustainable infrastructure is seen as smart, digitized, inter-connected transport and energy system, which optimizes the job availability [63]. It is observed that inclusive and sustainable infrastructure covers broad range of indicators that is directly linked to human welfare improvement. Transport infrastructure such as ramps and pedestrian sidewalks, crossings in urban settings, footbridges and access roads, road shoulders in rural settings are good examples of inclusiveness [64]. The infrastructure will remain as a global mobility system variable defined by its indicators and contextual purpose and goal. The development of infrastructure influence mobility system behaviour, technology choice and access.

2.2.2 System enabler: Fuel and technologies

Technology influences the human behaviour and the behaviour further pushes the technology development. In the history mobility technology development is largely influenced by the discovery of fossil fuel, which shifted the mobility technology design from steam engine to fossil fuel power internal combustion engine. For example, E-mobility technology is as old as internal combustion engine [65]. Electric Vehicles (EV) of 1900 held the world's long-range record of almost 290 km per charge with highest speed limit of 110 km/h [65]. However in the recent development, range anxiety has been identified as one of the main obstacles for the success of EVs [66]. The e-mobility technology concept is much older than it seemed in recent days, therefore it could have been viable long time back.

The dream of flying and invention of jet engine still offers the air transport facilities across the globe [67]. Although alternative aviation fuel sources are explored such as liquefied hydrogen, they are still at laboratory stage [68]. Therefore, currently aviation sector optimization rests on air route bundles and its optimal passenger capacity planning to increase efficiency, which is very limited within the choice of the flight operator providing the services. Influenced by high cost of ownership, they run already on sharing culture in contrast to ownership culture of surface mobility options, especially the passenger car. Road transports are fully dominated by vehicles. For mountain regions cable cars and ropeways are seen as an alternative to vehicles [69]. The cable car and ropeways have the potential to use clean electricity to power its pulley and motor system [69]. However, they suffer load capacity and other normal comfort that the road transport is able to offer [69]. In some case riverine transport also provides an alternative for surface transport. Such modes of transport technologies have now been used for cargo movement and tourist attraction [70]. Walking and cycling has been age-old travel behaviour which can offer a healthy mobility mode for all. The European Union calculated for the EU-27 the benefits of cycling [71]. The estimate of at least €205 billion per year, including health benefits, reduced congestion, emissions, pollution and noise are projected [71]. It is also interesting to note how the preferred option of today's e-mobility development is not real answer to the sustainable mobility system transformation. It is required to be qualified and quantified based on life cycle assessment approach that requires to incorporate the battery manufacture, waste and energy source as an important end product to consider for optimal alternative solutions for the choice of e-mobility [72]–[74].

The rationale for e-mobility initiatives as an alternative mode has three pillars such as greenhouse gas (GHG) emission control, de-couple economic growth and GHG emission from transport and reduce localized air pollution and protect human health [75]. Carbon equivalent emission of mobility also includes particulate matter (PM) and dus t[76]. Chronic exposure to particles ($\leq PM_{10}$) contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer [77]. To avoid such ambient air quality deterioration due to mobility, various measures such as oxidation catalyst and selective catalytic reduction (SCR) technology are used. If electricity source is clean, E-mobility has the potentials to replace the source of transport related emission. However currently EV represent 0.8% [73]combined market share and to meet fuel economy target EV market share need 16% [78], which can significantly address ambient air quality improvement. Diversifying e-mobility as an alternative mode such as e-bicycle, rope ways, cable cars, e-tramp and e-train can be justified based on life cycle assessment approach as it is impossible to claim zero emission from e-mobility [72], [74].

With continuous development, the e-bicycle and e-skate-board has already offered the range of 100-150 km with average speed of 25-40km/h per charging cycle, which takes about 2-6 h [79]. Further electric trains are operational in USA, Europe and Asia with alternating current (AC) rated at 25 KVA converted to DC rated 1.5 KV to power train movement [80]. Further the e-mobility in urban mass transit shows electric buses as a promising urban transport mode with massive technology development overcoming their operational limitations [81]. Alternatively, electricity enabled gravity ropeways or cable cars are offering options in countries like

Nepal [82]. Thus, it is evident that e-mobility inclusively covers most of the combustion engine technology services though cost and environmental impact is decisive at the moment.

Table 1: Technology development and fuel alternative [83]

Automobiles	Fuel alternatives	Source of fuel	Competitive advantage
Diesel vehicle	Bio-diesel	Energy crop	Use of fellow land for energy crop
Hybrid and plug-in vehicle	Electricity and other fuel	Renewable electricity	Localize pollution control
Flexible fuel vehicle	Ethanol blended with other fuel	Energy crop	Use of fellow land for energy crop
Fuel-cell vehicle	Hydrogen gas	Renewable electricity	Use of excess renewable energy
Natural gas vehicle	Natural gas, methane	Gas refinery	Use of second generation biomass
Propane vehicle	Propane fuel	Gas refinery	Fuel cost reduction

Carbon economy still dominates the share of fuel supply with almost 80% supply to various energy demands including mobility [14]. Aligning policy towards low carbon economy rests on three pillars as outlined by OECD member states. They are "1) sending a robust and credible price signal to internalize the cost of these emissions; 2) regulatory measures whenever pricing is not effective; 3) bringing promising low-emission technologies to commercial maturity in anticipation of more ambitious reductions" [14]. Augmenting these pillars there are various alternatives available for fuel substitutes. The few known examples are shown in table 1 [83].

Natural gas and renewable methane play important role and can increasingly become a mobility fuel substitute for future [84]. With the increase in renewable share of energy supply in the electric power grid, the technologies such as power to gas and power to liquid enabled energy storage as methane will also be part of transport fuel share [85]. Further liquid hydrogen (LH_2) from steam methane reforming (SMR), can provide between 13 and 21% less environmental and social impacts than jet fuel which is renewable fuel alternative for aviation sector [86]. Alternatively, the bio-fuels from algae has the potentials to substitute fossil energy source which are cost competitive and can be grown in saline water [87]. Addition to such options, the second-generation biomass is also offering fuel sources such as waste to energy conversion and methane gas purification. "Even if only 10% of the global agricultural and forestry residues were available in 2030, about half of the forecasted bio-fuel demand in the World Energy Outlook 2009 450 Scenario could be covered – equal to around 5% of the projected total transport fuel demand by that time" [88]. Thus, the switch from fossil to renewable is already seen as an alternative future.

2.2.3 System inclusivity: Multi-modality integration

Variety and diversity are heart of system resilience to uncertainty. For mobility system the multi-modal options with the support of technology increases the diversity and variety. Though technologies are ready to be used, compatibility of existing infrastructure and their development is critical [89]. For example, smart grid, hydrogen storage; bio-fuel and methane refilling station are important condition for decarbonisation and mobility technology integration in the existing system. In addition to physical infrastructure development, user-friendly mobility services will have greater impact on sustainable mobility system development. The feasibility study on bus rapid transit (BRT) and light-rail rapid transit (LRT) indicate that they are successful in city of Chennai, and Bangkok which is considered to be sustainable mobility paradigm shift in mass transit [90], [91]. Such type of mobility services can be further encouraged by means of ICT enabled technologies. Attard et al. (2016) identified user-friendly mobility services by using ICT technology such as geographic information system(GIS) and volunteered geographic information system (VGS) that can be integrated in smart phone apps for user travel decision making [92]. In developing countries these ICT technologies can further enable intermediate public transport (ITP), which is identified as an alternative way to solve developing countries transport accessibility challenges [6], [92]. Intermediate Public Transport (IPT), sometimes known as para-transit, refers to road vehicles used on hire for flexible passenger transportation, which do not follow a fixed time schedule [93]. The mode of transport includes cycle rickshaws, auto rickshaws, taxis, minibuses, carpools, vanpools, subscription buses and demand-responsive (dial-a-ride) vehicles. Inclusive and sustainable mobility services include rural urban linkages and the demand for such mobility pattern [12], [13]. As the world becomes more urban, rural sectors need to be transformed so that they can more efficiently and sustainably provide greater amounts of food, clean water and environmental services [94]. EU identifies the implementation of sustainable transport patterns in rural areas and mountain region, is one of the key success conditions for the attractiveness of rural-urban connectivity [95]. EU's consideration of lack of rural mobility system further emphasis on the lack of guidelines and policy that is useful for the design of rural mobility management system. Thus, the multi-modality and rural-urban dynamic plays vital role for the integration of new mobility system in the existing infrastructure, which is not enough though partly addressed for the design of mobility as a complete system in the current status quo.

2.2.4 System ethics: Behaviour and aesthetics

The system and the ethics involved in it are somewhat like a wicked problem [32]. Therefore, the singularity goal and objective definition of the system will not address the need of system user, which is much more complex than the physical conditions in connection to management challenges [32]. Furthermore, the system cannot generate solutions but will remain as it appears to be, the ontological part of the system [26]. The ethics defines what ought to be and what it is like, the epistemology of the system [26]. Therefore, there is nothing like binary true and false answer for wicked problem [32]. It has to be determined by the actors of system and system designers, which may be represented by the first and second order cybernetic for the design consideration. They are important soft change lever in the design theory and practice [9]. The fundamental problems in the design of a system are the planning dilemma and uncertainties [8], [28]–[30], [32], [33]. The determinants of social behaviour are intangible but are heavily influenced by the infrastructure and technology [8], [28]–[30], [32], [33]. The desires and wishes of the user appear to be much more complex than the tangible aspect of mobility such as technology and infrastructure, whose identification can only lead to robust and self-regulating mobility system development [8], [28]–[30], [32], [33]. They are strongly influenced by the actors/decision takers of the system[21]–[24]. The characteristics include the behaviour and the aesthetics. The fundamental question on behaviour shift is defined by acceptability and its attributes includes aesthetics (cleanliness, comfort, timely and affordable etc). Also, the demographic distribution has strong effect on behaviour, which require participatory approach including different actors of the system [21]–[24].

Figure 1shows world population distribution by age group [96]. Different demographic group has its own contextual need and cannot be generalized to one single solution. The solution spaces are neither correct nor wrong but dynamic owing to wickedness of the need and the acceptability [32]. Therefore, the population distribution of figure 1 also indicates that the wicked problem is connected to the need of user, where plurality goal and contextual need play critical role [8]–[11], [30]. This means that the system behaves as it is where as the actors ethics and behaviour give rise to what kind of re-orientation is needed, the way system ought to be [21]–[24]. Therefore, system infrastructure, enabler, control, and inclusivity have to be understood based on the ethics and how the decision taker would like to behave.

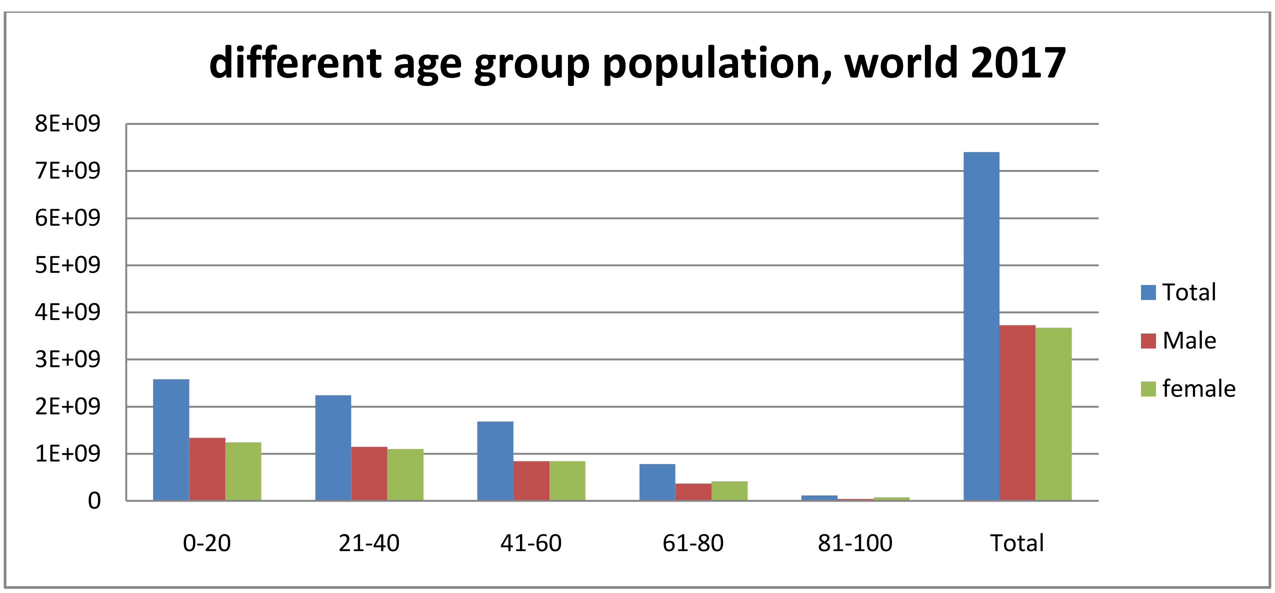


Figure 1: Illustration of world population distribution by age group

For example, the children age 20 and below represent 35% of world population and by the nature of life style their travel behaviour is highly dependent on public transport [97]. Pedestrians and bicycling are common mode of travel behaviour for children between the ages of 6-15 years due to their age group and restriction on use of motorized mode of travel independently [97]. Mostly the public transports such as school buses are their choices. These groups of population and the elderly are vulnerable to road crash and directly exposed to vehicle emission. In developing countries the proposition of children using non-motorized mode is higher than those in developed countries [97]. Similarly, the mobility behaviour of elderly is distinct. Haustein et al. (2011) concludes mobility behaviour of elderly citizens as four segments namely captive car users, affluent mobiles, self-determined mobiles, and captive public transport users [98]. Thus, it can be easily seen the heterogeneity in the mobility system and they appear to behave wickedly [32].

Because our knowledge is limited, our foresight imperfect, and out habits persistent, such informal modelling frameworks need to incorporate explicit treatments of learning and behavioural change [99]. The mobility behaviour shift can be partially triggered by incentivizing parking space and road usage, by imposing congestion charge and encouraging public transit facilities [100]. They include walk ways, bicycle lane and public bus services in core city. Demand responsive transportation systems (DRT) in rural areas and shared autonomous mobility (SAM) do have potential for behaviour shift [101]. However, such mobility systems are currently available only in OECD countries.

Gender is a significant factor accounting for differences in mobility and travel behaviour [102]. Role of women in green economy is identified vital [102].Women are also recognized as being more likely than men to adopt sustainable travel behaviour [102]. Women tend to travel shorter distance, adopt public transport service, mostly non-peak hour travel and more related to children and elderly escort [102]. Thus, including all forms of aesthetics (comfort, cleanliness, timeliness, safe and affordable etc.) to different population group will enable willingness for alternative use pattern and modal shift.

The alternative use patterns are the attributes related to the willingness of the society for modal shift from conventional individual passenger car ownership to multi-modal services of different kind. The willingness is further affected by the comfort/cleanliness, accessibility/ease to use, safety and security, reliability/frequency, environment friendliness and affordability for modal shift [103]. These attributes relate to attractiveness of new mobility deployment options. Further the mobility behaviour that reduces the ecological footprint adds value to social and environment cost which are growing concern these days for spatial policy and planning [104]. The impacts are settlement patterns with high consumption of scarce or non-renewable resources (especially land and energy), which are relatively recent phenomena internationally [104]. This type of subjective/qualitative nature of variables and their usefulness is often neglected for mobility system design and planning.

2.2.5 System heuristic: Boundary critique and resilience

System heuristic is an approach to intuitive judgement of a system through the social discourse practice that reveals the system boundary condition [21]–[24]. They include tensions such as ‘situation’ versus ‘system’, ‘is’ versus ‘ought’ judgements, concerns of ‘those involved’ versus ‘those affected but not involved’, stakeholders’ ‘stakes’ versus ‘stake holding issues’, and others [23]. They are identified by the source of motivation, source of control, source of knowledge and source of legitimacy emphasising who is involved and who is affected [23]. The above frameworks also give rise to scenario, situations, stakeholders, transparency and alternatives, which are key communication field for the design of a mobility system and their transition to sustainable mobility system among others [21]–[24]. Mobility system influences directly the quality of life and therefore the well-being, the social domain of sustainability. The determining conditions for well-being are justice and fairness, safety, resiliency and availability. They can only be discoursed through participatory approach [22].Therefore, mobility system's boundary critique for well-being and its attributes, the justice and fairness, safety, resiliency and availability, curtails the need of heuristic practice [21]–[24].

Justice and fairness are well established concepts in legal matters. However, they are also now quite relevant for understanding the heuristics within the system design. They are legitimate facts based on the principles of procedural fairness, expectation, needs and rights [105].These attributes express the dreams, wishes and emotional essence attached to the mobility system. The reasons to include the justice and fairness in mobility system planning are very clear as we see big disparity gap between the decision maker and decision taker [105]. Similarly, the mobility safety aspects discoursed through participatory approach reveal the safety attributes such as air pollution reduction, human error avoidance and the resiliency to natural disaster [58]. Among others human health is important requirement for well-being measure where air pollution and human behaviour influence the resiliency of mobility system. The capacity of mobility system to provide safety measures by lowering air pollution, human error and natural disaster is therefore the mobility system resiliency [106]. Some commonly known safety aspects are summarized in Table 2. Resiliency tends to incorporate the principle of system's heterogeneity properties where diversity, efficiency, adaptability, and cohesion define the state of an open system [106]. Mobility system is an open system and their behaviour depends on how the heterogeneity properties are addressed. Unfolding the need for better quality of life therefore is inevitably linked to system resiliency which will require heuristic practice [21]–[24]. Once again the heuristic practice resembles the epistemological aspect of system investigation, which is based on stakeholder engagement for systemic communication for decision making process [26]. Therefore this is another augmentation that system design requires paradigm shift in research methodology with the inclusion of both ontological world view and the epistemological world view [26]. Based on system's ontological world view, the knowledge about possible intervention is necessary conditions for heuristic practice [21]–[24].

Table 2: Safety and human-well being

Safety aspects	Resiliency	Scale and frequency	How human-well-being can be addressed?
Unpredictable	Earthquake, Tsunami, Flood, fire, cyclone, accidents etc	Seldom but large scale	Response time and after effect control mechanism
Human induced	Standards practice, enforcement and monitoring mechanism	Daily basis and small scale	Fatalities, injury, disabilities due to accidents and control mechanism
Indirect influence	Air pollution, dust and noise	Daily basis and large scale	Air quality monitoring and health impact measurement

Thus, the participatory approach attempts to collectively define standards, road rules, safety rules and enforcement mechanisms in a user-centric manner. Various aspect of resiliency is mostly planned in a hierarchical order, often times leading to imposed regulatory measures through top-down planning decision which turns out to be wicked problem [32]. Mobility regulations are those elements that offer services to measure and monitor the resiliency of mobility system whose attributes are safety, reliability, accessibility, and technology adoption. Thus, the co-ordination between policy choices, stakeholder engagement, willingness by user, scope for alternatives and non-transport mobility services are emerging themes that will be accompanied by those elements [107]. Those elements here refer to different aspect of resiliency. For example, the mechanisms that ensure the user centric mobility system are shown in table 3 [108].The idea of all those aspects shown in table 3 for mobility system planning is roughly known by now. The only missing aspect is the communication and information dissemination which the heuristic practice allows to some extent, the process of system judgement and user centric common decision making [21]–[24].

Table 3: Behaviour change attributes

Sl. No	Aspect	Intervention required	User prospective
1	Road infrastructure	Investment on walk ways and cycle lane	High usage
2	Rail-based public transport	Optional bus/rail depending on urban size	Benefits urban poor
3	Road-based public transport	Optional bus/rail depending on urban size	Benefits urban poor
4	Support for non-motorized travel modes	Dedicated lane for user	Benefits urban poor

5	Technological solutions	Intelligent Transport System and alternative fuel	Better awareness
6	Awareness-raising campaigns	Travel behaviour and status of vehicle ownership	Slowly changes travel behaviour
7	Pricing mechanisms	Coupon system for more sustainable practice	Encourage sustainable mode
8	Vehicle access restrictions	Coupon system for more sustainable vehicle	Encourages sustainable vehicle
9	Control of land-uses	Toll fee, dedicated lane for public transport	Better access for road user

The user behaviour of table 3 opens an alternative strategy for user decision rather than the decision imposed by the mobility system planner to the decision taker, through incentive mechanism in which user engage in decision making on their own choice [109]. With the incentivised mobility system development, the business models operate on award scheme. For example, the coupon system that gives an opportunity cost for many other businesses through sustainability rating of an individual is an attractive tool. Further the idea of consumer perspectives and willingness to sustainability performance are quite useful in mobility system planning through eco-design concepts and theories [18], [110]. Thus, the heuristics involves the participation and user acceptability for mobility system design in more transparent and communicative manner.

2.2.6 System holism: External influence

Holism is arguable when it comes to specialized scientific investigation, but for the design of a system it is practical. Universality (open system) rather than isolation (closed system) is the core concept of system holism [111]. Any real-world system is an open system and therefore mobility system is an open system that obeys the principles of holism. Mobility system composes three types of movement, the movement of people, the movement of goods and the movement of services. While movement of people and goods are straightforward, the movement of service are those economic transactions that require medium of exchange. For example, the home delivery services, postal mails, virtual offices etc, this can be enabled through ICT technology. The movements of people, goods and services are influenced by the external force, the characteristics of economic development, urbanization trend and the environment. The demand side management strategy of avoid-shift-improve (ASI), though widely preferred, still does not address holistically the complete mobility system [25]. The ASI concept basically covers the movement of people. The other two aspects, the movement of goods and the movement of services are practically not visible. As introduced in the A-P-S approach in section 2.1.2 and 2.1.3, the ontological and epistemological world views for system design has the potential to capture all aspect of mobility [10], [11]. This would require systemic reorientation, where it addresses systemic transitions from product centric growth model to service centric value proposition of the mobility system and therefore the re-design of the existing system by incorporating all those missing elements.

The concept of access and movement requirement is multi-dimensional, where identification of *Accessibility* as key indicator to mobility system design is very broad in addressing movement requirement by various measures to address human welfare [112]. For example, the use of ICT services for availing the services are some good example of virtual access among others. On the other side the mobility and housing cost relation show the lesser the housing cost the higher the mobility cost and the total accessibility cost in principle remains constant [113], [114]. This generalised theory also shows travel time and travel budget remain constant for an individual with the constant of 1.1 h/day/person and 10-15% of expenditure respectively [113], [114]. Although it is arguable for the constant values defined, the housing and accessibility theory reveals, if it is wise to re-design the mobility system or economic system, especially the settlement pattern. The question is paradigmatic in nature and envisions for long term perspectives. Similarly, it is estimated that the world urbanization growth rate is expected to increase [115]. The change in demographic density, space utilization, and the varying empirical ambiguity on urbanization and population growth rate is still future prediction, which however is still uncertain in context to system theory. However, it is worthwhile to consider the influence from such external condition for the design of mobility system. The systemic approach on why people attempt to rural-urban migration, what causes this urbanization, and how it effects the design of mobility system is very important [116]. Thus, the urbanization trend has very strong influence on the design of mobility system, which is not desired but also hard to control.

Environment on the other hand is very broad field that influences the mobility system in various aspects. Health and transport are, for example, very important external influences for the design of sustainable mobility system [58], [77], [117], [118]. Similarly, air pollution and climate change attribute to mobility is very significant. The effort of UNFCCC to enable paradigm shift of mobility system stresses on transport system should be seen as low emission, efficient, accessible and affordable mobility solution to all [119]. Therefore, these external influence factors strongly affect the robust mobility system design. The impacts of these global variables are mostly invisible when mobility is observed as an isolated system. Therefore, the holistic world view where the mobility system as it appears and as it ought to appear needs to be inquired.

2.2.7 System control: Policy and enforcement

With the global urbanization trend and increased motorization, understanding mobility as a system and its behaviour is vital [120]. For example, the urban mobility system disposes with challenge of congestion, demanding the design of sustainable urban mobility, where the spatial dynamics are prioritized [120]. Similarly, the rural mobility system is faced with the challenge of availability, where the access and connectivity are lacking [95].At global scale the national and international mobility system seems to function differently.

Therefore, large amount of data set on access, safety, motorization trend, urban growth and rural-urban migration are available but all in disintegrated form. Although such data sets provide insight into the mobility situation, they do not show how they interact and influence each other. Therefore, mobility system control will increasingly remain challenging owing to lack of contextual leverage point, which requires the design of mobility system model representing mobility system in an explicit form for the control conditions. The control deployment depends on well-defined mobility policies regulating the behaviour of the system. They evolve, transform and finally control the performance of the system. This would mean the need of comprehensive mobility system model representation by all its controlling factors, the variables of the system.

Having identified that current mobility system development required systemic behaviour change, policy as an enabler to sustainable transition is introduced [12]–[14], [25], [49]. However, the policy development currently does not depend on the mobility system model because they are not yet available in explicit form. For example, the inclusive transport policy although desirable is still challenged by financing sustainability [13]. The reasons are lack of knowledge about mobility system variables interaction, which will influence the system behaviour and to recognize self-regulation potentials. The inclusive policy encourages cost competitiveness, demand driven, de-regulation rather than conventional state-owned public transport services [13]. However, unless the influence factors, both internal and external are agglomerated, the singularity goal definition continues to define the mobility policy. For example, the 100% regulated transport policy seems to have considered cost, travel speed, crash rate and environment impact but failed to provide other aspects of mobility such as non-motorized transport, indirect environment impact, ownership and congestion, health and accessibility and different mode of transport [112]. The representation of singularity goal trying to define the mobility system vision does not adequately address the mobility system innovation potentials [10], [11], [28], [29], [32], [33]. Therefore paradigm shift in the policy design require paradigm shift in mobility system model design, which is vital for the transition of current mobility system to sustainable mobility system in future [25], [50]. Sustainable mobility system design therefore demands, the paradigm shift in mobility system with the inclusion of social, economic and environmental criteria [12]–[14], [25], [49]. However, the paradigm shift is only possible with explicit representation of mobility system by all set of variables defining the system and with the contextual conditional leverage point [7], [8]. This requires viewing mobility system in its explicit form by defining the system ontology and analysing the critical behaviour with the stakeholder involved in the system the epistemology, and that is defined by all variables which at the moment seem to be lacking.

2.2.8 What defines mobility as a system

As of now the mobility as a whole system seemed to have been vaguelyviewed and the image of the system is very versatileowing to its huge impact on livelihood and economy [12]–[14], [25], [49]. Though there are emerging ideas on *Seamless Integrated Mobility System Design (SIMSystem)*, they are still not conseivable as they are based on the prediction thatfuture population growth will increase and it is likely that more than 60% of the population will be residing in urban area,yet another single future [44]. Designing mobility system on such pre-defined goal will lead to mobility system design of future for urbanization and more motorization clearlymissing the systemic world view, which is vital for system self-regulation [7], [8].

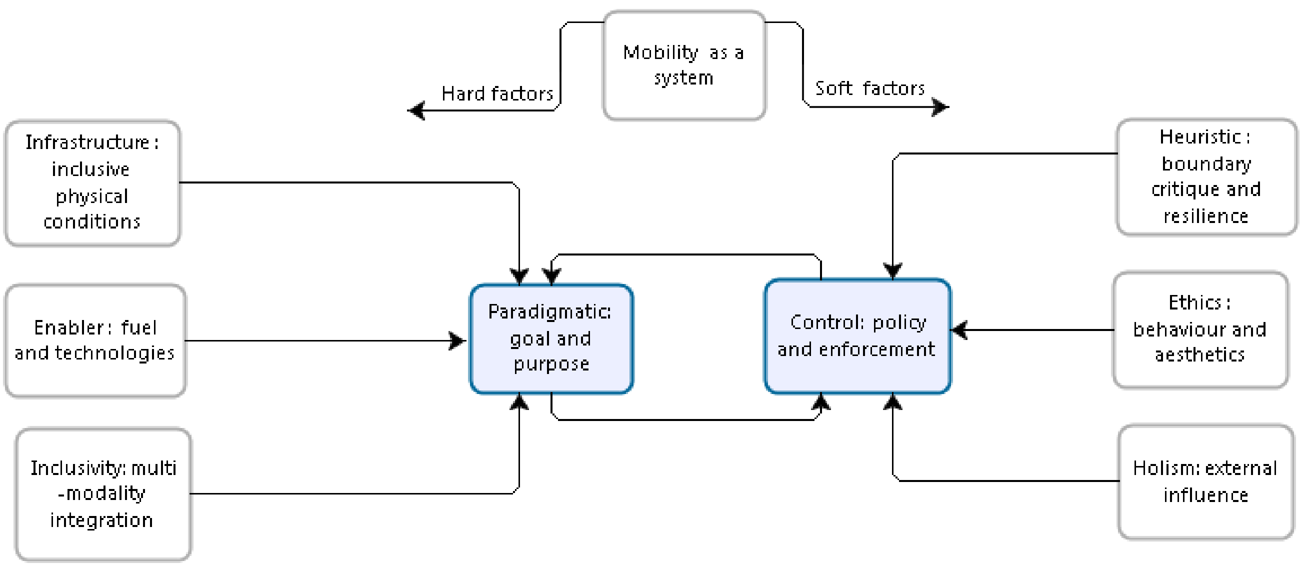


Figure 2: Mobility as a system image

The mobility as a system illustrated in figure 2 is a generic framework of mobility-system that can adapt to inclusivity and contextual need [12]–[14], [25], [49]. They are characterized by hard and soft factors that will represent the ontological and epistemological world view of mobility system [10], [11], [28], [29], [32], [33]. The paradigmatic goal and purpose are defined by hard factors like infrastructure, fuel, technology and multi-modality, which represent the ontological view. Similarly, the control of these hard factors, the policy and enforcement is defined by the soft factors like heuristics, ethics and holism, which will influence epistemological view of the mobility system and is negotiable [21]–[24]. The hard and soft factors are in feedback loop where the dynamics of paradigmatic and control generates the properties of the system, this is where the research paradigm shift is required and therefore an ideation of the need of the system re-orientation. When the mobility system is re-oriented for research as shown in figure 2, system exhibits the properties of complex system which is unpredictable and irreducible [10], [11]. But still how do we define the mobility as a compelete system rest onidentification of its sub-system by which specific influence factors determine the functioning of the system, which may be called as the global variables of the system, which roughly define the system [8]. The variables are those element of the system that dipicts the part of complete but rough system image and whose variability will effect the functioning of the system [8]. While the variables influence the system image formation, they influence each other and get influenced by them [8]. Therefore the imageing of the mobility system needs both variable identification and their influence factor, which will define the mobility system with all the criteria as illustrated in figure 2, the general model of the mobility system.

3 System description: Mobility system image

Mobility system is a system that is characterized by its functional service for the movement of people, goods and services from one location to another [12], [18], [25]. The movement of people, goods and to cater services have become basic human need to fulfil basic daily life activities. Therefore, to sustain daily human need, the service of mobility system has to be sustainable for example the service like free floating car [121]. However current challenge is of unsustainable society that is heavily influencing the mobility to be identified as material goods to be owned for movement requirement and that is unsustainable. We needed the societal sustainability and the mobility system transformation might be an alternative and initial trigger for societal sustainability.

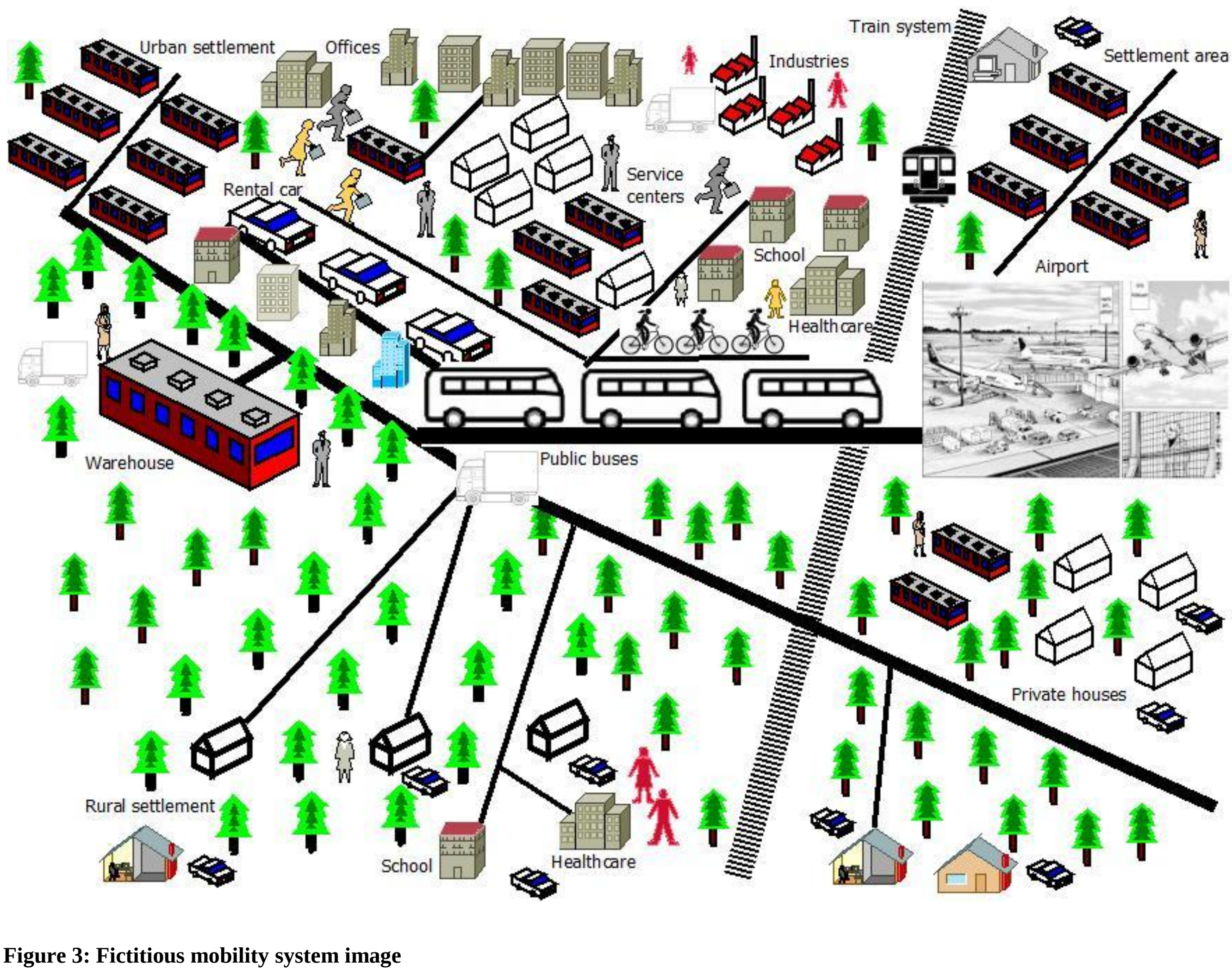


Figure 3: Fictitious mobility system image

The basic human needs that demand mobility requirement ranges from any specific activities such as; transport of goods, travel of people, and delivery of daily services, which goes on to international trade. Transport of goods includes any form of consumable materials goods such as supply of food, textile products, household commodities, construction material etc., from the source of its origin to the consumption destinations. Similarly travel of people includes tourism, visit to families, leisure time travel etc. Delivery of service ranges from simple delivery of post mail to movement of large number of people to schools, hospital, market, work place and offices as seen in the fictitious mobility system image in figure 3.

To enable the daily human needs in a well-developed techno-economic system, it is enhanced by the technology support, such as automobiles, trains, aeroplanes, helicopters, ships, ropeways, and two wheelers [6], [56]. This enabling support system is called as motorization. To accommodate all the technology enablers, the movement function demands the design and development of relevant infrastructure suitable for the choice of technology and need of motorization. The deployment of enabling conditions and infrastructure further requires organizational and institutional capacity. These are physical conditions that enable the dual mobility demand such as mobility as a derived demand or valued activities [48]. Mobility as valued activities could actually be replaced by some other activities such as family gathering, spending time in parks, hiking and music, which are actually much more valuable for leisure time activities.

The movement function however is built within the biosphere, where constant quantity like land, air, water and energy is shared by plants and animal. These are physical limit conditions. In general, the mobility system is formed by three aspects, mainly the function of mobility system (service need), enabling support system (built environment) and limit conditions (the natural environment). Services are determined by human needs to fulfil the desired activities, the daily societal need. The human intervention for any changes can be possible only within the domain of service need and built environment as shown in figure 3.

The way people settle and as they create societal transaction will determine the sustainability of mobility system and it is very important criteria for the design of mobility system. For example, the settlement pattern of city is different from that of rural areas. Similarly, the settlement pattern of different cultural background is different from region to region. More significantly the regional settlement pattern is unique in different ethnic society. Linear and clustered settlement patterns are usually seen in urban areas, whereas both clustered and scattered settlements are seen in rural areas. The mobility system that fulfils the demand and supply of consumables and services to different settlement pattern will influence the development of infrastructure and access requirement to carry out daily economic activities in the community or in urban centres. Thus, the settlement pattern and access need to all the economic activities sufficiently influence the mobility system's interaction with its surrounding environment. The main concern is on how efficiently the space and distance to access location are designed, so that the mobility system design establishes optimal value creation with the surrounding environment. It is also therefore the question to be asked, if it is wise to increase the urban mobility infrastructure or rural mobility infrastructure, so that the urban capacity and rural growth are balanced, instead of straining the limited urban space. The access distance then determines the need of motorization and non-motorized travel behaviour and type of mobility that is needed. Therefore, mobility system description depends on the variables defining all such criteria and to figure out leveraging scenarios in addressing its sustainability. All the variables are somehow interconnected. The influencing effect of the variables in the mobility system is in a way very complex, owing to varying degree of uncertainties. The uncertainties especially arise from those of social factors such as the behaviour and life style. Even if robust and sustainable infrastructure and technologies are put in place, without the changes in the life styles and behaviour, the structure of daily mobility pattern will remain unchanged. Therefore, careful consideration of variables and their influencing strength will require addressing the challenge of how to orient the design of a mobility system as an enabler for it to exhibit sustainable growth model. For that purpose identification of right variable that defines mobility as a complete system is critical.

3.1 Mobility system: Variable consideration

The qualitative assessment of the literature sources in chapter 2, for example the source list [6], [12], [122]–[124], [13], [14], [55], [58], [95], [103], [112], [119] and the system image of figure 2,reveal that the mobility system is a complex system, which depends on many other subsystems. The complete mobility system is an agglomeration of infrastructure, technology, environment, people, and economy that cause and influence the movement function. Mobility system facilitates the movement of people, goods and services from one point to another for variety of purposes. The functioning of mobility system is influenced by the physical conditions, the hard factors and the control conditions, the soft factors [13], [60], [98], [106]. They are the variables that expresses; enabling support system, the physical-built-environment and the variables expressing normative socio-culture, the dream, wishes and feeling. While the former control the physical enabling condition, the latter will unfold the reaction towards new development. However, both the physical condition and control factors are dependent on robust initial system planning, which is strongly influenced by the political, economic, ideological and power structure that has evolved and/or are still evolving. For example, the land use choice, construction of infrastructure, technology deployment, and economy orientation are critical for sustainable transition [6], [12].If it is currently faced with critical challenges, it is initial planning problem, which can only be addressed through reorientation of the system with multiple options rather than reinvention and too much concentration on corrective measure deployment in some part of the existing system [8], [28]–[30], [32], [33].Therefore, it is critical to identify the problem areas, which can only be visible by identifying roughly the original system image [8].The identification processes are heavily influenced by variables that influence the imaging of the system in transparent and fair conditions [7], [8], [21]–[24].

In the global context, the physical factors such as infrastructure and technology development for mobility system face the challenges of shift from fossil era to renewable era. Therefore, mobility system transition to sustainable mobility rests on the social acceptance of new alternatives that are available. But even before the transition from fossil era to renewable era, the need of mobility system reorientation is vital for example the mobility as service [45], [125]. Service development should intend to address the transition such as rural development instead of urbanization, service consumption instead of product consumption, economic value creations instead of economic growth, which are key aspects for system transformation and interventions requirement that are viable and more sustainable. However, they still face the challenge of acceptability by the system planner and are common problem everywhere [8], [9], [32].

The control factors that express the dreams, wishes and feelings of the actors of the system face the challenge of common agreement [8], [24]. Therefore, the participatory approach in planning and decision making is critical condition that enables the acceptance by the user [8], [24]. The imposed decisions are widely seen in the available policy as a system controller, where the need of the actors of the system are mostly discarded [8], [9],

[32]. For example, the decision taker believes the system is designed for the user as an actor, whereas the user believes the decision maker is responsible for system failure [9], [32]. On the contrary neither decision taker nor decision maker is responsible for the system failure but the process by which the system is designed [10], [11]. Both decision maker and taker of the system are actors of the system. The complete set of variables defining the system governs their success factors [8].

Understanding the degree of influence mobility system variables can cause with the inclusion of hard and soft factors characterize the overall mobility system image [8]. The possible conclusion can be drawn after analysing the mobility system image expressed with the help of interacting variables of the system. The behaviour of the system and the leverage condition for transition to sustainable mobility can only be analysed by investigating the complete system image and understanding systemic role played by the variables in the system [8]. For that reason, preliminary set of variables including that of first stakeholder consultation is listed in table 4,which are used for further investigation and understanding their influences to develop alternative and sustainable mobility system. The variables list of table 4isassembled from the existing literature sources reviewed in chapter 2 for system inquiry [6], [12], [122]–[124], [13], [14], [55], [58], [95], [103], [112], [119],which is also augmented with first stakeholder consultation through survey method. The list is however subject to further verification depending on context. Therefore, the current list provides holistic image of mobility system for further refinement. The variable may increase or decrease depending on the context.

Table 4: Preliminary variables with indicators

	Variables	**Indicators**	**Time of variability**	**Compiled from(source)**
1	Infrastructure development	Road network, train track, airport, wet and dry port, fueling stations, quick charging stations, ropeways and cable cars, walk ways and bicycle lane, electricity grid and ICT networks.	long	[6], [54], [60]
2	Technology development	Efficient technology, low emission vehicles, electric vehicles, fuel-cell car, electric train, electric two wheelers, hybrid electric vehicles, low emission trucks, low emission airplanes, low emission ship and boats, cable cars and autonomous driving vehicles	Medium	[46], [69], [92], [123]
3	Fuel energy security	Fuel energy efficiency, Security of supply, renewable share, import demand, subsidy and tax and alternative options	Short to medium	[68], [72], [126]
4	Institutional capacity	Institutional roles and responsibilities, training program, specialized education	Medium	Stakeholder input

5	Spatial dynamic	Infrastructure capacity(land, air and water), space capacity, congestion and time delay	Very Long	[6], [13], [25]
6	Accessibility	Service centers, market and shopping centers, schools and health care, job location, rural-urban dynamic, international connectivity, Public transport, airports, dry and wet ports, road network, and information and communication technology and fuel sources.	Short to medium	[6], [13], [25]
7	Mobility services	Multimodal mobility options, car rental, online booking system, local and regional connectivity, maintenance services, regular training, home office scheme, ownership free driving incentives (loan/company offer) and incentivized parking facilities	Short to medium	[45], [93], [125]
8	Resilience to accidents	Earthquake, tsunami, typhoon, hurricanes, wild fires, local accident and after effect control measures	Medium to long	[127]
9	Capital investment	Bank ability, collected revenue, annual budget, internal and external grants	Short to medium	[13], [123], [128]
10	Operation capital	Infrastructure maintenance, public transport operation, international fuel tax and subsidy, technology import duty tax, and cost of driving a car	Medium to long	[13], [109], [121], [123], [128]
11	Economic development	Type of businesses, financial flow, service sector, production center, consumption center, transaction type, tourism and recreation	Medium to long	[6], [50]
12	Environment pollution	Air pollution, waste generation, noise, space utilization and lubricant and fuel spillover	long to very long	[58], [117], [118]
13	Safety and security	Preventive measures, safety standards, enforcement mechanism, rescue and relief support, response time and communication system	Short to medium	Generalized from [129]
14	Enabling condition	Tax holidays, incentives, performance award schemes, law and policy reforms, reliable and affordable options	Medium	[109], [119], [125]
15	Cultural values	Travel behavior, belief system, business culture, ethics, social norms and disposition	Long	[97]–[99]
16	Attractiveness and aesthetics	Comfortable, clean, timely, friendly, safe, reliable, affordable and accessible to all population category	Short to medium	[97]–[99]
17	Awareness on new mobility	Advertisement, regular workshop and seminars, research publication, annual reports and ICT platform	Short to medium	Stakeholder input
18	participatory planning culture	Public sector, service provider, user, technology developer, business sector, standard and quality control authority	Short to medium	[8], [24]

19	Justice and fairness	Gender, senior citizen, children, public transport users, non-motorized mode commuters, rural populations, low- and high-income population category	Short to medium	[124]
20	Political influence	Political support for sustainable development and mobility system reforms that include willingness to adopt to change	Short to medium	Stakeholder input
21	Rural-urban dynamic	Demographic changes that include rural to urban migration, urban to rural migration	Medium to long	[6], [95], [100]
22	Human well-being	Quality of life, level of satisfaction, health and safety, freedom of choice and reduced financial burdens	Short to medium	[129], [130]

The list of variables in table 4 describes the rough image of mobility as a system. Although very rough, they represent the system holistically, which can be further analysed to understand the system behaviour and their leverage condition.In this preliminary list, the variables are assigned the time scale of short, medium and long, represented by short < 3 years, medium 3 to 10 years, and long > 10 years. The categorizations are done based on the assumption, which is subject to stakeholder feedback. For example, the Environment pollution (12) falls under time scale of long (>10 years), considering the slow process of negative influence due to emission and also the slow process of correction measure, whereas Capital investment (9), fall under the time scale of medium to long (3 to 10 years, >10 years), considering the possible short and long-term investment in infrastructure. The variability of these system variables governs the current status quo and their future perspectives of the mobility system. The identification of alternative future scenarios depend on the degree of variables impact and influence on the mobility system and recognizing the behaviour pattern in different time scale established by them, which will show the variables influencing strength on the system in the future [8]. Therefore, identifying variables systemic role and variability duration in the system ascertains the leverage condition of the mobility system with multiple possible alternative scenarios for transition to sustainable system [8], [11], [29], [30]. It has to be noted that the variables influence factor, system transition, new development are all contextual given the versatility of mobility as a system [8], [11], [24]. Therefore, there is no fix rule and fit for all strategy in defining mobility system that behaves sustainably. It depends on the context and consideration by the stakeholders involved in decision making process. Thus, planning and system design for future is negotiable. Technology choice, economic development and policy choice cannot be the baseline condition to define system sustainability in isolation [8], [11], [29], [30]. They will have to be analysed based on the variables influence factor, which is fully dependent on the actors involved in the system. Perhaps the lifestyle change is an answer to sustainable development, which is highly complex [8], [11], [18], [51].

3.1.1 Variable relevance check

The degrees of adequacy by which the set of variables defines the system is called relevance check, which can be scrutinized on the basis of theoretical screening and stakeholder comments as shown in figure 4 [8]. The first theoretical screening covers four basic domains, the sphere of life, physical category, dynamic category and system relation [8]. Sphere of life includes 7 aspects of complex system[8]. They are population, economy, land use, human ecology, natural balance, infrastructure and communal life. Physical categories are matter, energy and information [8], [39]. Dynamic categories are flow quantity, structural quantity, structure and space change [8], [39]. The system relation rules out, how the variable interact with the system i.e. influence the system from inside, influence from outside, influence by change of input and influence by change of output [8], [39].

Criteria →

● FULLY applicable
○ PARTIALLY applicable

		SPHERES OF LIFE							PHYS. CATEG.			DYN. CATEGORY				SYSTEM RELATIONS			
		Economy	Population	Space utilization	Human ecology	Natural balance	Infrastructure	Rules and laws	Matter	Energy	Information	Flow quantity	Structural quantity	Temporal dynamics	Spatial dynamics	Opens through input	Opens through outp.	Influenced f. inside	Influenced f. outside
1	Infrastructure development	○		●			●									○	○	○	
2	Technology development	●					○										○		○
3	Fuel energy security	○								●		●				○			
4	Institutional capicity						○	●			○		●					●	
5	Spatial dynamics			●		○			●			○			●		○		○
6	Accessibility	○	○		●								●					○	
7	Mobility services	●	○		○		●						○			○	○	○	○
8	Resilence to accidents					○	○							●			○		○
9	Capital investment	●						●			●								○
10	Operational capital	●						○			○	○				○		○	
11	Economic development	●						○			●						●		●
12	Environment pollution					●		○					○		○		●	○	○
13	Safety and security				●									○			○		○
14	Enabling condition							●			○						●		○
15	Cultural values		○		●												○		●
16	Attractiveness and asthestics				○						○		●			○		○	
17	Awareness on new mobility							○			●		○			○			○
18	participatory planning culture		●					○			○		○						
19	Justice and fareness		●					○					○		○	●		○	
20	Political influence	●									○		●						●
21	Rural-urban dynamic			○	●						○	○			●			○	
22	Human well-being				●			○			○		○			○	○	○	○
	Sum:	7.5	3.5	2.5	6.0	2.0	3.5	6.5	1.0	1.0	7.0	2.5	7.0	1.5	3.0	4.5	7.0	5.5	8.0

Figure 4: Criteria matrix second step of Vester Sensitivity Model[39]

The theoretical screening is an initial process of variable validation [8], [39]. However, it provides some degree of justification for imaging the mobility system by roughly focusing on 7 aspects of complex systems for structured screening. All variables require fulfilling the 7 complex system theoretical criteria to adequately describe the system under investigation for roughly correct system image generation [8], [39]. While screening; the variable that has direct influence on the system, receives full point and those that influence indirectly but are important, receive half point. At least one of the criteria should be fully covered by the set of variables that influence the system. The verification process of the variables is based on perspective future thinking process adopted by the researcher, which may or may not differ from context to context and different stakeholder view. Therefore, they can have varying magnitude of influence factor depending on the context and logical reasoning. The theoretical qualification of variables is an initial step for stakeholders engagement for the system assessment, which may be further scrutinized based on the stakeholder justification and the views of the expert involved in the system. Therefore, the current list of variables is hypothetical, which is subject to further refinement based on stakeholder judgement. The process of variable listing is iterative and it is subject to addition/removal over the course of further scrutiny. However, the current list of variables provides sufficient baseline condition where research context can be holistically addressed.

The theoretical system relevance test of figure 4 shows, the listed variables in table 4 sufficiently describe the mobility system. The empty circles indicate the partial fulfilment of the variable defining the system and those with black coloured circle fulfil the system description fully. The first online survey, which is based on yes and no question to qualify the variable list, was additionally carried out. Since the study is intending to address the context of Bhutan, the first stakeholder participation for yes and no question was carried only for Bhutan. The question said, "Do the following variables effect mobility system design?" The answer option given is yes and no for the respondent.

A total of 57 respondents took part in the survey. The general score of more than 60% yes to all the variables was received with further addition of one variable "institutional capacity development". Therefore, the first conclusion was drawn from the theory and feedback from general professional category to test the variable relevance to describe the mobility system. However, the list is subject to further feedback and comment involving the stakeholders that are not involved in the system. The process is iterative depending on the context for actual implementation for the design of executable mobility system.

The variable influence factor is additionally elaborated in chapter 7 as empirical evidence referring to national data of Bhutan and the historical mobility system development trend in Bhutan as a case study. The structuring of this chapter and chapter 7 is iterative where the case study may be referred for further validation of variable list. However, for the international purpose the specific case of Bhutan is insufficient. Therefore, the general list has to be considered. The above listed variable set is global and they fulfil roughly the complete mobility system imaging.

3.1.2 Variable validation using survey

A two-phase online survey was conducted to validate the mobility system variables. The first survey concluded with the binomial approach of yes and no question specific to Bhutan, to test theoretical list from the literature compilation, where 57 respondents responded with more than 60% yes score in the case of Bhutan. In the first phase of survey, the conformed variable list is shown in table 4 that includes addition of one more variable, the institutional capacity, referring to Bhutan mobility system design and their behaviour development. In the second phase of the survey, a range of possible options were given for the respondent, to retest variable relevance to define mobility system. The same 22 variables listed in table 4 were checked again but with different stakeholder that are not involved and do not reflect the context of Bhutan mobility system.

Table 5: Survey result descriptive statistics using SPSS tools

Mobility variables	Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Variance	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Range	Minimum	Maximum	Sum
Infrastructure development	5.5131	0.03202	6	6	0.88376	0.781	-2.342	0.089	5.936	0.177	5	1	6	4201
Technology Development	5.563	0.02881	6	6	0.79542	0.633	-2.399	0.089	6.656	0.177	4	2	6	4239
Fuel energy security	5.294	0.0394	6	6	1.08759	1.183	-1.925	0.089	3.602	0.177	5	1	6	4034
Institutional capacity	5.1089	0.04064	5	6	1.12197	1.259	-1.531	0.089	1.938	0.177	5	1	6	3893
Spatial dynamic	4.9633	0.04345	5	6	1.19952	1.439	-1.248	0.089	0.846	0.177	5	1	6	3782
Accessibility	5.2743	0.03562	6	6	0.98322	0.967	-1.76	0.089	3.3	0.177	5	1	6	4019
Mobility service	5.2415	0.03823	6	6	1.05535	1.114	-1.57	0.089	2.013	0.177	5	1	6	3994
Resilience to accidents	5.1312	0.04188	6	6	1.15596	1.336	-1.481	0.089	1.617	0.177	5	1	6	3910
Capital investment	5.1759	0.04048	6	6	1.11756	1.249	-1.404	0.089	1.203	0.177	4	2	6	3944
Operational capital	5.0407	0.04251	5	6	1.17337	1.377	-1.219	0.089	0.659	0.177	5	1	6	3841
Economic development	5.2073	0.0402	6	6	1.10977	1.232	-1.521	0.089	1.626	0.177	5	1	6	3968
Environment pollution	5.3543	0.0351	6	6	0.96885	0.939	-1.836	0.089	3.506	0.177	5	1	6	4080
Safety and security	5.3346	0.03591	6	6	0.9912	0.982	-1.854	0.089	3.518	0.177	5	1	6	4065
Enabling conditions	5.0276	0.0428	5	6	1.18156	1.396	-1.395	0.089	1.328	0.177	5	1	6	3831
Cultural values	4.9751	0.04531	5	6	1.25077	1.564	-1.242	0.089	0.758	0.177	5	1	6	3791
Attractiveness and aesthetics	4.9265	0.04299	5	6	1.18681	1.409	-1.097	0.089	0.438	0.177	5	1	6	3754
Awareness on new mobility	5.3018	0.03401	6	6	0.93871	0.881	-1.58	0.089	2.585	0.177	5	1	6	4040
Participatory planning culture	5.1089	0.04047	5	6	1.11728	1.248	-1.514	0.089	2.001	0.177	5	1	6	3893
Justice and fairness	5.1877	0.03966	6	6	1.09482	1.199	-1.528	0.089	1.837	0.177	5	1	6	3953
Rural urban dynamic	5.1601	0.03739	5	6	1.03199	1.065	-1.403	0.089	1.629	0.177	5	1	6	3932
Political power	5.3255	0.03773	6	6	1.04138	1.084	-1.773	0.089	2.691	0.177	5	1	6	4058
Human wellbeing	5.1614	0.03907	5	6	1.07849	1.163	-1.446	0.089	1.616	0.177	4	2	6	3933

For the survey questionnaire one single question was asked that is "Do you think following set of mobility system variable will influence the behaviour of the mobility system development?" with range of possible answers for each variable. The levels start with high score of 6 for strong impact and low score of 3 for no impact and score of 1 for option for the respondent to give additional information in others tab. They are as shown in the following list.

Influence Magnitude	**Values**
Very strong impact	6
Moderate impact	5
Weak impact	4
Has no impact	3
I don't know	2
Others	1

The range of possible answers to the single question for 22 mobility system variables was done online by involving student from different countries. The students are from India, Nepal, Bangladesh, Croatia, Brazil and Nigeria who took part in the survey questionnaire. The online survey lasted for one academic semester interdisciplinary project for students, which is taken as regular class for the semester. Students were given as an assignment to collect the generic stakeholder view using the predefined Google form questioner, which is regularly monitored. The assignment resulted with the simple random sample size of 762 respondents from 6 different countries. The sample is simple random sample as mobility system in general represents global functional service that can be availed by any population categories. It is assumed that the categorical population sample will have more or less the same expected outcomes. As mobility system serves globally the same function of movement, the idea of the survey was to understand the global context of mobility system behaviour based on the defined global variable list, which are present in various literature sources as shown in table 4. The result of the survey is compiled as descriptive statistics using standard SPSS tool for interpretation, which is shown in table 5. The descriptive statistics shows six significant statistical parameters to validate the result:

1. Mean: the mean score by all the variable range between 5 to 6, which is within the range of moderate to very strong. Therefore, the response indicates that the variable lists are sufficient to define the mobility system behaviour for further analysis.
2. Standard error: The sample statistics deviation from the population parameter is less than 5%, which indicates that the variables can be considered as global.
3. Median: The median falls within the range of 5 and 6 for the entire variable list, thus indicating the variable list influence the mobility system fully or partially and can be further analysed.
4. Mode: The mode from variable list is 6, which indicates that the most repeated response shows that the variables strongly impact the mobility system behaviour which can be further screened depending on the context and stakeholder group.

5. Standard deviation: The standard deviation range between 0.75 to 1.5 for the list of variables, which shows the central tendency towards strongly impact the behaviour of the system, is narrow indicating less error factor.
6. Variance: The Square of the deviation from the central tendency is in the range 0.75 to 1.5, which indicates the lower degree of possible error factors.

Based on these six statistical parameters, the lower score of weak impact, no impact, I don't know and others can be regarded insignificant for the moment. Therefore, it can be concluded that the variable list is sufficient for further analysis for the design of mobility system. The ranking list of 22 variables is illustrated in figure 5. Further there is no further addition of variable from the respondent, which limits the variable list to 22 as observed in the first survey and the theoretical list from the literature sources.

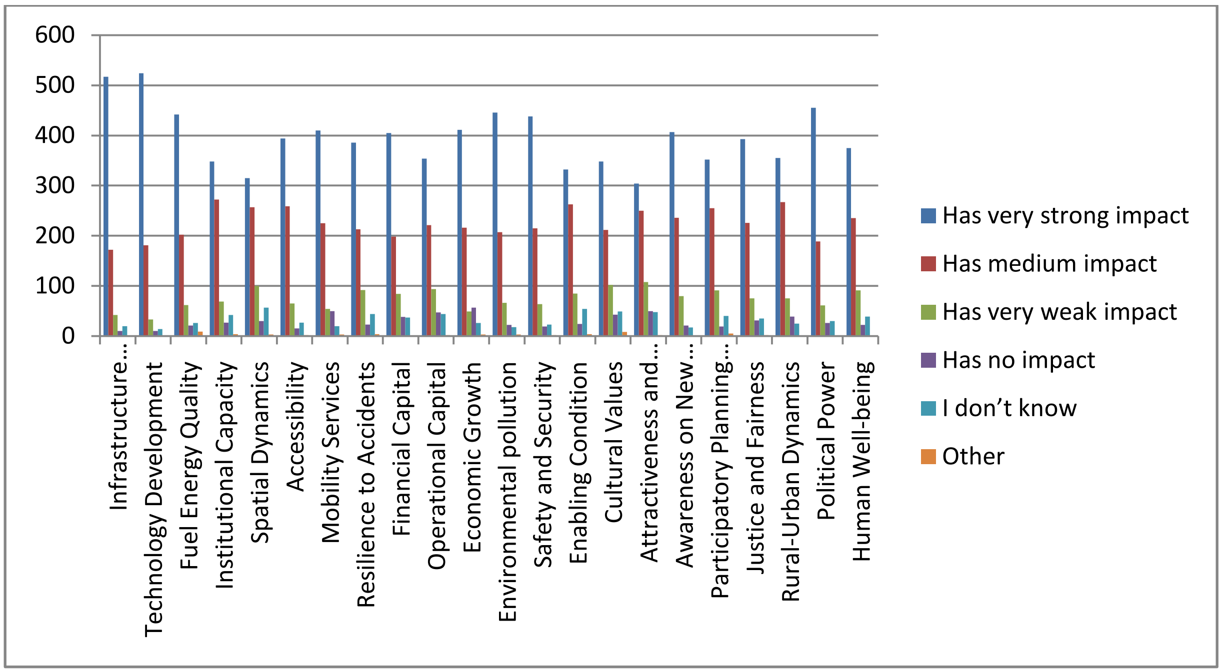


Figure 5: Variable score ranking

In addition to the survey result, the variables are further screened in the form of workshop, where specific cases from different countries and respondent feedback is presented by individual students. The workshop also included mobility experts to provide further feedback and comment. The validated variables are then analysed by students in cross-impact matrix in Vester Sensitivity software [39]. This way the first step system analysis is performed. It has to be noted that statistically validated variables are not the final stage of verification process and they are subject to modification for system design consideration. However, it can be concluded from this assessment that a rough system image can be visualized based on the variables listed in table 4.

3.1.3 The systemic role of the variables in the system

Sustainability is a system property and system-elements cannot be sustainable on their own [17], [18]. The variables that define the system tend to have cybernetic effects, with the system as a whole and among the variables itself, exhibiting variables cross causality, that exhibit system property [8], [39]. Therefore, understanding the role of a variable in the system requires cross-impact assessment of the variable that defines the system, which applies to mobility system as well. The cross-impact assessment of the variables is the process of enquiring the system and by doing that, rough image of the system is known, which can be further analysed [8], [39]. The process involves the stakeholder consultation, which is part of the data source for system model design validation process [8], [11], [39]. The process is participatory, which aims to assess the system to generate roughly true image rather than working on particular aspect of system in isolation [8], [11], [39]. Therefore, linearity and singularity worldview are avoided as much as possible during the process of system inquiry, which is logically iterative. For that purpose, the system inquiry is done. This is based on consensus matrix or matrix of influence using cross-impact analysis between the variables and observing their cybernetic effect that eased the process [8], [11], [39]. The complexities involved are the variables that can influence can also get influenced by others, which show the variables causality and feedback cycles. While analysing the cross-impact assessment, the degree to which the variables influence and get influenced by the others are calibrated (0=No impact, 1=Weak impact, 2=Medium impact, 3=Strong impact) [39]. A square matrix of zero diagonal is formed from the complete variable influence analysis. The size of the square matrix is determined by total number of variables. The sum of horizontal row of the square matrix is called active sum (AS)and is the strength of a variable that will influence other variables [39].The sum of vertical column of square matrix is called passive sum (PS)and is the strength of influence of other variables on the influencing variable [39]. Product of AS and PS is called P value and quotient of AS and PS is called Q value, which indicate the variable's role in the system as shown in figure 6.

	Influence by ↓ to →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	AS	P
1	Infrastructure development	X	2	2	0	3	2	2	3	1	1	1	3	2	3	2	2	0	0	2	0	2	2	35	525
2	Technology development	1	X	2	0	0	0	3	2	1	1	1	3	2	1	0	2	0	0	0	0	0	1	20	400
3	Fuel energy security	0	3	X	0	0	1	2	1	0	2	1	3	1	2	0	0	2	0	0	0	0	2	20	420
4	Institutional capicity	2	2	2	X	2	2	3	2	1	1	2	2	2	3	0	2	2	2	2	0	0	1	35	525
5	Spatial dynamics	0	0	0	0	X	2	2	2	1	2	0	3	2	2	1	2	0	1	2	0	0	2	24	504
6	Accessibility	0	0	0	0	2	X	2	2	1	1	3	0	2	2	2	2	1	1	2	0	2	2	27	594
7	Mobility services	1	1	1	1	1	3	X	2	1	3	2	2	2	2	2	3	1	0	2	1	2	3	36	1188
8	Resilence to accidents	1	1	1	1	0	0	1	X	2	2	1	0	3	2	1	1	0	0	1	0	2	1	21	483
9	Capital investment	2	1	2	3	1	2	3	2	X	2	1	2	2	2	0	2	1	1	2	0	1	2	34	612
10	Operational capital	1	1	2	2	0	2	2	2	2	X	1	2	2	2	0	2	1	1	2	0	1	2	30	690
11	Economic development	0	2	2	2	2	1	2	0	1	1	X	3	1	2	2	1	1	2	2	1	2	2	32	992
12	Environment pollution	0	1	0	0	0	0	0	0	1	0	0	X	2	0	0	0	1	1	1	2	2	3	14	560
13	Safety and security	0	0	0	0	0	0	0	0	0	0	1	1	X	2	0	2	0	1	1	0	2	2	12	372
14	Enabling condition	1	2	2	1	2	2	2	1	0	1	2	2	2	X	2	2	2	1	1	0	2	1	31	1085
15	Cultural values	0	0	0	1	0	0	2	0	0	0	2	2	0	1	X	2	0	1	1	0	1	2	15	360
16	Attractiveness and asthestics	0	0	0	0	0	0	1	2	0	0	2	0	1	2	2	X	1	0	1	1	2	2	17	476
17	Awareness on new mobility	0	1	1	1	1	0	2	1	0	0	1	3	2	0	2	0	X	0	1	0	1	0	17	272
18	participatory planning culture	2	0	1	1	1	2	2	1	0	1	1	2	1	2	3	1	2	X	3	2	2	1	31	527
19	Justice and fareness	0	0	0	0	0	2	1	0	0	0	2	0	0	2	2	1	0	2	X	0	0	3	15	420
20	Political influence	2	2	2	2	1	1	1	0	3	2	2	2	1	3	1	1	1	2	2	X	2	3	36	360
21	Rural-urban dynamic	2	1	1	0	3	0	0	0	2	2	3	2	1	0	0	0	0	1	0	1	X	2	21	588
22	Human well-being	0	0	0	0	2	0	0	0	1	1	2	3	0	0	2	0	0	0	0	2	2	X	15	585
	PS	15	20	21	15	21	22	33	23	18	23	31	40	31	35	24	28	16	17	28	10	28	39		
	Qx100	233	100	95	233	114	123	109	91	189	130	103	35	39	89	62	61	106	182	54	360	75	38		

Consensus | Compare with
A B C D E F | A B C D E F

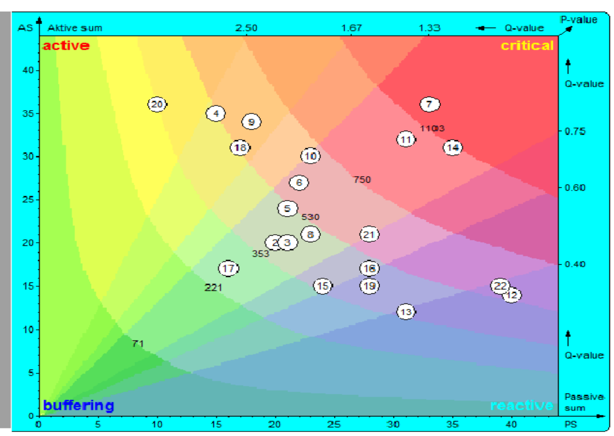


Figure 6: The impact matrix and variables systemic role

For 'n' number of variables, the percentage deviation from the total points scored by the variables under investigation to the minimum score of $(n-1)^2$ indicates the overall system stability, the k-value deviation. The negative k-value indicates system is buffering, zero indicate the system is neutral and positive indicates system is critical/unstable [39]. The degree to which the system is buffering and its instability is known by the k-value. Entry of points to influencing variable is guided by the question "if variable A is changed, how strongly variable B changes". Only the direct impacts are considered relevant for the entry of impact values.

The completed cross-impact analysis and the variables systemic role is as shown in figure 6. The screen shot image of the variables cybernetic effect and their systemic role is hypothetical until execution level consultation is taken into account, which is purely dependent on to contextual judgement with involved stakeholders and is participatory process. Therefore, the hypothetical mobility system model is a theoretical base for decision support, which has to be validated based on the contextual condition. The cross impact assessment is a basis for variables cybernetic evaluation of any system [8], [11], [39]. The cybernetic effect system is a simplified model representation, which provides insight into feedback loop for system's future scenario judgement. Thus, the theoretical image of mobility system is a much more generalized system model that can be adopted for variables cybernetics and the contextual case study analysis.

Table 6: The PS, AS, P and Q values

SL.No	Variables	Active sum	Passive sum	Product	Quotient
1	Infrastructure development	33	11	363	3.0
2	Technology development	20	16	320	1.3
3	Fuel energy quality	20	18	360	1.1
4	Institutional capacity	35	13	455	2.7
5	Spatial dynamic	24	17	408	1.4
6	Accessibility	25	21	525	1.2
7	Mobility services	33	32	1056	1.0
8	Resilience to accidents	19	23	437	0.8
9	Financial capital	33	13	429	2.5
10	Operational capital	29	19	551	1.5
11	Economic development	28	26	728	1.1
12	Environment pollution	10	36	360	0.3
13	Safety and security	10	29	290	0.3
14	Enabling condition	29	32	928	0.9
15	Cultural values	14	23	322	0.6
16	Attractiveness and aesthetics	14	27	378	0.5
17	Awareness on new mobility	16	15	240	1.1
18	participatory planning culture	27	14	378	1.9
19	Justice and fairness	15	26	390	0.6
20	Political influence	36	10	360	3.6
21	Rural-urban dynamic	21	28	588	0.8

22	Human well-being	11	34	374	0.3

To augment the screen shot image of figure 6, arithmetic values of PS, AS, P and Q are as shown in table 6. The values of AS, PS, P and Q are very important condition for the system model design, which is the result of collective assessment of the system by the involved stakeholders. The robustness of the system design depends on the stakeholder participation and collective judgement [8], [11], [39]. This is where the ideation of plurality system perspective is critical, in contrast to fixed statistical evidence for complex system planning decision support, which is most of the time overlooked[8], [11], [39]. This study tries to incorporate the baseline condition for system validation for planning decision support to model mobility as an optional system as shown in figure 6 and table 6.

The score of table 6,when it is transferred to strategic plot of 50 uniquely defined strategic fields, which is shown in figure6 with different colour codes indicate the systemic role of the variables [8]. The strategic positioning of the variable is the result of common agreement with the involved stakeholder (in this case between the researcher, student and supervisor).Assessment process is contextual and iterative (in this case for Bhutan). Based on these criteria, variables receive unique strategic plot, which is called as systemic roles of the variables in the system as it defines variables behaviour in the system, which is shown in table 7. The strategic statements are predefined for the variable orientation in the system and they are based on experience according to Vester (et al 2007), which is applied in the software Sensitivity Analysis [8]. This way the first image of mobility as a system is analysed.

Table 7: Variables systemic role derived from Vester Sensitivity Model [8], [39]

Variables	Systemic role	Cybernetic effect
Infrastructure development	Active variable whose modification may get things going. However, to obtain a lasting influence it should be protected against the immanent compensation of the system or strengthened by concerted action with components acting in the same direction.	Strong lever of change
Technology development	Neutral section between active, reactive, buffering and critical. There are little means to steer the system via the components of this area which are on the other hand well-fitted for self-regulation if integrated in feed-back cycles.	Very strong stabilizing feedback control
Fuel energy security	Neutral section between active, reactive, buffering and critical. There are little means to steer the system via the components of this area which are on the other hand well-fitted for self-regulation if integrated in feed-back cycles.	Very strong stabilizing feedback control

Institutional capacity	Active variable whose modification may get things going. However, to obtain a lasting influence it should be protected against the immanent compensation of the system or strengthened by concerted action with components acting in the same direction.	Strong lever of change
Spatial dynamic	Neutral section between active, reactive, buffering and critical. There are little means to steer the system via the components of this area which are on the other hand well-fitted for self-regulation if integrated in feed-back cycles.	Very strong stabilizing feedback control
Accessibility	Interventions in components of this section often cause pendulum movements which may compensate rather soon corrections in the system. A control of this self-dynamics (which may stop a wanted development) will be better carried out from outside the system.	Very strong feedback control
Mobility services	The strong influence of this component on the rest of the system can be extremely strengthened as well as collapse by strong positive feedback. Beware of over steering	Very strong leverage
Resilience to accidents	Neutral section between active, reactive, buffering and critical. There are little means to steer the system via the components of this area which are on the other hand well-fitted for self-regulation if integrated in feed-back cycles.	Very strong stabilizing feedback control
Financial capital	Rather active but slightly critical steering lever which will not be untouched by the repercussions of its own interventions. It therefore should be kept under control even after its use as a lever.	Active lever of change
Operational capital	Interventions in components of this section often cause pendulum movements which may compensate rather soon corrections in the system. A control of this self-dynamics (which may stop a wanted development) will be better carried out from outside the system.	Lever of change
Economic development	Changing this critical component may cause trouble because of its equally strong activity and reaction. If not intended to give a strong initial impact it has to be bound in feedback-cycles when modified.	Strong leverage
Environment pollution	Un-reflected interventions into the slightly critical but highly reactive variable of this section can cause a lot of unexpected consequences which cannot be reversed by the same way.	Strong indicator

Safety and security	Easily movable component compensating many interventions because of its integration in feedback cycles. Caution if connected to active or critical components because in this case an intervention may easily destabilize the system.	Weak indicator
Enabling condition	Changing this critical component may cause trouble because of its equally strong activity and reaction. If not intended to give a strong initial impact it has to be bound in feedback cycles when modified.	Strong leverage
Cultural values	Interventions to components of this slightly reactive neutral section very often feint desired effects which, however, will be compensated quickly by self-regulation.	Indicator feedback
Attractiveness and aesthetics	Interventions to components of this slightly reactive neutral section very often feint desired effects which, however, will be compensated quickly by self-regulation.	Very strong feedback indicator
Awareness on new mobility	Slightly reactive and weakly buffering component which is contributing to the self-regulation of the system without being an indicator.	Neutral feedback
Participatory planning culture	Active variable whose modification may get things going. However, to obtain a lasting influence it should be protected against the immanent compensation of the system or strengthened by concerted action with components acting in the same direction.	Lever of change
Justice and fairness	Rather mobile reactive component where interventions can easily be undertaken leading obviously to the desired result. However, the latter may soon be neutralized by repercussions from the system.	Very strong indicator feedback
Political influence	Rather mobile and very active lever which can be activated from within the system, but also be easily compensated by repercussions.	Strong lever of change
Rural-urban dynamic	Interventions in components of this section often cause pendulum movements which may compensate rather soon corrections in the system. A control of this self-dynamics (which may stop a wanted development) will be better carried out from outside the system.	Critical feedback control
Human well-being	Un-reflected interventions into the slightly critical but highly reactive variable of this section can cause a lot of unexpected consequences which cannot be reversed by the same way.	Strong indicator

The strategic statements of table 7 spread across the five different description fields such as; buffer, reactive, critical, active and neutral zone allows further grouping of the variables. The buffer zone shows, the sluggishness of the variable, indicating poor performance but the variables are in stable state [8], [39].The reactive region shows, the variable plays the role of system indicator [8], [39].The critical region shows, the variable has strong leverage point but are also highly risky region as the influence may result in unintended development [8], [39]. The active region shows the potential lever of change, where intervention can be made. The intersection region of buffer, reactive, critical and active is a neutral zone indicating self-regulatory dynamic of the system [8], [39]. The variables occupying the region of neutral section are system stabilizing variable, which is suitable for feedback control. The position of the variable in the system defined by sluggishness, feedback control, system indicator, system leverage, and system change lever will depend on the cross-impact assessment score of table 6 [8], [39]. The robustness of the system is however influenced by the process by which the variables are listed and the system is analyzed. Therefore, the position of the variables in the system is a test model system enquiry using cross-impact assessment and is a theoretical image, which can be used for executable planning decision support.

The theoretical assessment of mobility system variables shows Political power (20) as strong change lever. Institutional capacity (4), Participatory planning culture (18) and Infrastructure development (1) as change lever. The Mobility service (7), Economic development (11) and Enabling condition (14) indicate strong leverage potential, which is risky intervention for transition to sustainable mobility system development. The variables Environment pollution (12) and Human wellbeing (20) are made to behave as system indicator. The Technology development (2) and Fuel energy security (3) indicate strong system stabilizing feedback variables. The more detailed effects of other variables and their invisible cybernetic behaviour can be further analysed in the effect system, which can be used to visualize mobility system model and to project future scenario for sustainable transition.

4 Case study of Bhutan: Background

The empirical justification of mobility system variables are further augmented in this chapter, which will be extensively elaborated in chapter 6 with contextual scenario of Bhutan. Bhutan's development model, which is based on the Gross National Happiness (GNH) philosophy is value oriented that is reflected in the vision, mission, goals and objectives statement (1, i, a, b, c, d, e, f) defined by Gross National Happiness Commission (GNHC), the institution responsible to monitor the development [138]. Therefore the system is a regulated system, where mobility system development has to abide by the following national development path [138].

Vision:

1. An institution that promotes development with values

Mission:

i. To steer national socio-economic development guided by the principles of GNH.

Goals:

a) Guide and steer the integration of GNH principles in all policies and plans.
b) Ensure the effective delivery of Five Year Plan Key Results.
c) Institutionalize a robust National Monitoring and Evaluation System.
d) Ensure the needs of vulnerable groups are addressed.
e) Ensure the mainstreaming of cross-cutting issues in policies, plans and programmes.
f) Establish GNHC as a legal Entity for national development planning and GNH mainstreaming

Objectives:

a) To guide long-term sustainable socio-economic development and strategies
b) To spearhead five year and annual planning and guide public policy formulation
c) To ensure that GNH principles are mainstreamed into plans and policies in cognizance of regional and international commitments
d) To mobilize adequate resources on a timely basis and ensure equitable and efficient allocation
e) To monitor, facilitate, and coordinate implementation of policies, plans and programs for effective delivery
f) To evaluate polices, plans and programs on a timely basis and provide feedback and undertake corrective action.

The development approach caters to the national population size of approximately 727,145 people occupying the geographic boundary of 38,394 km^2area, which is divided into 205 community and 20 districts[139].The planning and execution of the plan is based on the five year development target [140], [141], [150], [142]–[149]. Five year plan targets are enacted by the elected government under the framework of democratic constitutional monarchy since 2008 [151]. Bhutan is entering into 12th five year development plan [150], which means that the documented data can be traced back to 55 year of post growth or value addition. Mobility system development defined under the transport and communication falls within this 5 year development target. The 55 years of mobility sector development summery is as shown in table 8, which is referenced to the following national development plan document [140], [141], [150], [142]–[149]. The development trajectory is unique and contextual. Same is also true for different countries and therefore require contextual case study.

Table 8: 55 year of mobility development overview

Plan	Plan period	Target	Total plan budget for development (Mil Nu)	Approximate mobility budget(Mil Nu)	Visible outcome in mobility sector development
1st plan [140]	1961-1966	Basic infrastructure development for road transport services	1,747.00 Nu	695.00 Nu	1,770 km road construction work and basic transport services started
2nd plan [141]	1966-1971	Construction and improvement of existing road infrastructure and transport services	2,214.00 Nu	754.00 Nu	Continuation of road construction, Maintenance, up gradation, and widening of existing roads. The budget also covered housing, electricity and water supply
3rd plan [142]	1971-1976	Construction and improvement of existing road infrastructure and transport services	3,550.00 Nu	760.00 Nu	755 km road construction completed with 31 passenger bus and 52 trucks on road to cater mobility services
4th plan [143]	1976-1981	Increasing the leaving standard of people	7,779.90 Nu	0.00 Nu	Increased access for rural economic growth and further development of other sectors from the basic infrastructure
5th plan [144]	1981-1986	Increase accessibility to modern economic system to enhance development priorities	43,381.10 Nu	459.17 Nu	Aviation sector started, International port for water way signed in Calcutta port and 2050 km domestic road construction with 1,200 km black topped and 2,690 registered vehicles noted
6th plan [145]	1987-1992	De-centralization and people's participation	95,236.00 Nu	1,574.96 Nu	Aviation service operational, 2,273 km road completed, road classification started, engagement of domestic contractor for infrastructure development and maintenance

7th plan [146]	1992-1997	De-centralization and people's participation with value orientation in economic growth	15,590.70 Nu	1,308.00 Nu	Increased accessibility for rural populace with improved mule track, suspension bridges, and rope ways to urban centers. The road length of 2,674 km catered the mobility of 7002 vehicle
8th plan [147]	1998-2003	Long-term sustainable development and self reliance	39,523.82 Nu	4,797.96 Nu	Rapid urbanization, International trade, improvement in aviation, 3,200 km road infrastructure developed and road sector master plan development
9th plan [148]	2003-2008	Holistic development addressing life quality, good governance, environment, culture and economy	70,000.00 Nu	10,030.54 Nu	3,746 km road , expansion of airport, dry port, road standards, automation of road construction, and the vehicle number increased to 19,463
10th plan [152]	2008-2013	Political democracy, economic empowerment and poverty alleviation	1,48,074.00 Nu	17,433.32 Nu	4,352 km road, highway expansion, spatial planning, farm road extension for all community, urban development, efficient transport and expansion of public transport services. Total vehicle number is 67,926
11th plan [149]	2013-2018	Self Reliance and Inclusive Green socio-economic Development	60,083.82 Nu	18,006.92 Nu	3 domestic airport established, explored e-vehicle, rope ways, cable car, railway link, 10,578.26 km road infrastructure developed, vehicle number increased to 92,008

From table 8, it additionally justifies that the need of 22 global variable lists is necessary to define mobility system, which are addressed in mobility system model in chapter 3 to enquire mobility system development. In table 8 the summery of the mobility system development of Bhutan is shown, where the system image can be visualized by recognizing the variable defining the historical development of mobility system. The first column shows the development plan, the second column shows the plan period and years, the third column shows the national development target for that plan period, the forth column shows the overall national development budget allocation, the fifth column shows the approximate mobility budget derived from national development plan budget and the sixth column shows the key outcome of the mobility development in that plan period. The numerical figure indicating the budget is an approximate figure expressed in Bhutanese currency million ngultrum (mil Nu.), as documented data also indicate there are alternative budget used in some cases. The start of the five year development plan indicated that Bhutan did not have motorization or any form of modern transport system until 1961 [140]. The mode of transport was fully dependent on foot for passenger mobility and use of animal power for goods transport. At the end of the 11th five year plan, Bhutan's mobility sector has changed drastically, where the mobility goal is defined by the inclusive green socio-economic development [149]. Bhutan is now in the process of implementing 12th five year development plan and will be entering the 13th five year development plan [150]. Therefore the mobility system transformation can potentially fall within the next plan period.

The summery in table 8 is a very clear conception on how the mobility system model trajectory is formed and not just by the specific aspect of transport function. These explain the ontology of mobility system, which defines how mobility system, is. Therefore conclusion cannot be drawn from specific aspect for system transformation as it is interdependent on many other system variables. For the mobility system design consideration and desired transformation, the variables list are; Infrastructure development (1), Technology development (2), Fuel energy quality (3), Institutional capacity (4), Spatial dynamic (5), Accessibility (6), Mobility service (7), Resilience to accident (8), Capital investment (9), Operational capital (10), Economic development (11), Environment pollution (12), Safety and security (13), Enabling condition (14), Cultural values (15), Attractiveness and aesthetics (16) Awareness on new mobility (17), Participatory planning culture (18), Justice and fairness (19), Political power (20), Rural urban dynamic (21) and Human wellbeing (22). Cybernetic deduction of the above variables with the involved stakeholder is critical for successful transition of mobility system to sustainable mobility system, which will unfold the epistemology of mobility system on a contextual basis. The more meaningful system enquire is however dependent on the communication with the stakeholder involved for the design of the system. Due to time limitation and other logistic difficulty, the stakeholder consultation with the actors of the system is separated for the moment. Therefore the observer defines the mobility system of Bhutan based on historical data available so far and potential opportunities arising from that. Since Bhutan's hydropower is a main energy source for national economy, the desirable system can also be aligned to the energy economy and associated values that will enable living standard of people of Bhutan. Therefore potential future alternative can be explored from in scenario 4 (refer chapter 6) that represent the current scenario of Bhutan after cybernetic deduction of the variables effect in addressing Human wellbeing (22) and Environment pollution (12), which may be realigned to desirable scenario 1 as outlined in section 6.6. The scenarios of mobility system will be discussed in detail in chapter 6.

4.1 National acts and policies: System enabler

Until the first five year plan began, Bhutan's transport was fully dependent on animal power for goods transport and on foot for passenger travel [140]. Although no documented data is available for the design and development of foot paths and mule track, they are fully coordinated with the government and the community. The access to outside economy seemed very challenging. The period before 1961 witnessed the bartered system of economy, where Bhutan exchanged animal products with salt and other essential grocery with India in the south and Tibet in the north. The formal acts and policies started to evolve after the five year plan development started in 1961, which will also enable the guidelines for mobility act and policy.

Due to landlocked nature, surface transport is one of the main modes of transport adopted in Bhutan although the aviation sector is currently seen as alternative fast travel option. The surface transport of Bhutan is formally registered under the Ministry of Information and Communication (MoIC) at the end of 7th five year plan in 1997 under Road Safety and Transport Authority guided by the Road Safety and Transport act 1999 [153]. The Road Safety and Transport Act 1999 provides the comprehensive directives for vehicle classification, road rules, vehicle registration, road driving standards, licensing for both private and government vehicle and any changes in the surface transport policy and planning. The surface transport act is enforced through traffic police division under royal Bhutan police [153], [154]. Similarly the road infrastructure development started in the first five year plan in 1961, where today's Department of Road (DoR) got its name transformed from Bhutan Engineering Service (BEA) to Public Work Department (PWD) to Department of Road (DoR), which was under the Ministry of Information and Communication (MoIC) and bifurcated to Ministry of Works and Human Settlement (MoWHS) in 2003 [155]. The road infrastructure development is guided by the Road Act 2013 [156]. The Road Act 2013 provides the road development guidelines, road classification, road standards, road right of ways, road environment compliance requirement and the alteration of policy and plan for road development, which is also guided by the road development master plan, urban road standard and road rules and regulation [156]–[159]. These acts and policies can be summarized as mobility system defining variable Enabling condition (14).

The air transport service was launched in 2nd five year plan and started fully operational in 5th five year plan [160]. The civil aviation or the air transport service is guided by the civil aviation act 2000 [161], which is scheduled to be replaced by civil aviation act 2017. The civil aviation act will guide the air route bundling, safety standards, domestic and international connectivity and aviation sector policy and plan formulation. All the above mentioned acts and guidelines are based on the five year development plan and Bhutan Vision 2020 document part 1 and part 2 [130]. Therefore the Bhutan's mobility system is fully monitored and selective as per the planning framework formulated in the documented data.

In 2006 the government identified the need to re-design the policy and plan that is robust for transport sector development influenced by fast growing economy, where Bhutan is envisioned to be graduated from least developed economy by the end of 2023 [138]. Therefore an integrated transport vision 2040 was launched with the support of Asian Development Bank (ADB) to cope with the fast growing economy. The integrated vision outlines the transport sector development as inclusive and sustainable transport [129]. The 2040 transport vision stated "to provide the entire population with a safe, reliable, affordable, convenient, cost effective, and environment-friendly transport system in support of strategies for socioeconomic development" [129]. Based on this integrated 2040 vision, the national transport policy of 2006 [162] was recognized insufficient to address all those conditions defined in the integrated vision 2040. The new and robust transport policy, which is envisioned to be inclusive to meet all the challenges, is desired. Thus new policy was launched in 2016 with the view to capture the defined vision, titled as inclusive national transport policy 2017 [127]. The new transport policy influences the other national policy such as economic development policy 2016 [163], alternative renewable energy policy 2013 [164]and National environment act of Bhutan [165]. The cross-cutting policy guides the holistic development approach, which is based on Gross National Happiness(GNH) philosophy and is guided by the vision 2020 document part1 and part 2 [130] and forms the main guiding tool for transport sector policy and future plan. All together transport sector development has a complex determinant which cannot be reduced to one specific aspect. Therefore the key condition for transport sector development in future depends on inclusivity to meet the growing challenges. Whereas the inclusivity itself is determined by the new transport policy 2017 [127], the alternative mobility development is taken care by alternate renewable energy policy [164], [166]. The alternate renewable energy policy is an indicative for e-mobility development in Bhutan, where electricity is abundantly available from the clean hydro source. On the other hand the socio-economic perspectives and regional trade is defined by the economic development policy 2016 [163]. Aviation sector seem to appear autonomous although it is extensively described in the transport policy 2017. Although these national acts and policies define the long-term plan based on the value oriented national vision of peace, prosperity and happiness, it shows organizational overlap on the defined roles and responsibility among the executing authorities as shown in table 9&10 [127], [153], [156], [161], [163]–[165].

Table 9: Overlap of act and policy

	Transport policy	**Economic development policy**	**Renewable energy policy**
Transport act	Strong influence	moderate influence	weak influence
Road act	Strong influence	moderate influence	weak influence
Aviation act	Strong influence	moderate influence	weak influence
Environment act	Strong influence	strong influence	strong influence

The ministry of information and communication and ministry of works and human settlement share common roles and responsibilities for national plan, which has the potential to merge together. Therefore success of long-term transport vision can also be influenced by organizational re-orientation. The organization involved for various roles and responsibilities are summarized in table 10 [127], [153], [156], [161], [163]–[165].

Table 10: Organization role for transport vision of Bhutan

National acts& policy(enabler)	Institutions responsible					Soft control Functional role
	MoWHS	MoIC			MoEA	
	Surface infrastructure	Surface transport	Air transport	Alternative transport	National Ports	
Road act	DoR	DoR	not applicable	not defined	Not defined	Infrastructure development and access to economic development
Transport act	RSTA	RSTA	Not applicable	not defined	Not defined	Road rules, compliance requirement, licensing and enforcement
Civil aviation act	not applicable	RSTA	Civil aviation	not defined	Department of Trade	International trade and regional connectivity
Environment act	NEC	NEC	NEC	NEC	NEC	Minimum environment standards requirement and monitoring the change
Transport policy (overlap)	Infrastructure development	Mass passenger transit, goods transport, personal vehicles	internation al route bundling, domestic airlines	Rope ways, cable car, e-mobility , walk ways and bicycling	Inland dry port and access to international wet port	Inclusive transport for the mobility of goods, services and passenger

Table 10 shows potential for the formation of new corporate office responsible for inclusive transport service development for the future to address integrated transport vision 2040 for Bhutan [129]. The pull of department from different ministries to form integrated transport corporate office has the potential to value add to innovative mobility system development, where inclusivity play critical role for economy and environment. The evolution of organizational roles and responsibilities defined by acts and policies are what we can relate to the mobility system variable Enabling condition (14), which is fully regulated in the case of Bhutan.

4.2 Mobility system development trend: Historical consideration

The mobility system development trend can be explained with the help of variable list of chapter 3 and their relevant statistical data. The variable, Justice and fairness (19) and Rural urban dynamic (21) define the basic mobility demand and associated demographic changes. The variable Justice and fairness (19) strongly influences different population categories such as different age group and different income group, which will determine the potential development of rural and urban population size. In the case of Bhutan, the annual population size is a projected population from the actual record of population census data 2005 and 2017 that is recorded every 10 year. The actual population size of Bhutan in 2005 was recorded 634,982 people, where male population dominated the total population size by 52.54% and female 47.46%, out of which 30.9% lived in urban area and 69.1% in rural area [167]. Similarly the population size of 727,145 people was recorded in 2017, where the male and female distribution were very close to 2005 that is 52.3% male and 47.6% female out of which 37.8% dwelled in urban area and 62.2% in rural area [139]. Both the population data shows, the highest population categories fall in the age group of 10-30 year.

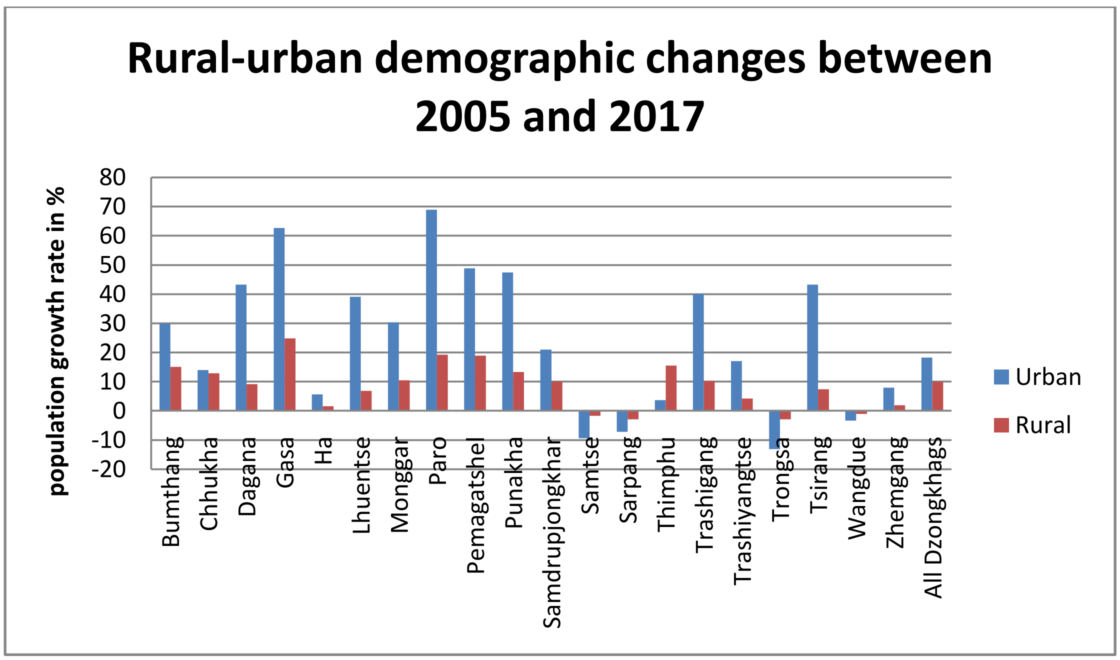


Figure 7: Population growth from 2005 to 2017 by district

Figure 7 shows the population growth and distribution in all 20districtsof Bhutan referenced to the base year 2005. Except for three districts, Samtse, Sarpang and Trongsa all district's urban population has increased compared to rural population. This indicates that in general Bhutan as any other countries experiences the rural urban migration at an average actual population growth of 18% urban and 10% rural. The overall population growth is 12% compared to 2005 and the rural-urban migration is approximately 6% within 10 years [139],

[167]. The above demographic changes have strong influence on the mobility infrastructure development, which give rise to arguable conclusion.

The variable Infrastructure development (1) and Technology development (2) defines the mobility system development and current state of motorization trend. Bhutan is a very fast growing economy where the motorization started very recently. The five year plan data and the national statistic show that the infrastructure development was the major focus for initial development plans. The more clear and detailed statistics are only available since the 7th development plan. The major infrastructure development is seen in the surface transport especially the road network. In the 6th development plan which starts in 1987 shows, the early infrastructure was road construction and airport in addition to the conventional mule track and foot path. By the end of 6th plan 2,468.58 km road and one air port was constructed [168]. The infrastructure development at the end of 11th plan showed 18,286 km of road network and 4 domestic airports in addition to the existing international airport in Paro [169]. The initial road plan are classified as national high way, district road and feeder road, which is now extended to express way, primary national high way, secondary national high way, district road, urban road, access road, farm road and forest road.

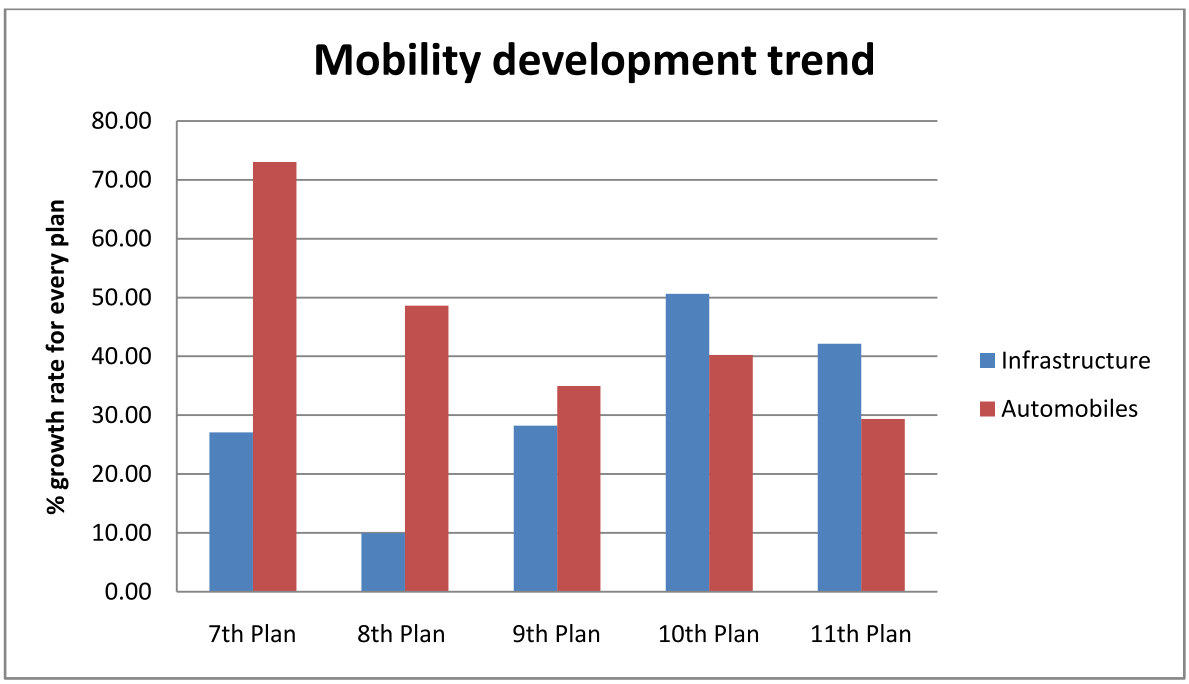
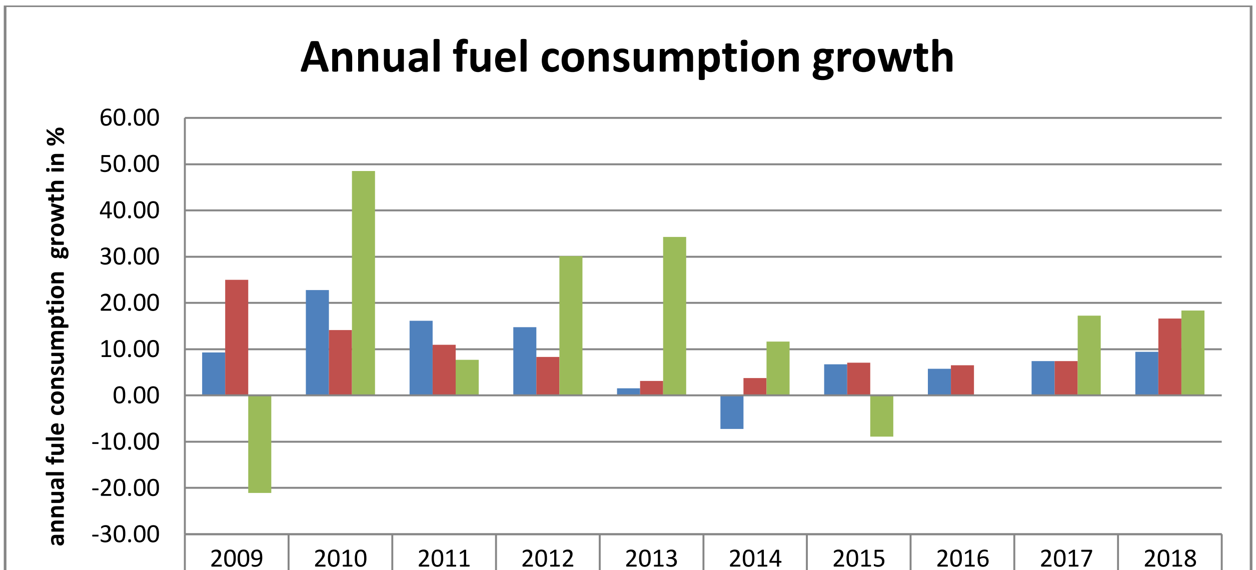


Figure 8: Infrastructure and automobiles development trend

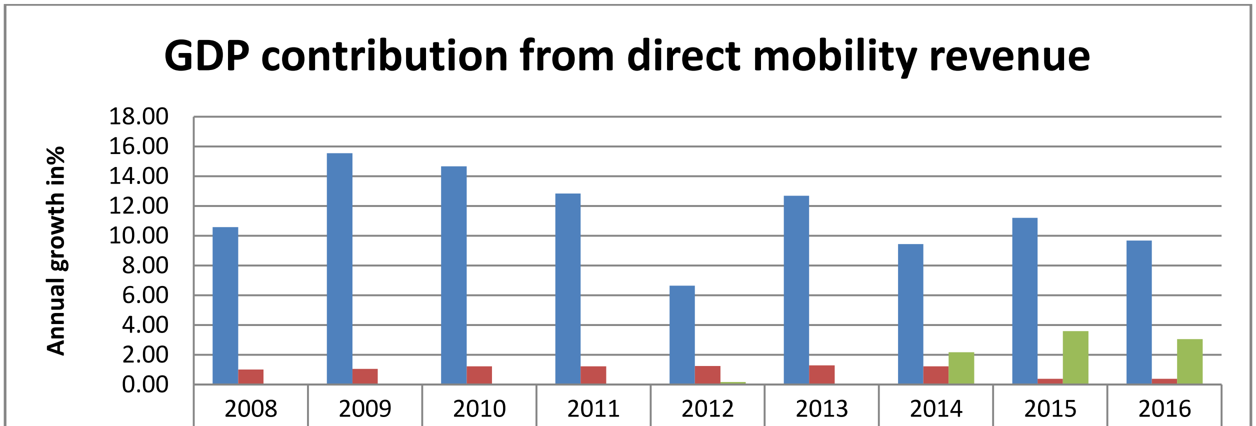
Figure 8 shows the mobility development trend that potentially explains the demographic distribution and infrastructure development gap for mobility demand. The significant changes can be seen in the growth of infrastructure development versus the growth of automobiles. The break-even was achieved between 9th and 10th development plan, where the infrastructure growth is higher than that of automobiles growth. Since the start of the initial motorization, Bhutan strongly focused on infrastructure development to facilitate the growing automobiles. In the 6th development plan 3,660 vehicles are plying on the road network, whereas in 11th plan it was 96,306 vehicles [168], [169]. The growth of infrastructure and the growth of vehicle shown in figure 8 indicate that Bhutan's road infrastructure capacity is higher than that of the automobiles on road. However the situation is arguable as urban centres experiences congestion, which cannot be explained from the figure 8 but with the demographic changes of figure 7. The drastic growth of urban population due to rural urban migration attributes to the spatial limitation in the urban region. On the other hand Bhutan's rural road network is mostly unpaved farm road as compared to express way, primary national highway, secondary national highway and district road, which is still under development. The other alternative infrastructure such as e-mobility, rope ways, cable cars, train network, inland dry port and non-motorized infrastructure are clearly missing. The detail on this will be discussed in surface transport in section 4.3.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Diesel	9.29	22.76	16.14	14.76	1.52	-7.23	6.76	5.76	7.45	9.46
Petrol	24.99	14.12	10.95	8.32	3.16	3.77	7.06	6.54	7.43	16.61
ATF	-21.06	48.50	7.71	30.12	34.28	11.63	-8.93	0.09	17.28	18.37

Figure 9: Mobility fuel consumption growth in Bhutan since 2008

The variable Fuel energy security (3) will play critical role for the development of resilient mobility system as motorization trend continue to grow as seen in infrastructure and automobile development trend in the above statistical data record. Due to the initial design of the infrastructure, which is mostly designed for fossil fuel vehicles, the mobility fuel in Bhutan is per-dominantly import dependent petroleum products like many other countries in the world. Bhutan imports high speed diesel, petrol and Aviation Transport Fuel (AFT) kerosene. Fuel import statistic shows, in 2008 Bhutan imported 62,207.36 KL of diesel, 15,417.58 KL of petrol and 837.23 KL of AFT kerosene, which has increased to 159,722.50 KL diesel, 46,912.34KL petrol and 4,878 KL AFT in the year 2018 [139], [169], [170]. The fuel import is based on the bilateral trade agreement between India and Bhutan, which also share similar electrical energy trading. The detail on fuel import and energy trading will be elaborated in alternative mobility in section 4.4. Figure 9 shows the annual fuel import growth trend in Bhutan since 2008. The fuel statistical data is available in actual volume only after 2007. Except for the year 2009, 2014 and 2015 the fuel import has been continuously increasing. Although there is no clear evidence on why there is a sharp decrease in import of AFT fuel in 2009, the decrease in diesel import in 2014 and decrease in petrol import in 2015 is attributed to temporary ban on purchase of personal car in 2012 [171] and initial conception of e-mobility in 2014 [172]. The average annual fossil fuel import growth is seen to be 9.6 % diesel, 11.4 % petrol and 15.3 % AFT for the last 10 years starting 2008.



	2008	2009	2010	2011	2012	2013	2014	2015	2016
GDP	10.58	15.55	14.66	12.83	6.63	12.69	9.45	11.20	9.69
Revenue	1.02	1.05	1.22	1.24	1.24	1.30	1.22	0.38	0.38
Green tax	0	0	0	0	0.17	0.01	2.17	3.59	3.06

Figure 10: GDP characteristics of mobility

The variable Economic development (11) has strong influence on mobility development as seen in chapter 3. This can also be seen in statistical data of Bhutan. While the gross domestic product of Bhutan in 2008 was 54,744.29 million ngultrum, revenue collection from transport sector was 143.39 million ngultrum, which increased to 164,627.92 million ngultrum in 2016, where the direct revenue from transport sector was 114.08 million ngultrum [139], [169], [170]. The decrease in transport revenue is attributed to introduction of green tax in 2014 which is applicable to automobile purchase. On the other hand the indirect revenue generation from operation, penalties, automobile registration and driving licences are part of national revenue for transport sector. For example in 2018 Road Safety and Transport Authority (RSTA) collected Nu. 438,525,198.87 as a transport revenue [169].The influence of economic growth on mobility development trend is very significant whereas the economic contribution through mobility sector development is often time invisible. Figure 10 represent the direct mobility revenue contribution to GDP growth in Bhutan on an annual basis. Average contribution to GDP growth from transport sector revenue growth in Bhutan for ten years is approximately 1% including the green tax, which is significant for average national GDP growth of 11.47%.

4.3 Surface transport development trend

Due to landlocked geography and difficult mountain terrain, Bhutan's transport system is mainly based on surface transport. Significant changes in surface transport are observed since the start of 10th development plan. Although international and domestic air transport are currently promoted with the establishment of 4 airport and 61 helipad in west, east and central part of Bhutan, surface transport will remain as main mobility mode [173]. The statistical data in table 11 shows the annual growth trend of automobiles classified as heavy, medium, light, two wheeler, power tiller, tractor, earth mover and electric vehicle in 5 regional locations in Bhutan since 2008 until 2018 [139], [169], [170].

Table 11: Automobiles statistic since 2008

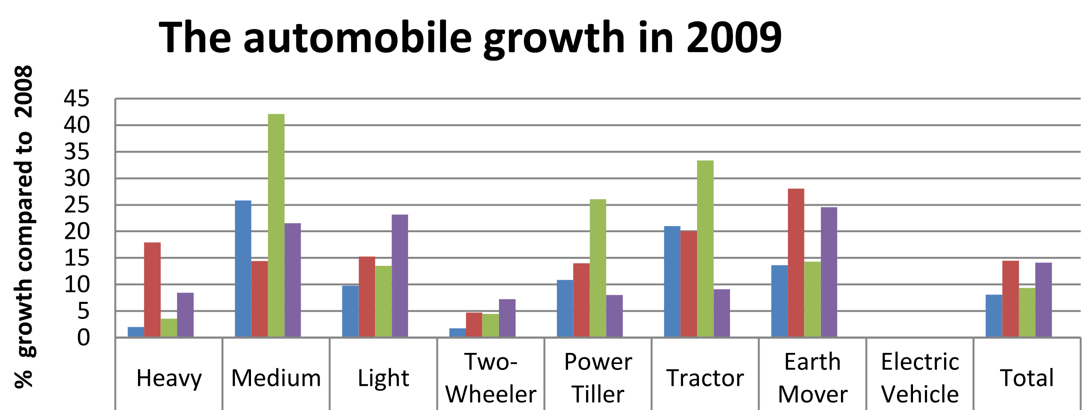
Year	Region	Heavy	Medium	Light	Two- Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
2008	Thimphu	1,867	89	15,484	3,720	344	49	316	-	21,869
	P/ling	2,273	498	6,985	2,242	43	68	354	-	12,463
	Gelephu	163	11	671	812	51	2	12	-	1,722
	S/Jongkhar	324	51	789	963	172	30	43	-	2,372
	Monggar	-	-	-	-	-	-	-	-	-
2009	Thimphu	1,905	120	17,164	3,787	386	62	366	-	23,790
	P/ling	2,770	582	8,241	2,352	50	85	492	-	14,572
	Gelephu	169	19	776	850	69	3	14	-	1,900
	S/Jongkhar	354	65	1,027	1,038	187	33	57	-	2,761
	Monggar	-	-	-	-	-	-	-	-	-
2010	Thimphu	2,318	195	19,565	3,953	438	71	447	-	26,987
	P/ling	3,732	693	9,860	2,885	59	103	733	-	18,065
	Gelephu	223	55	957	916	82	4	24	-	2,261
	S/Jongkhar	361	70	1,312	1,204	215	38	73	-	3,273
	Monggar	-	-	-	-	-	-	-	-	-
2011	Thimphu	2,615	273	22,065	4,083	614	85	576	-	30,311
	P/ling	4,684	830	11,482	3,044	66	138	990	-	21,234
	Gelephu	300	80	1,152	956	103	14	68	-	2,673
	S/Jongkhar	373	78	1,521	1,351	247	41	82	-	3,693
	Monggar	-	-	-	-	-	-	-	-	-
2012	Thimphu	2,711	296	23,811	4,192	709	88	611	-	32,418
	P/ling	5,015	864	12,515	3,161	66	140	1,141	-	22,902
	Gelephu	321	92	1,331	999	103	14	82	-	2,942
	S/Jongkhar	396	78	1,667	1,387	250	41	84	-	3,903
	Monggar	-	-	-	-	-	-	-	-	-

2013	Thimphu	2,719	304	23,912	4,164	789	115	619	-	32,622
	P/ling	5,094	871	12,576	3,173	66	141	1,182	-	23,103
	Gelephu	325	94	1,389	1,009	103	16	87	-	3,023
	S/Jongkhar	406	78	1,719	1,404	251	46	83	-	3,987
	Monggar	-	-	-	-	-	-	-	-	-
2014	Thimphu	2,684	327	25,150	4,271	899	117	641	-	34,089
	P/ling	5,058	891	13,388	3,268	66	141	1,192	-	24,004
	Gelephu	328	99	1,571	1,011	132	23	87	-	3,251
	S/Jongkhar	404	75	1,760	1,395	284	46	85	-	4,049
	Monggar	-	-	55	43	-	2	-	-	100
2015	Thimphu	2,587	352	28,159	2,854	1,214	131	733	57	36,087
	P/ling	5,222	932	15,347	3,516	67	166	1,267	4	26,521
	Gelephu	343	110	2,054	1,095	140	28	97	2	3,869
	S/Jongkhar	404	74	1,956	1,409	284	56	102	-	4,285
	Monggar	10	14	310	105	10	3	9	-	461
2016	Thimphu	2,838	400	31,919	3,117	1,418	149	893	70	40,804
	P/ling	5,752	977	16,962	3,722	67	171	1,403	6	29,060
	Gelephu	402	125	2,586	1,162	146	34	137	4	4,596
	S/Jongkhar	442	79	2,166	1,428	285	58	126	-	4,584
	Monggar	46	24	647	212	28	9	36	-	1,002
2017	Thimphu	2,916	417	33,466	3,223	1,553	158	972	57	42,762
	P/ling	5,983	992	17,681	3,812	84	178	1,473	6	30,209
	Gelephu	425	138	2,867	1,182	180	41	185	4	5,022
	S/Jongkhar	451	81	2,278	1,433	287	60	156	-	4,746
	Monggar	57	29	792	216	28	9	48	-	1,179
2018	Thimphu	3,171	460	36,486	3,537	1,988	174	1,140	57	47,013
	P/ling	6,743	1,045	18,831	4,026	85	186	1,564	7	32,487
	Gelephu	503	155	3,340	1,224	190	47	243	4	5,706
	S/Jongkhar	479	87	2,441	1,448	306	61	194	-	5,016
	Monggar	76	37	1,060	244	56	10	58	-	1,541

The vehicle statistic of table 11 is subject to statistical error in reporting from ministry to the national statistical bureau as there are differences in counts, which can also be attributed to the de-registration of the vehicles on account of its end of operational life span. For example the e-vehicle count in 2018 by ministry of information and communication is 98, whereas it is recorded to be 70 in the statistical bureau, which is a significant variation with the deviation of 28% [169], [173]. Similarly there are possible variations in other vehicle statistics. Therefore statistical error of about 10-20% deviation should be taken into account for the national statistical data compared to ministries annual reporting. This study however will be based on the statistical data referenced to National Statistical Bureau (NSB) as NSB is public data source and the centralized for all statistics of Bhutan for research purpose.

4.3.1 Annual automobile growth trend and influence factor

The annual growth can be computed and referenced to the base year 2008 as shown in figure 11. In 2009 maximum growth is seen in medium vehicle, power tiller and tractor which can be attributed to the development of rural infrastructure such as the district road and farm road. The road infrastructure increased to 4,272.5 km in 2009 compared to 3,741.5 km in 2008 especially the farm road and district road in rural Bhutan [170]. The regional automobile growth was highest in Phuntsholing and Samdrup-dzongkhor compared to Thimphu and Gelephu. The automobile count of Monggar region was included in Samdrup Jongkhor. In total the growth of automobiles in Thimphu region is 8%, Phuntsholing region is 14%, Gelephu region is 9% and Samdrup Jongkhor region is 14%. The high growth of automobiles in Phuntsholing is attributed to industrial development, whereas high growth in Samdrup Jongkhor is due to mining industries. Additionally Phuntsholing is a trade route to international trade for western region, whereas Samdrup Jongkhor is a trade route to international trade for eastern region.

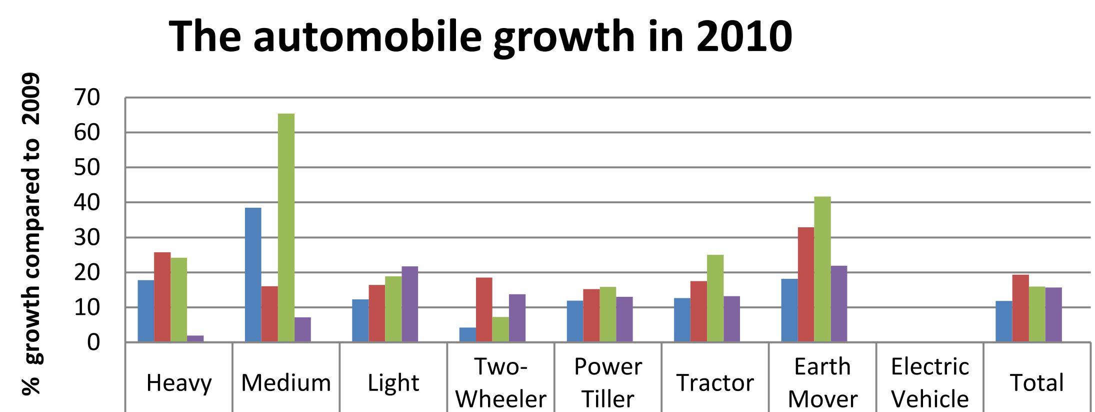


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	2	26	10	2	11	21	14	0	8
Phuntsholing	18	14	15	5	14	20	28	0	14
Gelephu	4	42	14	4	26	33	14	0	9
Samdrup Jongkhar	8	22	23	7	8	9	25	0	14
Monggar	0	0	0	0	0	0	0	0	0

Figure 11: automobile growth in 2009

The statistical data and automobile growth trend in 2009 can be attributed to the variable Accessibility (6) from the mobility system variable list in chapter 3. In general the access to mobility has increased in Bhutan with increased access to infrastructure and automobiles. Although the access to motorization has increased, it did indicate the mobility as a challenge in urban areas especially Thimphu and Phuntsholing. Therefore Bhutan's mobility development trend indicates that the increase in accessibility is inevitable considering the state of rural living standard and rural urban connectivity. The major urban mobility challenges are attributed to the variable Spatial dynamic (5). Rural-urban migration and urban centric economic growth appears to be the major mobility challenges rather than mobility growth itself. Due to difficult terrain and limited space, urban infrastructure expansion is extremely difficult, which will result in bottle neck situation that requires alternative approach.

Figure 12 shows the growth of different automobiles type in 5 different regions in Bhutan in 2010. The maximum growth is seen in heavy vehicle, medium vehicle and earth mover which can be attributed to the development of large scale hydropower and expansion of farm road. The road infrastructure increased from 4,272.5 km in 2009 to 4,660.7 km in 2010 [170]. The regional automobile growth was highest in Phuntsholing, Gelephu and Samdrup-dzongkhor compared to Thimphu. The automobile count of Monggar region is included in Samdrup Jongkhor. In an average the growth of automobiles in Thimphu region is 12%, Phuntsholing region is 19%, Gelephu region is 16% and Samdrup Jongkhor region is 16%. The high growth of automobiles in Phuntsholing is attributed to industrial development, whereas high growth in Samdrup Jongkhor is due to mining industries. Additionally Phuntsholing is a trade route to international trade for western region, whereas Samdrup Jongkhor is a trade route to international trade for eastern region.

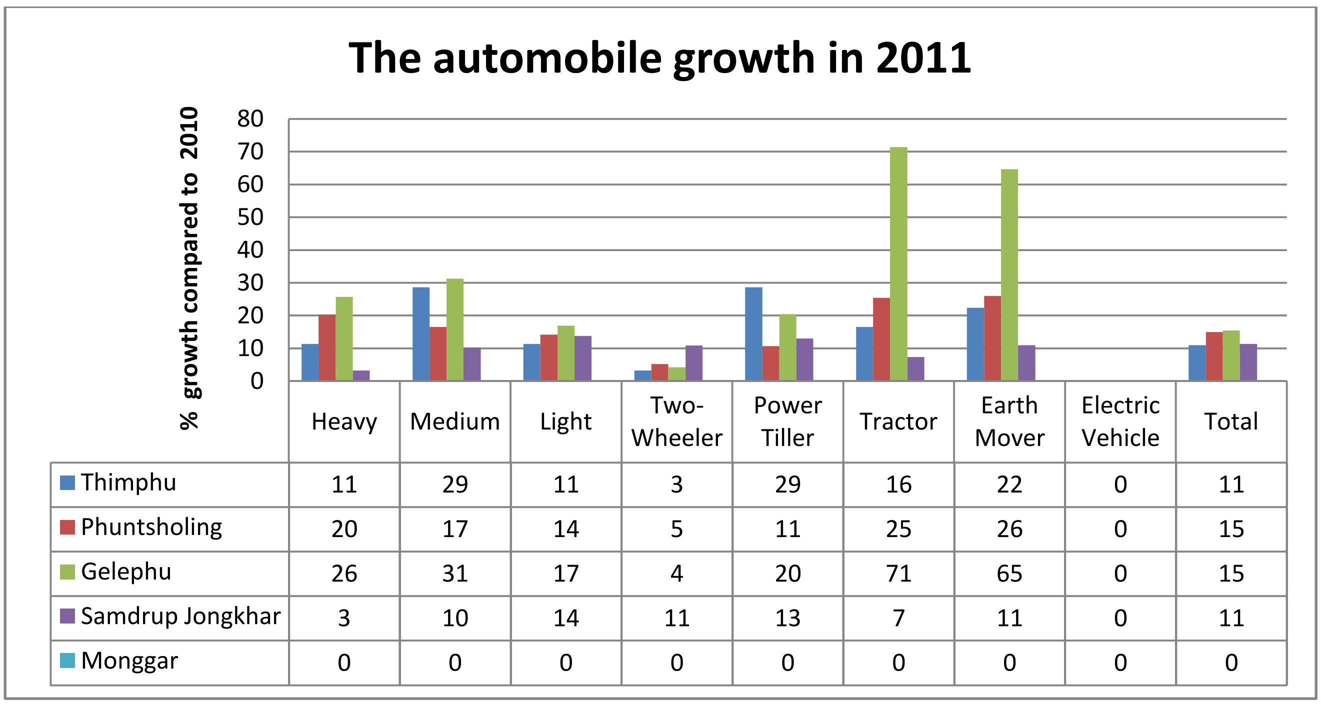


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	18	38	12	4	12	13	18	0	12
Phuntsholing	26	16	16	18	15	17	33	0	19
Gelephu	24	65	19	7	16	25	42	0	16
Samdrup Jongkhar	2	7	22	14	13	13	22	0	16
Monggar	0	0	0	0	0	0	0	0	0

Figure 12: Automobile growth in 2010

The statistical data and automobile growth development in 2010 is attributed to the variable Economic development (11) from the mobility system variable listing in chapter 3. In general the access to motorized mobility has increased compared to 2010 with increased access to infrastructure and automobiles. Although the access to motorization has increased, it did indicate the mobility as a challenge for goods transport for hydropower development especially between Thimphu and Phuntsholing route. Therefore Bhutan's mobility infrastructure expansion was critical for economic growth. The major infrastructure development challenges are attributed to the variable Economic development (5). Rural-urban migration and urban centric economic growth appears to remain the same as it was in 2009. Due to difficult mountain terrain, road infrastructure expansion is extremely difficult, which will result in bottle neck situation for large scale hydro project.

Figure 13 shows the growth of different automobiles type in 5 different regions in Bhutan in 2011. The maximum growth is seen in heavy vehicle, medium vehicle, earth mover and tractor which can be attributed to the development of road infrastructure and plan for large scale hydropower project. The road infrastructure increased from 4,660.7 km in 2010 to 8,366.2 km in 2011 [170]. The regional automobile growth was high in Gelephu and Phuntsholing compared to Thimphu and Samdrup Jongkhor. The automobile count of Monggar region was included in Samdrup Jongkhor. In total the growth of automobiles in Thimphu region is 11%, Phuntsholing region is 15%, Gelephu region is 15% and Samdrup Jongkhor region is 11%. The high growth of automobiles in Phuntsholing is attributed to industrial development, whereas high growth in Gelephu is attributed to large scale hydropower project. Additionally Phuntsholing is a trade route to international trade for western region, whereas Gelephu is a trade route to international trade for central region where major hydro are located for route directness for transport of heavy goods.

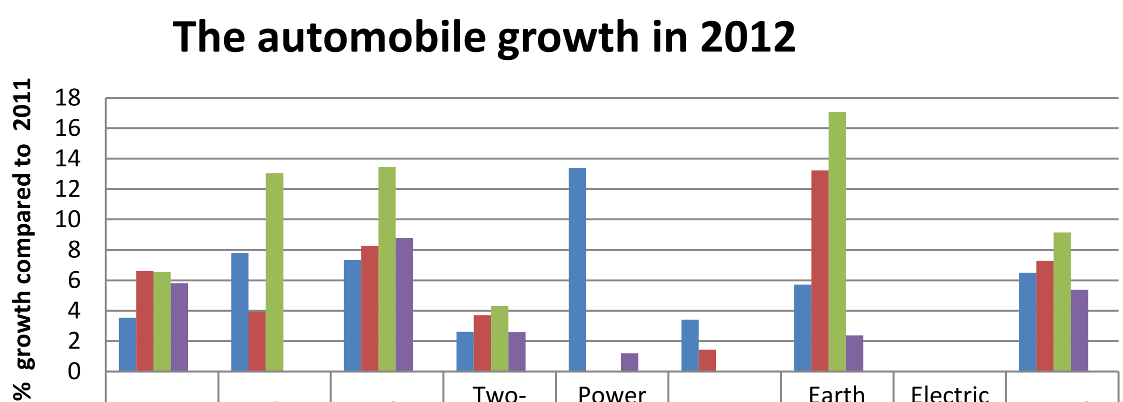


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	11	29	11	3	29	16	22	0	11
Phuntsholing	20	17	14	5	11	25	26	0	15
Gelephu	26	31	17	4	20	71	65	0	15
Samdrup Jongkhar	3	10	14	11	13	7	11	0	11
Monggar	0	0	0	0	0	0	0	0	0

Figure 13: Automobile growth in 2011

The statistical data and automobile growth development in 2011 is same as in 2010, which is attributed to the variable Economic development (6) from the mobility system variable list of chapter 3. In general the access to mobility has increased compared to previous years with increased access to infrastructure and automobiles. Although the access to motorization has increased, infrastructure bottleneck was still persistent especially in Thimphu to Phuntsholing route and Gelephu to Wangdue route. Therefore Bhutan's infrastructure development shows bottleneck situation considering difficult terrain. The major infrastructure development challenges are attributed to the variable Economic development (5), which is same as in 2010. Rural-urban migration and urban centric economic growth appears to remain the same as it was in 2010. The major challenges are transport of heavy goods for hydropower project site in 2011.

Figure 14 shows the growth of different automobiles type in 5 different regions in Bhutan in 2012. The maximum growth is seen in light vehicle and heavy vehicle, which can be attributed to start of major hydropower projects. Two major hydro power projects started in 2012 in western and central part of Bhutan. The road infrastructure expansion was major development in 2012. The primary national highway and secondary national highway expansion increased from 1,757.2 km and 516.4 km in 2011 to 1,768.6 km to 521.2 km in 2012, whereas the overall road infrastructure increased from 8,366.2 km to 9,491.5 km to facilitate economic growth [170]. The regional automobile growth was highest in Gelephu compared to Thimphu, Phuntsholing and Samdrup Jongkhor. In an average the growth of automobiles in Thimphu region is 6%, Phuntsholing region is 7%, Gelephu region is 9% and Samdrup Jongkhor region is 5%. The high growth of automobiles in Gelephu is attributed to hydropower development in central Bhutan and increased economic growth in central region. Further the goods transport for hydropower has been diverted via Gelephu route.

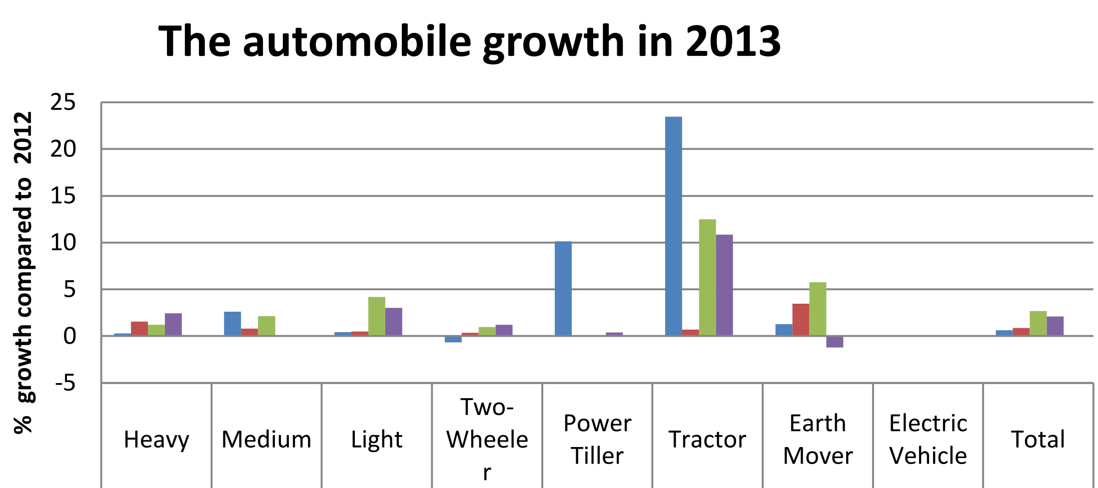


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	4	8	7	3	13	3	6	0	6
Phuntsholing	7	4	8	4	0	1	13	0	7
Gelephu	7	13	13	4	0	0	17	0	9
Samdrup Jongkhar	6	0	9	3	1	0	2	0	5
Monggar	0	0	0	0	0	0	0	0	0

Figure 14: automobile growth in 2012

The statistical data and automobile growth development in 2012 is attributed to the variable overall Economic development (11) including the large scale hydropower from the mobility system variable listing in chapter 3. In general the access to mobility has increased with increased access to better infrastructure and more automobiles. Due to high growth in number of light vehicle, since 2012 Bhutan started to experience urban traffic congestion. Urban traffic congestion is heavily influenced by major project office location in urban centres. The urban mobility challenges are attributed to the variable Spatial dynamic (5). Rural-urban migration and urban centric economic growth appears to remain the major mobility challenge which is same as in the start of 2008. In 2012 fast urban growth is main cause for mobility challenges.

Figure 15 shows the growth of different automobiles type in 5 different regions in Bhutan in 2013. The maximum growth is seen in tractor and power tiller which can be attributed to the development of rural infrastructure such as the farm road. The farm road increased from 4,380.9 km in 2012 to 5,255.5 km in 2013, whereas the overall road infrastructure increased from 9,491.5 km to 10,578.2 km[170]. The regional automobile growth was highest in Gelephu compared to Thimphu, Phuntsholing and Smadrup Jongkhor. The decrease in automobile growth compared to previous years is because of vehicle import ban enforcement in 2012 as a political decision. In total the growth of automobiles in Thimphu region is 1%, Phuntsholing region is 1%, Gelephu region is 3% and Samdrup Jongkhor region is 2%. Slightly high growth of automobiles in Gelephu and Samdrup Jongkhor is attributed to rural framing activities.

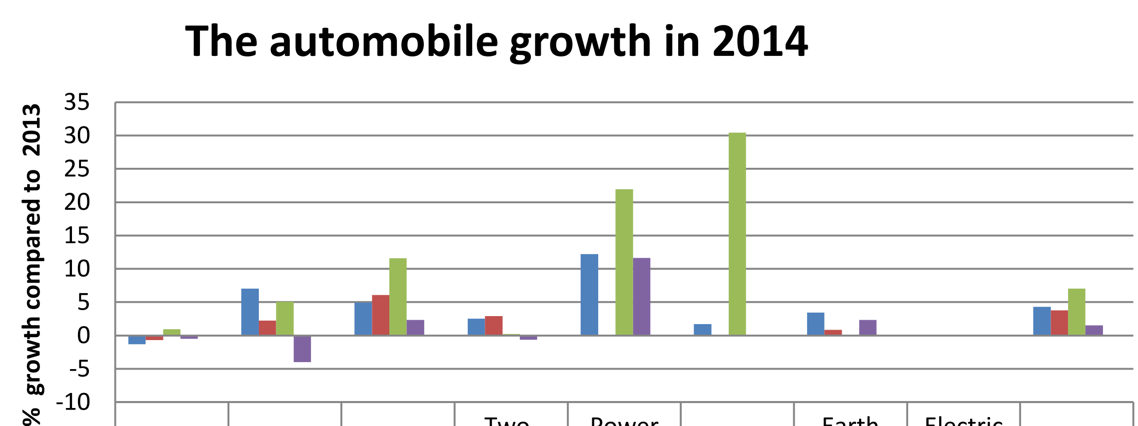


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	0	3	0	-1	10	23	1	0	1
Phuntsholing	2	1	0	0	0	1	3	0	1
Gelephu	1	2	4	1	0	13	6	0	3
Samdrup Jongkhar	2	0	3	1	0	11	-1	0	2
Monggar	0	0	0	0	0	0	0	0	0

Figure 15: Automobile growth in 2013

The statistical data and automobile growth development in 2013 is attributed to the variable Political power (20) and Accessibility (6) from the mobility system variable list in chapter 3. In general the access to mobility has increased in Bhutan with increased access to rural infrastructure and farm machinery. Although the access to motorization has increased, mobility challenges in urban areas especially Thimphu and Phuntsholing are persistent. The major urban mobility challenges are linked to the variable Spatial dynamic (5). Rural-urban migration and urban centric economic growth appears to face the major mobility challenges and regional economic development. Due to difficult mountain terrain, rural infrastructure expansion is extremely difficult, which resulted in bottle neck situation for rural urban access requirement for access to farm product supply chain management within Bhutan.

Figure 16 shows the growth of different automobiles type in 5 different regions in Bhutan in 2014. The maximum growth is seen in number of power tiller and tractor, which can be attributed to the development of rural infrastructure development and rural livelihood improvement such as increase district road and farm road. The district road and farm road increased from 1,178.3 km and 5,255.5 km in 2013to 1,260.7 km and 5,707.8 km in 2014[169]. Although the vehicle import ban is enforced, the regional automobile growth can be observed, which is linked to rural farming and rural livelihood improvement. On an average the growth of automobiles in Thimphu region is 4%, Phuntsholing region is 4%, Gelephu region is 7% and Samdrup Jongkhor region is 2%. The high growth of automobiles in Gelephu can potentially be attributed to agriculture sector development in central Bhutan.



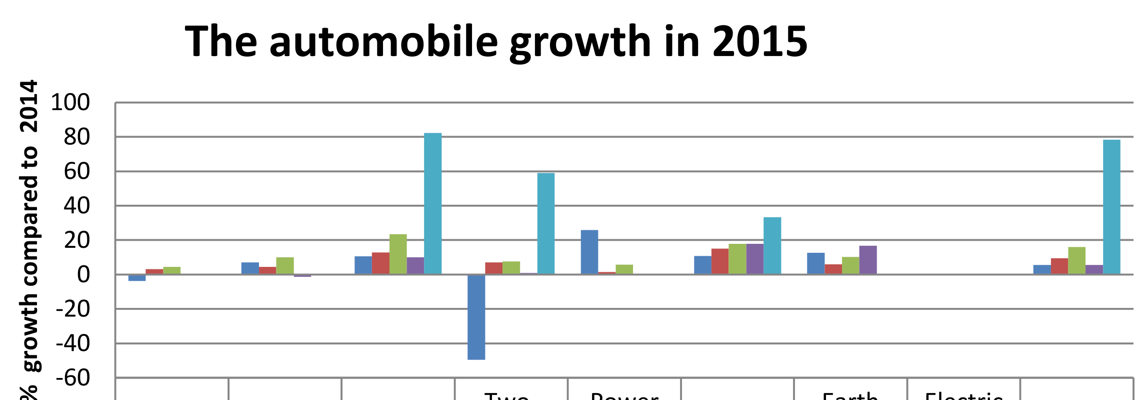
	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	-1	7	5	3	12	2	3	0	4
Phuntsholing	-1	2	6	3	0	0	1	0	4
Gelephu	1	5	12	0	22	30	0	0	7
Samdrup Jongkhar	0	-4	2	-1	12	0	2	0	2
Monggar	0	0	0	0	0	0	0	0	0

Figure 16: Automobile growth in 2014

The statistical data and automobile growth development in 2014can be attributed to the variable Awareness on new mobility (17) and Accessibility (6) from the mobility system variable listing in chapter 3. In general the access to mobility has increased in rural area with increased rural infrastructure. While vehicle ban was enforced, the urban mobility challenge continues to grow especially in Thimphu and Phuntsholing. Considering fast urbanization, alternative mobility options are explored such as electric vehicle. The major urban mobility challenges are still attributed to the variable Spatial dynamic (5) even if e-mobility is identified alternatives.

Rural-urban migration and urban centric economic growth appears to remain the major mobility challenges as in previous years. Due to limited space and difficult mountain terrain urban infrastructure expansion is extremely difficult, which will result in bottle neck situation that requires alternative approach.

Figure 17 shows the growth of different automobile type in 5 different regions in Bhutan in 2015. The maximum growth is seen in number of light vehicle, power tiller and tractor which can be attributed to the development of rural infrastructure such as farm road and ban lift for vehicle import. Road infrastructure decreased in 2015 from 11,243.4 km to 11,177.0 km in 2015 [170]. The decrease may be attributed to poor maintenance of farm road and removal of some road section for route directness. New regional mobility institution Road Safety and Transport Authority (RSTA) was opened in Monggar region. On an average the growth of automobiles in Thimphu region is 6%, Phuntsholing region is 9%, Gelephu region is 16%, Samdrup Jongkhor region is 6% and Monggar region is 78%. The high growth of automobiles in Monggar is linked to shift of part of regional vehicle registration from Samdrup Jongkhor to Monggar.

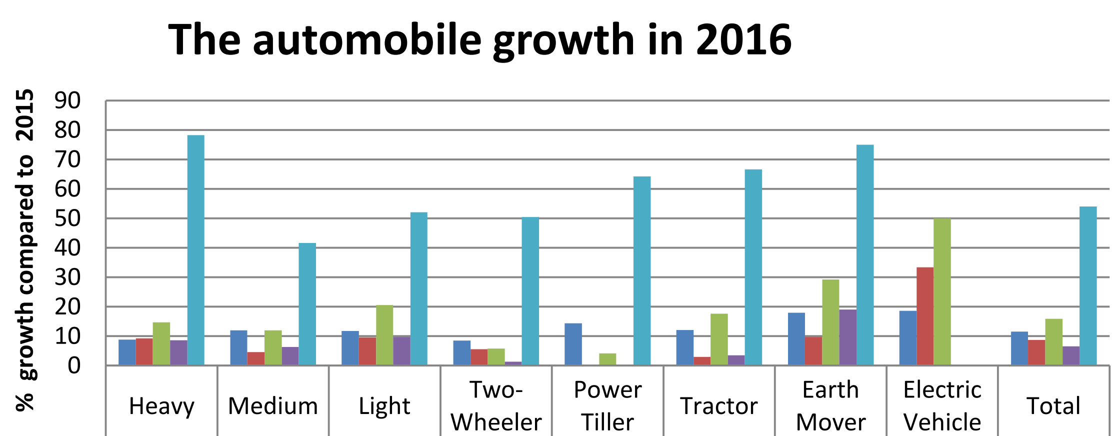


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	-4	7	11	-50	26	11	13	0	6
Phuntsholing	3	4	13	7	1	15	6	0	9
Gelephu	4	10	24	8	6	18	10	0	16
Samdrup Jongkhar	0	-1	10	1	0	18	17	0	6
Monggar	0	0	82	59	0	33	0	0	78

Figure 17: Automobile growth in 2015

The statistical data and automobile growth development in 2015 is attributed to the variable Economic development (11) and Accessibility (6) from the mobility system variable listing in chapter 3. In general the access to mobility has drastically increased with increased access to better infrastructure. To address urban mobility challenges, alternatives such as electric vehicle is introduced with the registration of 57 second hand electric vehicle imported from Japan in 2015 [139].Spatial challenge continues to grow even with the introduction of electric vehicle. The major urban mobility challenges are still attributed to the variable Spatial-dynamic (5). Rural-urban migration and urban centric economic growth appears to remain the major mobility challenges in urban area. Due to limited urban space and difficult mountain terrain, the urban infrastructure expansion is extremely difficult. The infrastructure development for e-mobility was realised important in 2015 considering the cost benefit analysis of e-mobility in Bhutan [172].

Figure 18 shows the growth of different automobile type in 5 different regions in Bhutan in 2016. The automobile growth is more or less the same for all automobile type with inclusion of electric vehicle, which can be attributed to improved rural infrastructure and vehicle import ban removal. However the green tax on import of fossil fuel vehicle was enforced, whereas electric vehicle were offered 100% tax holidays. On the other hand road infrastructure increased from 11,177.0 km to 12,348.7 km in 2016 [169]. The regional automobile growth was highest in Monggar, which is relatively rural compared to Thimphu, Phuntsholing, Gelephu and Samdrup Jongkhor. This indicates that the rural motorization demand has increased drastically. On an average the growth of automobile in Thimphu region is 12%, Phuntsholing region is 9%, Gelephu region is 16%, Samdrup Jongkhor region is 7% and Monggar region is 54%. The high growth of automobile in Monggar is attributed to automobile registration shift from Samdrup Jongkhor to Monggar and increased rural living standard. In addition to RSTA office in Monggar, establishment of cement factory in south eastern Bhutan in Nanglam and route diversion from Monaggar to Ngalam for international connectivity is major cause.

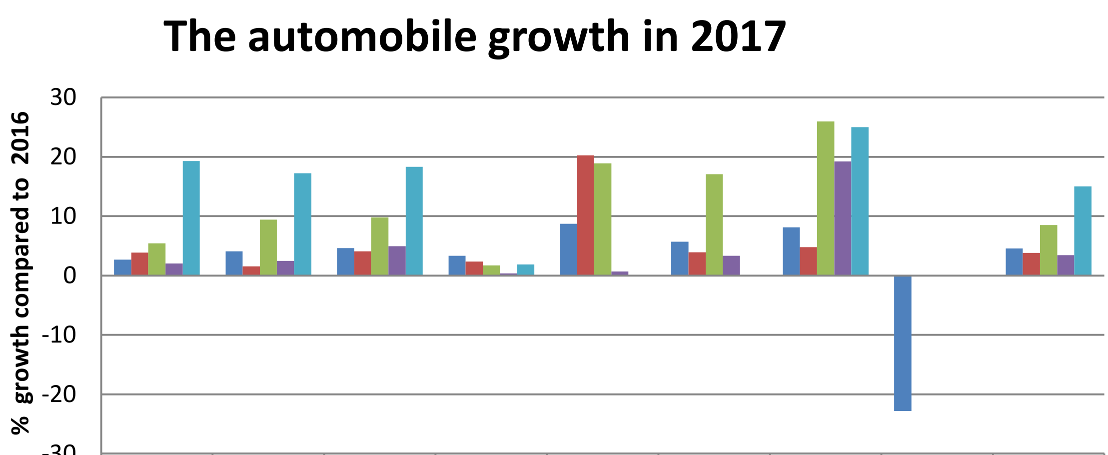


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	9	12	12	8	14	12	18	19	12
Phuntsholing	9	5	10	6	0	3	10	33	9
Gelephu	15	12	21	6	4	18	29	50	16
Samdrup Jongkhar	9	6	10	1	0	3	19	0	7
Monggar	78	42	52	50	64	67	75	0	54

Figure 18: Automobile growth in 2016

The statistical data and automobile growth development in 2016 is attributed to the variable Political power (20) Economic development (11) and Accessibility (6) from the mobility system variable listing in chapter 3. In general regional economy has increased in Bhutan with increased access to industrial job. Although the access to motorization has increased in both rural and urban region, urban mobility continues to face the spatial challenge especially in Thimphu and Phuntsholing. Electric vehicle is introduced to solve the issue of urban air pollution and to improve fuel energy security [166]. However the infrastructure developments for E-mobility remain as bottleneck situation for their development.

Figure 19 shows the growth of different automobile type in 5 different regions in Bhutan in 2017. The maximum growth is seen in number of earth mover, whereas electric vehicle decreased drastically. While the e-mobility development is expected to have increased, lack of quick charging infrastructure is a major problem faced. As of 2017 there were only 3 quick charging infrastructure operational in Thimphu and Paro[174], whereas the road infrastructure increased from 12,348.7 km in 2016 to 18,181.3 km in 2017[169]. The regional automobile growth was highest in Monggar which is emerging as new urban centre in the eastern part of Bhutan. In an average the growth of automobile in Thimphu region is 5%, Phuntsholing region is 4%, Gelephu region is 8%, Samdrup Jongkhor region is 3% and Monggar is 15%. The high growth of automobile in Monggar is attributed to fast economic growth and urbanization in eastern Bhutan.

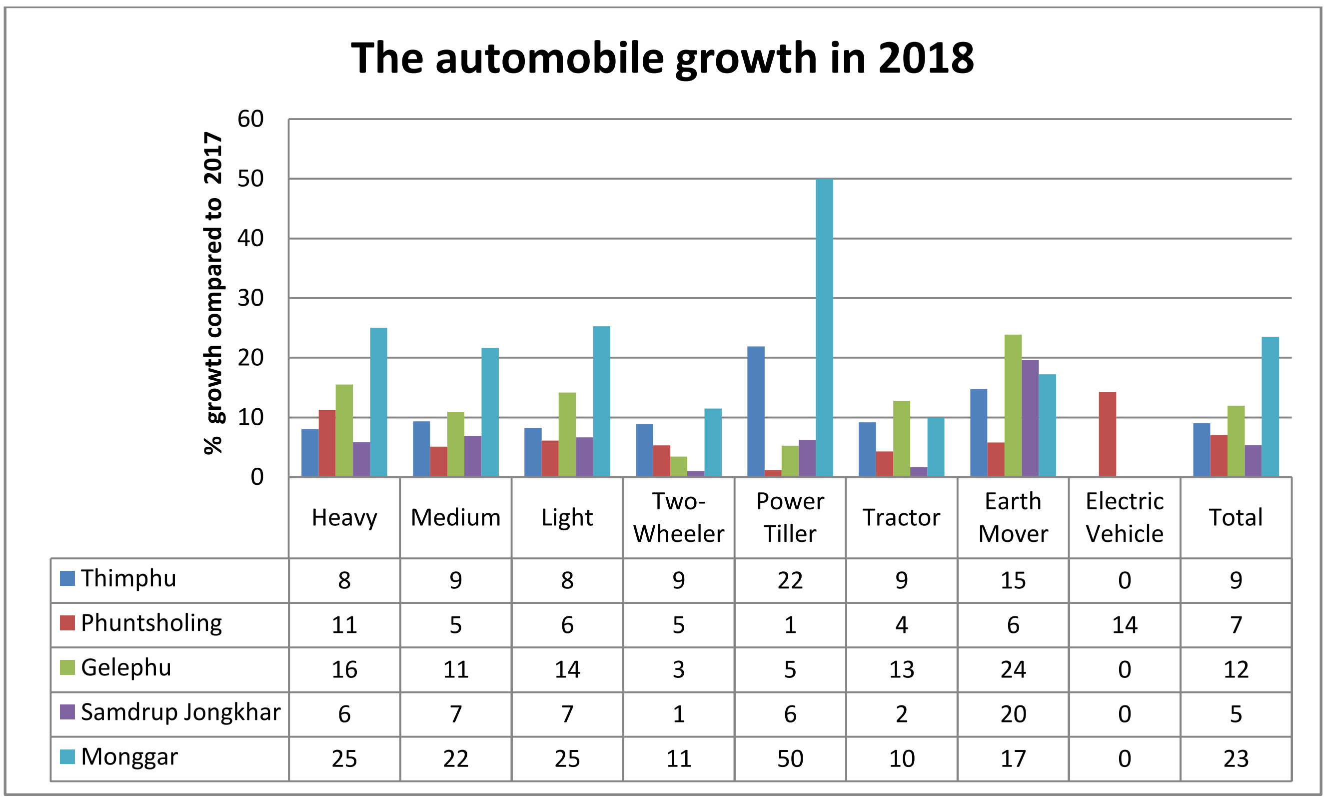


	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	3	4	5	3	9	6	8	-23	5
Phuntsholing	4	2	4	2	20	4	5	0	4
Gelephu	5	9	10	2	19	17	26	0	8
Samdrup Jongkhar	2	2	5	0	1	3	19	0	3
Monggar	19	17	18	2	0	0	25	0	15

Figure 19: Automobile growth in 2017

The statistical data and automobile growth development in 2017 is attributed to the variable Enabling condition (14) and Accessibility (6) from the mobility system variable listing in chapter 3. In general the regional economic growth enabled through infrastructure development and better access to industrial jobs in rural area is the main driver. Urban mobility challenge however remains the same in urban area especially in Thimphu and Phuntsholing. The major urban mobility challenges are attributed to the variable Spatial dynamic (5). Rural-urban migration and urban centric economic growth appears to be the major mobility challenges although alternative mobility is encouraged by providing tax holidays. Due to limited urban space and difficult mountain terrain, urban infrastructure expansion is extremely difficult, which will result in bottle neck situation that requires alternative approach even with alternative mobility such as electric vehicle.

Figure 20 shows the growth of different automobile type in 5 different regions in Bhutan in 2018. The automobile growth has once again increased compared to previous year for all automobile type. The increased mobility growth has strong link with the consumer behaviour development towards motorization, which has picked up since the start in 2008. The consumer behaviour is also influenced by the design and development of infrastructure, which is mostly enabling the motorization trend. In 2018 the road infrastructure has increased from 18,181.3 km to 18,282.00 km compared to 2017 with mostly paved road connecting to 205 community centres in Bhutan[169]. On an average the growth of automobile in Thimphu region is 9%, Phuntsholing region is 7%, Gelephu region is 12%, Samdrup Jongkhor region is 5% and in Monggar region is 24%. The high growth of automobile in Monggar is attributed to motorized travel behaviour of rural people and urban growth throughout the country.



	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	8	9	8	9	22	9	15	0	9
Phuntsholing	11	5	6	5	1	4	6	14	7
Gelephu	16	11	14	3	5	13	24	0	12
Samdrup Jongkhar	6	7	7	1	6	2	20	0	5
Monggar	25	22	25	11	50	10	17	0	23

Figure 20: Automobile growth in 2018

The statistical data and automobile growth development in 2018 is attributed to the variables Cultural values (15), Economic development (11), Rural-urban dynamic (21) and Accessibility (6) from the mobility system variable list in chapter 3. In general the motorized behaviour influenced by the urbanization is main cause of mobility challenges, although alternative mobility such as electric vehicle is encouraged. Main urban area especially Thimphu and Phuntsholing continue to face the spatial constraints. Therefore mobility system development in Bhutan indicates rural-urban migration and urban centric economic growth influenced by the motorized travel behaviour of commuter in both rural and urban region with high vehicle ownership is a problematic development trend.

4.3.2 Fuel demand growth trend

The automobile growth trend also influences the increase in fossil fuel consumption, which is mostly imported from India as a bilateral trade.

Table 12: Fuel statistics since 2008 in MT

Fuel	2008	2009	2010	2011	2012	2013	2014
Diesel	62,207.36	68,577.45	88,788.31	105,872.06	124,209.22	126,120.29	117,615.80
Petrol	15,417.58	20,554.78	23,934.81	26,877.82	29,316.90	30,272.20	31,458.20
ATF	837.23	98.70	1,342.87	1,455.00	2,082.02	3,168.00	3,585.00

2015	2016	2017	2018
126,139.40	133,851.27	144,620.70	159,722.50
33,846.60	36,214.80	39,119.50	46,912.34
3,291.00	3,294.00	3,982.00	4,878.00

Table 12 shows the fuel consumption growth trend to accommodate the automobile growth [139], [169], [170]. The summery result of motorization development trend can be computed from automobile growth trend since 2008 until 2018 and mobility fuel import as shown in figure 21. On an average automobile growth in 10 years is 8.76% annually, the diesel fuel consumption growth is 8.5% and petrol fuel consumption growth is 10.21% annually. The high share of petrol fuel consumption indicates there is higher number of light vehicle compared to heavy vehicle. Due to motorized travel behaviour of the commuter, even if regulatory measures are enforced the automobile growth has been steadily increasing both in rural and urban region.

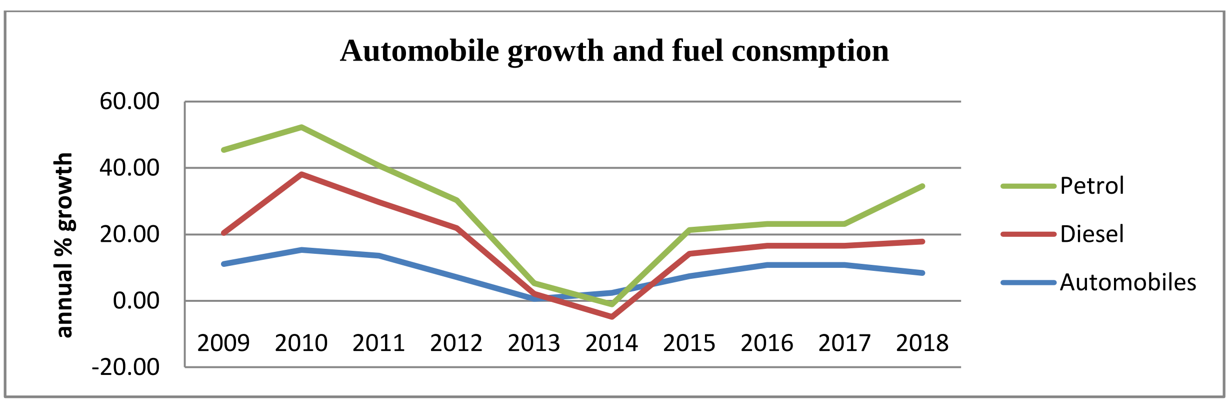


Figure 21: Automobile and fuel consumption growth trend

The automobile growth trend and fuel consumption is directly linked to the mobility system variables, Fuel energy security (3) and mobility Cultural value (15) from the mobility system variable list of chapter 3. On the other hand increase living standard is influenced by increasing the access to better mobility infrastructure, where growing vehicle ownership is economic and spatial challenges.

4.4 Impact on environment

Environment is an integral part of Bhutan's development philosophy, where forest conservation and energy source play central role for national environment protection plan. With the forest coverage of about 72%, the annual carbon sequestration capacity of approximately 6.3 million tCO_2 has significant contribution at the moment for the national pledge to remain carbon neutral [175]. On the other hand the availability of clean hydro energy source substantially contributes to carbon neutrality. However the grid emission factor of Bhutan is confusing as it shows un-expectedly high value 0.8819 tCO_{2e}/MWh [176]. Furthermore there is different literature showing different value. For example Asian Development Bank (ADB) emission guideline show 0.779 tCO_{2e}/MWh ;World Bank (WB) concept note for climate fund shows grid emission data used from India, which is 0.889 tCO_{2e}/MWh and IGES's regional record shows 0.8819 tCO_{2e}/MWh [175]–[177]. The default grid emission factor of hydro is in the range of 0.0005-0.152 t CO_{2e}/MWh [178]. Therefore the data gap of 82-99 % is noticed, which will require additional verification.

Transport sector is a main emitter compared to other energy sources in Bhutan as transport fuel is 100% fossil fuel and is imported. In 2019 Asian Development Bank (ADB) published, transport emission data of 2015, which shows 261,887 tons of CO_2, 1,724 tons of NO_2, 38.9 tons of Particulate Matter (PM) and 45 tons of SO_2emitted [139], [169], [179]. This also indicates emission database update is not readily available and therefore it can only be approximated. Currently National Environment Commission (NEC) emission standard is applied for two fuel standard for diesel and petrol, which shows the emission species for diesel fuel is Hartridge Smoke Unit (HSU) and for petrol is Carbon Monoxide (CO) [180]. Euro II and above vehicle are only allowed where the HSU limit of 70% for diesel and 4% CO for petrol are only enforced for the vehicle registered since 2005 [180]. National emission standard for aviation fuel is currently not available.

Table 13: Default emission factor Kg/TJ of fuel [181]–[183]

Transport fuel	CO_2	CO	SO_2	NO_x	N_2O	CH_4	NMVOC	$PM_{2.5}$	Sources
Diesel (road)	74 100	1000	190	800	0.6	3.9	200	4.8	IPCC & IMPRO-car
Petrol (Road)	69 300	8000	140	600	0.6	25	1500	4	IPCC & IMPRO-car
Kerosene (aviation)	71 500	100	-	250	2	0.5	50	-	IPCC

Table 13 shows the default emission factor for diesel, petrol and kerosene fuel, which is the only fossil fuel used for transport sector in Bhutan. Whereas CO, SO_2, NO_x, N_2O, CH_4, NMVOC are the default value directly applied from the IPCC as a default emission factor, $SO_2$and $PM_{2.5}$emission factor is used from EU data source of Environmental Improvement of Passenger Cars [181]–[185]. The environmental impact of the transport fuel consumption in Bhutan is calculated from the default values of table 13 as there is no updated emission data since 2015 specific to Bhutan [139], [169], [179].

4.4.1 Environment pollution due to diesel fuel consumption

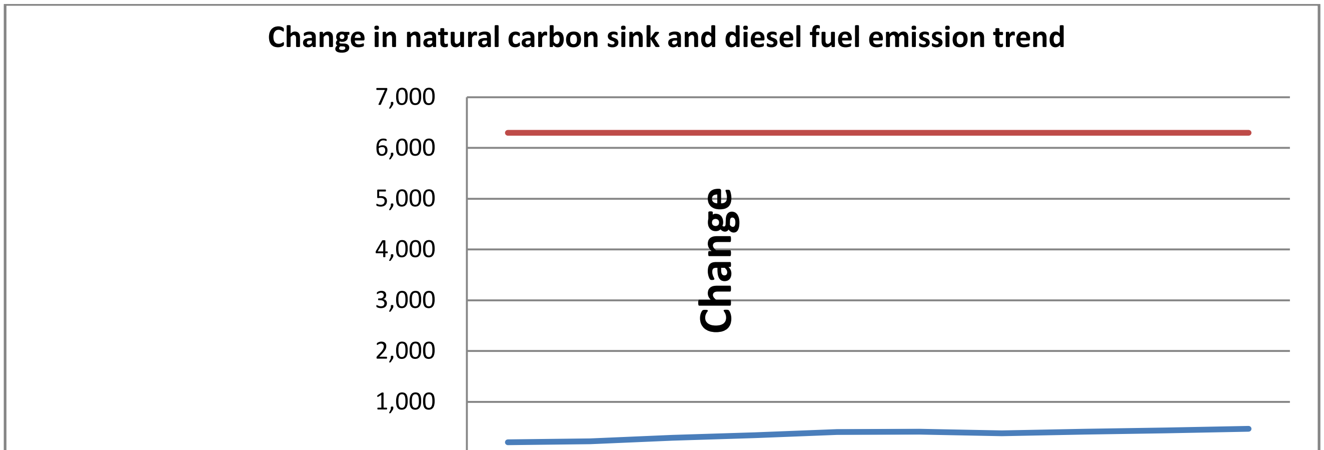
The fossil fuel consumption data of Bhutan shows diesel fuel consumption was 62,207.36 t in 2008, which has increased to 159,722.50 tin 2018 [139], [169], [170]. The net calorific value of diesel fuel is 43.33 GJ/t, which when applied to calculate the fuel energy content shows 2,695.44 TJ of primary energy consumption in 2008 [182]. The default emission factor from table 13 is applied to calculate different type of gaseous emission as by-product of fuel combustion, which shows 199,732.47 t CO_2, 2,695.44 t CO, 512.13 t SO_2, 2,156.36 t NO_x, 1.62 t N_2O, 10.51 t CH_4, 539.09 NMVOC and 12.94 t $PM_{2.5}$ of emission species from diesel fuel combustion in 2008 as baseline emission to observe the emission growth trend. Although the uncontrolled emission from transport sector shows transport fuel as major environment challenge, the national forest sequestration capacity of 6,300,000 t CO_2 seem to have contributed significantly as national carbon sink for different gaseous emission [175]. The forest sequestration capacity is expected to remain constant because of the national forest conservation act, which enforces strong regulation to maintain forest coverage of more the 60% of the national land use change [165].

Table 14: Emission due to diesel fuel consumption

Year	Tons of emission species								
	Diesel (TJ)	CO_2	CO	SO_2	NO_x	N_2O	CH_4	NMVOC	$PM_{2.5}$
2008	2695.44	199732.47	2695.44	512.13	2156.36	1.62	10.51	539.09	12.94
2009	2971.46	220185.25	2971.46	564.58	2377.17	1.78	11.59	594.29	14.26
2010	3847.20	285077.33	3847.20	730.97	3077.76	2.31	15.00	769.44	18.47
2011	4587.44	339929.03	4587.44	871.61	3669.95	2.75	17.89	917.49	22.02
2012	5381.99	398805.13	5381.99	1022.58	4305.59	3.23	20.99	1076.40	25.83
2013	5464.79	404941.10	5464.79	1038.31	4371.83	3.28	21.31	1092.96	26.23
2014	5096.29	377635.28	5096.29	968.30	4077.03	3.06	19.88	1019.26	24.46
2015	5465.62	405002.46	5465.62	1038.47	4372.50	3.28	21.32	1093.12	26.23
2016	5799.78	429763.37	5799.78	1101.96	4639.82	3.48	22.62	1159.96	27.84
2017	6266.41	464341.35	6266.41	1190.62	5013.13	3.76	24.44	1253.28	30.08
2018	6920.78	512829.50	6920.78	1314.95	5536.62	4.15	26.99	1384.16	33.22

Table 14 shows the approximate emission species due to diesel fuel use for transport purpose in Bhutan. The calculated values have the limitation due to the fact that the fuel consumed by specific vehicle type is not known. For example diesel is used mostly by heavy vehicle and is often very old bus and truck is major diesel consumer, which might lead to higher emission than the default values. Similarly the light vehicles also consume diesel, which might lead to lower emission than that of default values. However the detail calculation cannot be performed due to data limitation. On the other hand the vehicle emission test data are not public and the enforcement mechanism is not very clear, which limits the data reporting to approximated values and default emission standard values.

The visualization of emission growth and sequestration capacity of national forest sink can be observed from the approximate values from table 14. The sequestration capacity of 6,300,000 t CO_2will face annual stress with the current emission growth trend [175].



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO2e emission(Thousand ton)	200	220	285	340	399	405	378	405	430	464
Sequestration(Thousand ton)	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300

Figure 22: Environment impact trend due to diesel fuel combustion

Figure 22 shows the influence of variable Environment pollution (12) on mobility system from the variable list of chapter 3 and the emission calculation summery result due to diesel fuel combustion. Considering the base year 2008 and using the default emission factor of table 13, the diesel fuel combustion and forest sequestration capacity trend development shows, the national carbon sink will increasingly face the challenge of human interference. Currently the diesel fuel combustion emission growth is on an average 8.67% annually considering 10 years period and decrease in absorption capacity of forest is on an average 94% as against emission as seen in figure 22 which is significant. Therefore even if the national carbon sink is currently acting as natural carbon sink for carbon neutral vision, the emission from diesel fuel alone is significant.

It has also to be noted that the forest has the potential to observe CO_2 and not all the gases that is emitted for example the CH_4, which is still arguable topic [186], [187]. Therefore forest as carbon sink for mobility sector is still questionable, which has multiple toxic gas emission potentials. Therefore removable of toxic gases will remain increasingly challenging and will require additional measure.

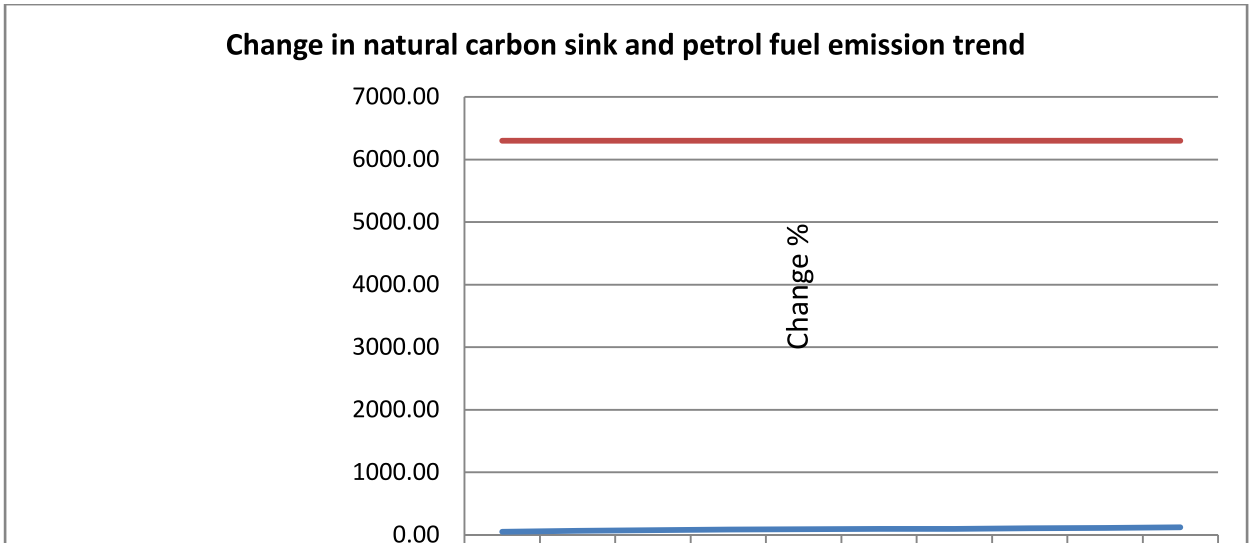
4.4.2 Environment pollution due to petrol fuel consumption

The fossil fuel consumption data of Bhutan shows petrol fuel consumption was 15,417.58 t in 2008, which has increased to 46,912.34 t in 2018 [139], [169], [170]. The net calorific value of petrol fuel is 44.8 GJ/t, which when applied to calculate the fuel energy content shows 690.71 TJ of primary energy consumption in 2008 [182]. The default emission factor from table 13 is applied to calculate the different types of gaseous emission as by-product of fuel combustion, which shows 47,866.04 t CO_2, 5,525.66 t CO, 96.70 t SO_2, 414.42 t NO_x, 0.41 t N_2O, 17.27 t CH_4, 1,036.06 NMVOC and 2.76 t $PM_{2.5}$ of emission from petrol fuel combustion in 2008 as baseline emission to observe the emission growth trend (refer table 15). Similar to diesel fuel, the emission from petrol causes significant environment challenge but the national forest sequestration capacity of 6,300,000 t CO_2 seem to have significant contribution as national carbon sink for different gaseous emission [175]. The forest sequestration capacity is expected to remain constant because of the national forest conservation act, which enforces strong regulation to maintain forest coverage of more the 60% of the national land use change [165].

Table 15: Emission due to petrol fuel consumption

Year	Tons of emission species								
	Petrol(TJ)	CO_2	CO	SO_2	NO_x	N_2O	CH_4	NMVOC	$PM_{2.5}$
2008	690.71	47866.04	5525.66	96.70	414.42	0.41	17.27	1036.06	2.76
2009	920.85	63815.19	7366.83	128.92	552.51	0.55	23.02	1381.28	3.68
2010	1072.28	74308.97	8578.24	150.12	643.37	0.64	26.81	1608.42	4.29
2011	1204.13	83445.96	9633.01	168.58	722.48	0.72	30.10	1806.19	4.82
2012	1313.40	91018.42	10507.18	183.88	788.04	0.79	32.83	1970.10	5.25
2013	1356.19	93984.28	10849.56	189.87	813.72	0.81	33.90	2034.29	5.42
2014	1409.33	97666.39	11274.62	197.31	845.60	0.85	35.23	2113.99	5.64
2015	1516.33	105081.51	12130.62	212.29	909.80	0.91	37.91	2274.49	6.07
2016	1622.42	112433.92	12979.38	227.14	973.45	0.97	40.56	2433.63	6.49
2017	1752.55	121451.96	14020.43	245.36	1051.53	1.05	43.81	2628.83	7.01
2018	2101.67	145645.93	16813.38	294.23	1261.00	1.26	52.54	3152.51	8.41

The emission reduction by fuel switch does not really indicate the improvement in the mobility emission trend and environment pollution, which has direct affect on human health. For example the switch from diesel fuel to petrol fuel has significant emission reduction potential of CO_2 emission species but it has the potential to increase the CH_4 and NMVOC (refer to table 13) emission and the CH_4 global warming potential is 25 times higher than that of CO_2 [181], [182], [184], [188]. The forest as sink for CH_4 is nevertheless changing based on new assessment of forest sequestration by different tree species [186], [187]. Therefore it may not be realistic to rely on forest as absolute sink for mobility emission, which is gradually increasing.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO2e emission (thousand tons)	47.87	63.82	74.31	83.45	91.02	93.98	97.67	105.08	112.43	121.45
Sequestration (Thousand tons)	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300

Figure 23: Environment impact trend due to petrol fuel combustion

Figure 23 shows the influence of mobility system variable Environment pollution (12) from the variable list of chapter 3 and the emission calculation summery result due to petrol fuel combustion. Considering the base year 2008 and using the default emission factor of table 13, the petrol fuel combustion and forest sequestration capacity trend development is shown in figure 23. Currently the petrol fuel combustion emission growth is on an average 10.29% annually considering the 10 years period and decrease in absorption capacity of forest is on an average 98.38% as against emission as seen in figure 23 which is significant.

However the growth trend of petrol fuel consumption is increasing drastically as seen table 12, which has the intention to reduce CO_2 emission but has significantly contributed the CH_4 emission(refer to table 13). Therefore it can be concluded that even if fuel switch from diesel to petrol is intended for CO_2 emission reduction, it does not fully address that intension due to increase in CH_4 emission, which has much higher global worming potential (factor of 25). In the case of Bhutan diesel and petrol are the only fuel adopted for surface transport requirement and is 100% imported. On the other hand Bhutan's abundant hydropower has the potential to overcome these environmental challenges, which will be elaborated as contextual internal scenario in section 4.5 alternative mobility options for Bhutan.

4.4.3 Environment pollution due to kerosene fuel consumption

The fossil fuel consumption data of Bhutan shows kerosene fuel consumption was 1,342.87 t in 2008, which has increased to 4,878.00 t in 2018 [139], [169], [170]. The net calorific value of kerosene fuel is 44.59 GJ/t, which when applied to calculate the fuel energy content, it shows 59.88 TJ of primary energy consumption in 2010 as there is an out layer in 2008 and 2009 [182]. The default emission factor from the table 13 is applied to calculate different type of gaseous emission as by-product of fuel combustion, which shows 4,281.32 t CO_2, 5.99 t CO, 14.97 t NO_x, 0.12 t N_2O, 0.03 t CH_4 and 2.99 NMVOC of emission species from kerosene fuel combustion in 2008 as baseline emission to observe the emission growth trend (refer table 16 and figure 24). Similar to that of diesel and petrol, the emission from aviation fuel also show environment challenge but the national forest sequestration capacity of 6,300,000 t CO_2seem to offsets the emission [175]. Forest is identified as significant national carbon sink for different gaseous emission. The forest sequestration capacity is expected to remain constant because of the national forest conservation act, which enforces strong regulation to maintain forest coverage of more the 60% of the national land use change [165].

Table 16: Emission due to kerosene fuel consumption

Year	Tons of emission species								
	ATF(TJ)	CO_2	CO	SO_2	NO_x	N_2O	CH_4	NMVOC	$PM_{2.5}$
2008	37.33	2669.24	3.73	0.00	9.33	0.07	0.02	1.87	0.00
2009	4.40	314.67	0.44	0.00	1.10	0.01	0.00	0.22	0.00
2010	59.88	4281.32	5.99	0.00	14.97	0.12	0.03	2.99	0.00
2011	64.88	4638.81	6.49	0.00	16.22	0.13	0.03	3.24	0.00
2012	92.84	6637.86	9.28	0.00	23.21	0.19	0.05	4.64	0.00
2013	141.26	10100.17	14.13	0.00	35.32	0.28	0.07	7.06	0.00
2014	159.86	11429.64	15.99	0.00	39.96	0.32	0.08	7.99	0.00
2015	146.75	10492.32	14.67	0.00	36.69	0.29	0.07	7.34	0.00
2016	146.88	10501.88	14.69	0.00	36.72	0.29	0.07	7.34	0.00
2017	177.56	12695.35	17.76	0.00	44.39	0.36	0.09	8.88	0.00
2018	217.51	15551.97	21.75	0.00	54.38	0.44	0.11	10.88	0.00

Aviation sector is a growing industry in Bhutan and it is expected that more domestic air services will be replacing surface transport mode for quick travel options and also due to difficult mountain terrain it becomes an alternative to surface mobility. On the other hand the national economy is fully influenced by tourism sector, which will further encourage the development of aviation sector [169]. The fuel substitute for aviation sector is very limited compared to surface mobility and therefore will continue to face the import dependency unless hydrogen becomes operational in near future as aviation fuel [68].

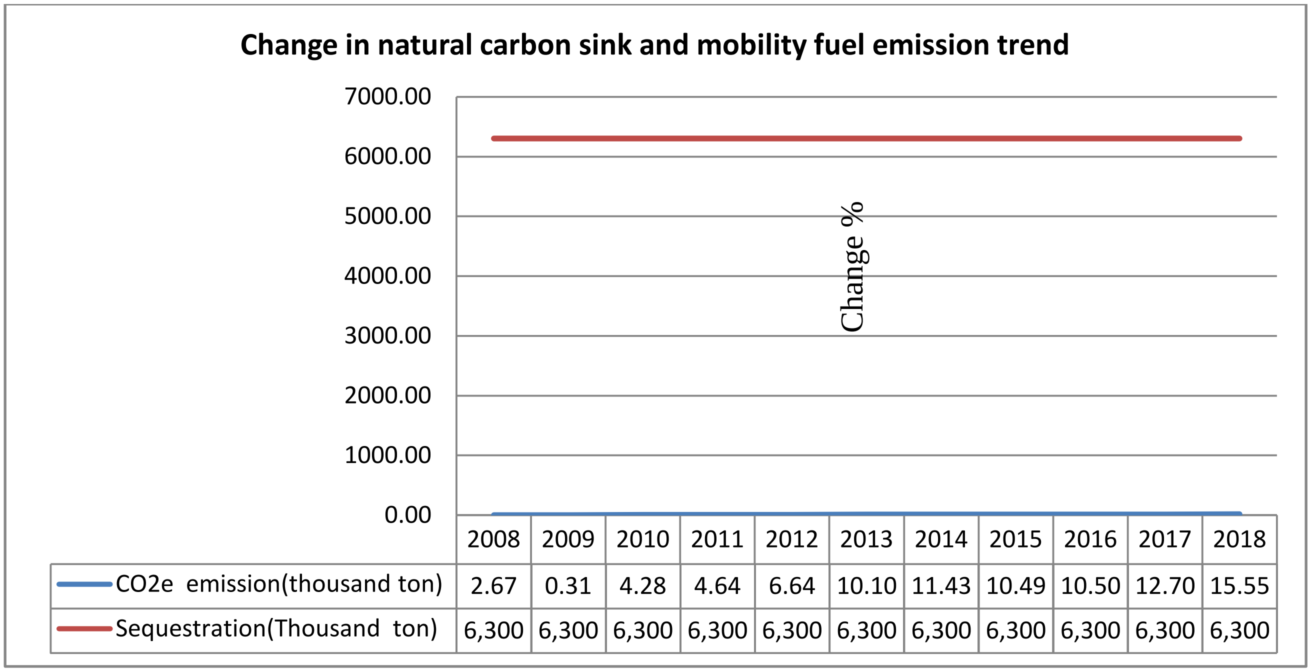


Figure 24 : Environment impact trend due to kerosene fuel combustion

Figure 24 shows the influence of mobility system variable Environment pollution (12) from the variable list of chapter 3 and the emission calculation summery result due to kerosene fuel combustion. Considering the base year 2008 and using the default emission factor of table 13, the kerosene fuel combustion and forest sequestration capacity trend development is shown in figure 24. Currently the kerosene fuel combustion emission growth is on an average 13.91% for last 10 years and decrease in absorption capacity of forest is on an average 99.86% as against emission as seen in figure 24 which is insignificant. However in future aviation sector for Bhutan is critical for alternative mobility mode for fast travel option.

Similar to that of diesel and petrol fuel, the kerosene fuel combustion has other gases that is emitted other than CO_2, which is often reduced to CO_{2e}. However the impact of the other gas as environment pollutant strongly influences human health [77]. Therefore only fuel switch as an alternative is not an option for such challenges but it requires systemic re-orientation, for example the travel behaviour alteration as reflected in desirable scenario in section 6.6 in chapter 6. Therefore environment play a critical mobility system indicator variable, which will be shown during the scenario formulation in chapter 6.

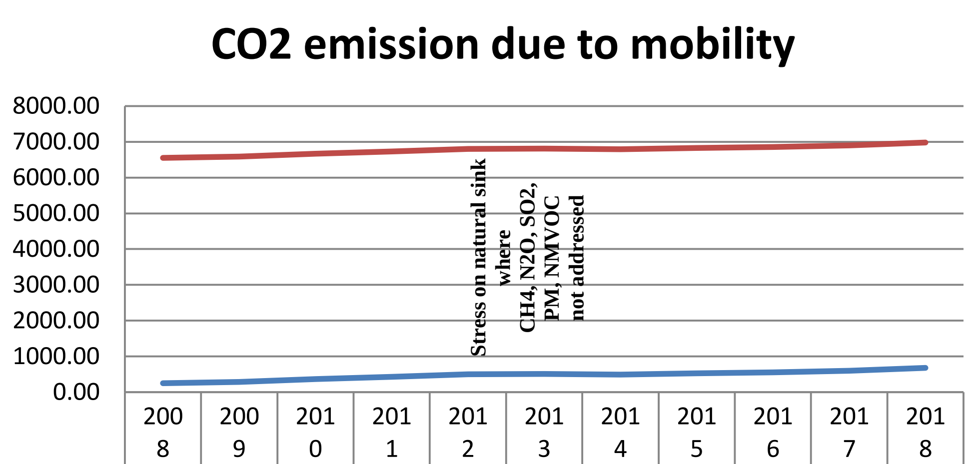
4.4.4 Environment pollution due to mobility

The combined emission due to combustion of diesel, petrol and kerosene is as shown in table 17 and figure 25. Although the forest sequestration has the potential to offset CO_2, the other pollutant such as $PM_{2.5}$, SO_2, NO_x and N_2O will have significant impact on human health, which requires additional measure.

Table 17: Combined emission due to fossil fuel combustion by weight in tons

	CO_2	CO	SO_2	NO_x	N_2O	CH_4	NMVOC	$PM_{2.5}$
2008	250,267.75	8,224.84	608.83	2,580.11	2.11	27.80	1,577.02	15.70
2009	284,315.12	10,338.73	693.50	2,930.78	2.34	34.61	1,975.79	17.95
2010	363,667.62	12,431.42	881.09	3,736.10	3.07	41.84	2,380.85	22.76
2011	428,013.80	14,226.93	1,040.19	4,408.64	3.60	48.03	2,726.92	26.84
2012	496,461.41	15,898.45	1,206.45	5,116.84	4.20	53.87	3,051.13	31.09
2013	509,025.55	16,328.47	1,228.18	5,220.87	4.38	55.29	3,134.31	31.66
2014	486,731.31	16,386.90	1,165.60	4,962.59	4.22	55.19	3,141.24	30.10
2015	520,576.28	17,610.92	1,250.75	5,318.98	4.48	59.30	3,374.95	32.30
2016	552,699.16	18,793.85	1,329.10	5,649.99	4.75	63.25	3,600.93	34.33
2017	598,488.66	20,304.60	1,435.98	6,109.05	5.17	68.34	3,890.99	37.09
2018	674,027.39	23,755.91	1,609.18	6,852.00	5.85	79.64	4,547.54	41.63

Figure 25 shows the combined sequestration reduction trend and emission due to all fuel type such as diesel, petrol and kerosene. The growth trend of emission from all fuel consumption is on an average 9.21% and the decrease in forest sequestration has reached to 91.72%, which is significant.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sequestration	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300
CO2e emission(thousand ton)	250.2	284.3	363.6	428.0	496.4	509.0	486.7	520.5	552.7	598.4	674.0

Figure 25: Environment impact trend due to all fuel combustion

Even if the forest acts as a carbon sink, the mobility pollutant will have significant impact on urban air quality, which will require additional measure. This impact attributes to the variable Human wellbeing (22) from the variable list of chapter 3. On the other hand the national emission data are still old even in the latest statistics update, which cannot be compared with the current calculated values (refer to table 18 for old national data). The national emission data is from 2000, which are the only data found in the latest national statistics and is from the second national communication report to UNFCCC [169].

Table 18: National green house gas record in tons[169]

	CO_{2e}	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Energy	270230	260310	380	10	1760	9000	1300	960
Industrial Processes	237760	237760	0	0	0	0	1690	100
Solvent & Other Product Use	0	0	0	0	0	0	0	0
Agriculture	1005300	0	25850	1490	200	410	0	0
Land-Use Change and Forestry	-6309000	-6309000	0	0	0	0	0	0
Waste	46270	0	2000	10	0	0	0	0
Total GHG Emission, excluding LUCF	1559560	498070	28230	1510	1780	9410	4700	1050
Total GHG Emission, including LUCF	-4750040	-5810900	28230	1510	1780	9410	4700	1050

Due to the lack of national emission data update, the comparison of calculated emission from transport sector with other sector is unrealistic at the moment as the changes can be noted since 2000. This is already evident from the calculated values since 2008 until 2018 concerning mobility fuel consumption. The calculated values can be used for the baseline analysis as energy related emission is mainly due to fuel consumption. On the other hand the national carbon sink that is seen from the national data, which is 6,309,000 t CO_2 is subject to changes due to forest fires and other infrastructure project development. Therefore clear conclusion cannot be drawn from the data comparison from currently available sources. The calculated values should be considered for the emission approximation. Moreover it is important to note the changing views regarding, the forest as net carbon sink for different toxic emission [186], [187]. Therefore at this stage assumption can be made for the case of Bhutan that the presence of hydro as energy source has the potential and opportunity to offset all the emission especially resulting from fuel use, which will be elaborated in section 4.5 and their multiple future scenarios for Bhutan mobility system development in chapter 6 section 6.7.

4.5 Current status quo

Bhutan's current mobility system is 100% dependent on internal combustion engine, and motorization dominated by road transport for both passenger and freight movement supported by very limited air travel services [189]. Therefore more focus has to be made on surface transport options. The road infrastructure change for 10 years period is compiled in table 19. Similarly the average vehicle growth trend for 10 years period is compiled in table 20. This data is used to calculate the road infrastructure density considering the road infrastructure classification and changes since 2008. The historical data indicate that on an average, the overall infrastructure has grown by 14%, where the paved road has increased by 8.39% and simultaneously the unpaved road infrastructure has increased by 15.81% annually. Currently the road density of Bhutan is 0.47 km/km^2, where approximately 50% of them are unpaved, which means the infrastructure up gradation and quality improvement will continue as per the current growth trend.

Table 19: Road infrastructure growth trend compiled from NSB [139], [169], [170]

Year	Quality	Express-way	PNHW	SNHW	District road	Urban Road	Farm Road	Access Road	All road	Road(km)/km^2	%change
2008	Total	6.2	-	-	482.0	324.0	1705.5	1223.8	3741.5	0.10	-
	Paved	6.2	-	-	449.5	310.9	0.0	304.6	1071.2	0.03	-
	Unpaved	-	-	-	32.5	13.1	1705.5	919.2	2670.3	0.07	-
2009	Total	6.2	-	-	490.7	380.8	2098.3	1296.5	4272.5	0.11	12.43
	Paved	6.2	-	-	454.2	364.1	2.7	301.0	1128.2	0.03	5.05
	Unpaved	-	-	-	36.5	16.7	2095.6	995.5	3144.3	0.08	15.07
2010	Total	6.2	-	-	1066.1	295.0	1980.3	1313.2	4660.7	0.12	8.33
	Paved	6.2	-	-	196.5	265.8	0.2	291.2	759.9	0.02	-48.47
	Unpaved	-	-	-	869.6	29.2	1980.1	1022.0	3900.8	0.10	19.39
2011	Total	6.2	1757.2	516.4	1112.9	303.6	3289.7	1380.3	8366.2	0.22	44.29
	Paved	6.2	1604.2	473.9	203.1	272.8	0.7	296.6	2857.4	0.07	73.41
	Unpaved	-	153.0	42.5	909.8	30.8	3289.0	1083.7	5508.8	0.14	29.19
2012	Total	6.2	1768.6	521.2	1050.9	326.9	4380.9	1436.7	9491.5	0.25	11.86
	Paved	6.2	1627.3	473.9	203.1	295.8	0.0	296.7	2902.9	0.07	1.57
	Unpaved	-	141.4	47.3	847.8	31.2	4380.9	1140.0	6588.5	0.17	16.39
2013	Total	6.2	1860.1	578.2	1178.3	349.7	5255.2	1350.5	10578.2	0.27	10.27
	Paved	6.2	1662.4	510.9	202.1	324.5	2.5	266.7	2975.3	0.08	2.43
	Unpaved	-	197.7	67.3	976.2	25.2	5252.7	1083.8	7602.9	0.20	13.34
2014	Total	6.2	1941.7	579.2	1260.7	349.7	5707.8	1398.1	11243.4	0.29	5.92
	Paved	6.2	1758.6	511.1	211.8	327.0	2.5	265.5	3082.7	0.08	3.48
	Unpaved	-	183.2	68.1	1049.0	22.7	5705.3	1132.6	8160.8	0.21	6.84
2015	Total	6.2	1974.6	584.5	1508.0	396.8	5221.5	1485.4	11177.0	0.29	-0.59

	Paved	6.2	1809.0	515.9	228.1	377.1	2.5	263.1	3201.9	0.08	3.72
	Unpaved	-	165.7	68.6	1279.9	19.7	5219.0	1222.3	7975.1	0.21	-2.33
2016	Total	6.2	1965.2	878.4	2606.2	436.8	5049.7	1406.2	12348.7	0.32	9.49
	Paved	6.2	1560.5	641.8	1075.3	350.0	0.0	0.0	3633.8	0.09	11.89
	Unpaved	-	404.7	236.6	1530.9	86.8	5049.7	1406.2	8714.9	0.23	8.49
2017	Total	6.2	1822.7	903.3	2004.7	417.1	11292.3	1735.1	18181.3	0.47	32.08
	Paved	6.2	1733.9	677.9	1135.1	402.8	12.6	506.7	4475.2	0.12	18.80
	Unpaved	-	88.8	225.4	869.6	14.3	11279.7	1228.4	13706.1	0.35	36.42
2018	Total	6.2	1772.4	997.6	2060.4	417.1	11292.3	1736.0	18282.0	0.47	0.55
	Paved	6.2	1730.4	792.5	1190.9	402.8	12.6	506.7	4642.0	0.12	3.59
	Unpaved	-	42.0	205.1	869.6	14.3	11279.7	1229.4	13640.1	0.35	-0.48

The average annual automobile growth trend for 10 year period is shown in table 20, which is based on the values compiled from the table 11 automobile statistics since 2008 in section 4.3. The overall average automobile growth trend shows, the heavy machinery such as earth mover (16.29%) is the highest, which may be attributed to new infrastructure development trend especially the farm road construction connecting rural Bhutan. Similarly the farm machinery growth is significant (13.31%), which may be attributed to rural development and mechanized farming. On the other hand the growth of light and medium vehicles is significantly high, which is mostly used for personal use and light duty vehicles for goods transport. The detail on vehicle classification will be further discussed in section 4.6 in alternative mobility. On an average the overall automobile growth for 10 year is 11.46% annually, which is significant. Further the automobile growth has been high in Monggar region although total automobile count is relatively low. Monggar is a growing urban centre. This indicates that the urbanization trend influences the automobile growth trend.

Table 20: Automobile growth trend

Region	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle	Total
Thimphu	5.47	15.58	9.00	-1.64	16.44	10.32	12.96	-0.47	8.05
P/ling	11.00	7.73	10.34	6.18	6.97	10.13	14.51	5.29	9.96
Gelephu	11.34	22.38	16.29	4.43	13.14	26.45	25.87	5.56	12.43
S/ Jongkhar	4.21	5.48	11.56	4.31	6.05	7.41	15.06	0.00	7.88
Monggar	13.62	8.95	19.77	13.65	12.70	12.22	13.03	0.00	18.98
Bhutan	9.13	12.02	13.39	5.39	11.06	13.31	16.29	2.08	11.46

In section 4.5.1 to 4.5.3 road infrastructure density, vehicle density and vehicle per capita will be further analysed specifically focused to regional distribution in Bhutan based on above statistics(table 19 & 20), which may be used for comparative study and can be used as an indicator of motorization trend.

4.5.1 Road infrastructure density

Table 21 shows the road classification and distribution across Bhutan and in different district to show the infrastructure development trend, which is critical for mobility system planning.

Table 21: Road infrastructure of Bhutan compiled from NSB [139], [169], [170] in 2018

Districts	Land area km^2	Express way	Primary NHW	Secondary NHW	District road	Urban road	Farm road	Access road	Total	$Road(km)/km^2$(district)
Bumthang	2708	0	93	66	18	2	262	107	547	0.20
Chhukha	1880	0	219	0	188	29	492	218	1145	0.61
Dagana	1734	0	18	167	122	2	644	50	1002	0.58
Gasa	3101	0	0	46	8	0	41	2	97	0.03
Haa	1885	0	44	113	19	8	275	81	539	0.29
Lhuentse	2838	0	0	45	108	1	692	140	984	0.35
Monggar	1946	0	181	21	288	12	1170	63	1735	0.89
Paro	1278	0	98	32	17	5	665	85	903	0.71
Pemagatshel	1033	0	120	128	144	0	600	43	1035	1.00
Punakha	1110	0	48	33	36	4	431	102	653	0.59
Samdrupjongkhar	1894	0	77	72	120	7	431	44	751	0.40
Samtse	1296	0	51	109	111	8	753	40	1072	0.83
Sarpang	1676	0	98	0	107	16	327	164	711	0.42
Thimphu	1782	6	40	7	55	282	113	232	735	0.41
Trashigang	2193	0	133	97	285	7	1709	32	2262	1.03
Trashiyangtse	1439	0	45	0	71	9	468	28	621	0.43
Trongsa	1814	0	143	0	37	1	365	40	585	0.32
Tsirang	642	0	63	3	69	3	351	20	509	0.79
Wangdue	4035	0	141	5	105	9	976	188	1424	0.35
Zhemgang	2425	0	161	55	156	14	529	58	972	0.40
total	38710	6	1772	998	2060	417	11292	1736	18282	0.47
$Road(km)/km^2$(Bhutan)		0.000	0.046	0.026	0.053	0.011	0.292	0.045	0.472	

As of 2019 there are 106,681(all type) vehicles with the build-up road infrastructure of 18,286 km for rural and urban access [139], [169], [170]. However for the purpose of current status quo analysis we establish baseline from the data set of 2018 because other data set influencing mobility system development is still not published even if vehicles statistics are quarterly published. Table 21 shows the road density expressed as length of road per km^2 for different district and for Bhutan classified as express way, primary national high way, secondary national high way, district roads, urban road, farm road and access road. The road density range in the district between0.2 to 1.03 km/km^2, where Bumthang district is seen to have least road density and Trashigang district is seen to have highest. On the other hand considering nationwide road density, the express way density is negligible 0.0 km/km^2, which is 6.5 km existing only in capital city Thimphu and farm road is highest 0.292 km/km^2. The national road density of Bhutan is currently seen to be 0.472 km/km^2 in total including all kinds of road. The major road connecting the districts, major town, cities and international connectivity is shown in figure 26, which is mostly used for transport route planning. In addition to district to district connectivity, there are three main international trade route in Phuntsholing (connecting the western Bhutan), Gelephu(connecting central Bhtutan) and S/Jongkhor(connecting eastern Bhutan) with its nearest neighbor India for international trade access(refer to figure 26).

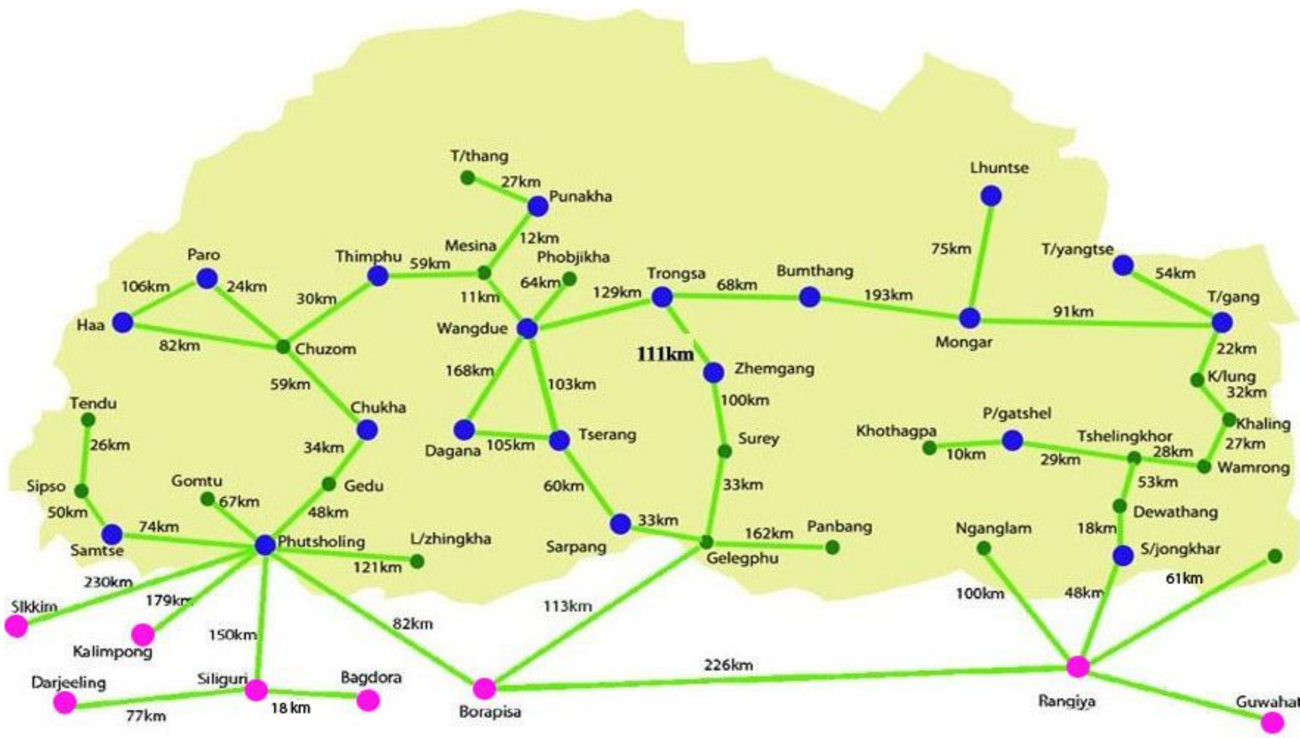


Figure 26: Road network of Bhutan [190]

The air transport service includes 1international airport with runway width 30 m and length 2,265 m and 4 domestic airport with runway width 30 m and 1,200 to 1,500 m length, located in Paro(west), Yonphula(east), Gelephu(south-central) and Bumthang (central) enabling national and international flight by 5 aircraft[189]. While most of the passenger and freight movement for domestic purpose is fully dependent on to road transport, international passenger and freight movement is enabled by limited number of flight service. The domestic air travel service is used for tourist and on demand Bhutanese travellers for fast travel requirement.

The road classification of Bhutan is shown in table 22, which is compiled from the primary transport audit survey report [166]. The classification shows both the design condition and current status quo. The design standard for the right of way (RoW) for all road type is 30 m wide whereas the carriage way for primary national high way (PNHW) is 6.5 m and that of other roads are 3.5 m wide [157]. The design condition and the actual road differ slightly. For example, carriage way for district road is 4-5 m instead of 3.5 m. The road design speed of 30 to 60 km/h is allowed for greater than 200 vehicle in primary national high way, 20 to 50 km/hr for 100 to 200 vehicle in secondary national highway (SNHW), 15 to 40 km/hr for 30 to 100 vehicle in district road and 10 to 30 km/hr for less than 30 vehicle in farm road depending on the level, rolling, mountainous and steep terrain [191]. Although actual driving condition depends on the driving behaviour, the maximum speed will not exceed 60-70 km/hr in Bhutan because of narrow road and difficult mountain terrain.

Table 22: current status quo and design condition of road infrastructure [166]

Category	RoW	Carriage way	Hill side shoulder	Valley side shoulder	Remarks
Expressway	7m to 12m	5m to 8m	0.2m to 3m	0.2m to 1m	(more than 95% paved)
PNHW	7m to 12m	5m to 8m	0.2m to 3m	0.2m to 1m	(more than 95% paved)
SNHW	7m to 12m	5m to 8m	0.2m to 3m	0.2m to 1m	(more than 95% paved)
District Road	6m to 8m	4m to 5m	0.2m to 1m	0.2m to 0.5m	(paved)
Urban Road	15m to 20m	10m to 12m	2m to 4m	2m to 4m	(paved)
Access road	5m to 8m	4m to 8m	0.2m to 0.5m	0.2m to 0.5m	(all unpaved with stones)
Forest road	5m to 8m	4m to 8m	0.2m to 0.5m	0.2m to 0.5m	(all unpaved with stones)
Feeder road	5m to 8m	4m to 8m	0.2m to 0.5m	0.2m to 0.5m	(all unpaved with stones)
Project road	5m to 8m	4m to 8m	0.2m to 0.5m	0.2m to 0.5m	(all unpaved with stones)
Farm road	5m to 8m	4m to 8m	0.2m to 0.5m	0.2m to 0.5m	(all unpaved with stones)

From the national data concerning automobile and infrastructure statistics and the current status quo of the design condition of road infrastructure combined with the limited availability of air transport options, Bhutan faces the challenge of accessibility and transport efficiency. Therefore even if alternative mobility options are available, the primary requirement is to upgrade the infrastructure that supports automobile mobility in rural area and non-motorized travel options in urban region.

4.5.2 Vehicle density

Vehicle density is a calculated value based on the existing automobile data and infrastructure availability in 2018 as shown in table 11, 20, 21 & 22. Although infrastructure data are available district wise, the automobile data can only be found for specific region. Therefore availability of infrastructure in the region and the automobile count is used to estimate the vehicle density. Vehicle density is total number of vehicle that the road infrastructure is able to accommodate expressed in vehicles per length (km) of road and their classification. Table 23 shows the total automobile and road infrastructure classification in different region in Bhutan.

Table 23: Vehicle and infrastructure regional distribution compiled from[139], [169], [170] 2018

Region	Automobiles	Express way	Primary NHW	Secondary NHW	District road	Urban road	Farm road	Access road
Thimphu	47013.00	6.20	370.56	235.99	239.16	307.84	2500.91	690.07
P/ling	32487.00	0.00	270.05	109.00	298.87	36.83	1244.91	257.23
Gelephu	5706.00	0.00	482.65	224.58	489.81	35.34	2215.09	331.96
S/Jongkhar	5016.00	0.00	374.89	297.01	619.65	22.64	3207.88	147.01
Monggar	1541.00	0.00	274.24	131.00	412.94	14.43	2123.50	309.76
Bhutan	91763.00	6.20	1772.39	997.58	2060.43	417.08	11292.29	1736.03

Theoretically the automobiles registered in the region have more than 90% chance to use the infrastructure of the region even if small portion of travel takes place in other region. Therefore it is logical to estimate the vehicle density regionally and qualify the road congestions. Table 24 shows the calculated values of road congestion region wise and in Bhutan. The road congestion shows that the highest vehicle density is seen in express highway followed by urban road and lowest in farm road.

Table 24: Vehicle density regional, automobiles per km

Region	Express way	Primary NHW	Secondary NHW	District road	Urban road	Farm road	Access road
Thimphu	7582.74	126.87	199.22	196.58	152.72	18.80	68.13
P/ling	0.00	120.30	298.05	108.70	882.08	26.10	126.30
Gelephu	0.00	11.82	25.41	11.65	161.46	2.58	17.19
S/Jongkhar	0.00	13.38	16.89	8.09	221.55	1.56	34.12
Monggar	0.00	5.62	11.76	3.73	106.79	0.73	4.97
Bhutan	14800.48	51.77	91.99	44.54	220.01	8.13	52.86

Even if 50% of the vehicles are on road that is approximately 3,791 vehicles per km, Express highway is already congested, which is in the capital city Thimphu. However the farm road is relatively free with only about 8 vehicles per km. This means good quality infrastructure and enabling access for rural area is critical.

4.5.3 Automobile share to citizens

Automobile share to citizens is a calculated value that qualifies the automobile ownership trend for mobility among the population expressed in automobiles per population. Since the automobile data are found only in specific region, the district covered by the region and approximate population of the region is compiled in table 25 in 2018. The population are further broken down into rural and urban in that region.

Table 25: Regional population classified as urban and rural compiled from[139], [169], [170]

Region	Districts covered	Population		
		Urban	Rural	Total
Thimphu	Thimphu, Gasa, Haa, Paro,Wangdue Phodrang, Punakha	148820	124765	273585
Phuntsholing	Samtse, Chhukha	45195	86361	131556
Gelephu	Sarpang, Trongsa, Zhemgang, Tsirang, Dagana	28290	102778	131068
S/Jongkhar	Samdrup Jongkhar, Pemagatshel, Trashigang, t/yangtshe	33454	88075	121529
Monggar	Monggar, Lhuentse, Bumthang	19208	50199	69407
Bhutan	All district	274967	452178	727145

Table 26 shows the vehicle statistics in 2018 in different region. It has to be noted here that the vehicle statistics are easily available data, which is updated annually but the actual population and rural urban migration are only approximate value because the actual population data are updated only in ten years period. Therefore the current data indicates the approximate values of population in 2018 and the vehicle number. The historical data shows that the automobile growth rate is on an average 11.46 % (refer to section 4.5 table 20) for 10 years period and the population growth of urban area is 18% and that of rural area is 10% in 2017 compared to 2005(refer to section 4.2 mobility system development trend). The rural urban migration rate is therefore approximately 6%, which is very important condition to understand the current mobility situation in Bhutan.

Table 26: Vehicle statistics and population in 2018 compiled from NSB [139], [169], [170]

Region	People	HV	MV	LV	TW	PT	Tractor	EM	EV
Thimphu	273585	3,171	460	36,486	3,537	1,988	174	1,140	57
Phuntsholing	131556	6,743	1,045	18,831	4,026	85	186	1,564	7
Gelephu	131068	503	155	3,340	1,224	190	47	243	4
S/Jongkhar	121529	479	87	2,441	1,448	306	61	194	-
Monggar	69407	76	37	1,060	244	56	10	58	-

Table 26 shows total regional population and automobiles in the region. The detail on vehicle classification will be discussed in section 4.6. The current status quo shows the share of automobiles to regional population classified as heavy vehicle(HV), medium vehicle (MV) and light vehicles (LV) and other automobile categories such as two wheeler (TW), power tiller (PT), tractor, earth mover (EM) and electric vehicle(EV). It is important to note here that the share of automobile to citizen is significant because all automobile categories influence the normal daily lifestyle of the overall population in the region and in Bhutan. Based on the current status quo and the calculated value of automobile per inhabitants are shown in table 27. The calculation shows that there is highest share of light vehicle per inhabitants followed by heavy vehicles (refer to table 27) and lowest share of electric vehicle per inhabitants. For example for every 1000 inhabitants there are 85 light vehicles, 2 heavy vehicles and negligible electric vehicle in Bhutan. This indicates high share of light vehicle, which is mostly own by government and ordinary population categories.

Table 27: Share of vehicle per inhabitant according to vehicle classification

Region	Settlement	Heavy	Medium	Light	Two-Wheeler	Power Tiller	Tractor	Earth Mover	Electric Vehicle
Thimphu	Urban	0.0213	0.0031	0.2452	0.0238	0.0134	0.0012	0.0077	0.0004
	Rural	0.0254	0.0037	0.2924	0.0283	0.0159	0.0014	0.0091	0.0005
	Total	0.0116	0.0017	0.1334	0.0129	0.0073	0.0006	0.0042	0.0002
Phuntsholing	Urban	0.1492	0.0231	0.4167	0.0891	0.0019	0.0041	0.0346	0.0002
	Rural	0.0781	0.0121	0.2180	0.0466	0.0010	0.0022	0.0181	0.0001
	Total	0.0513	0.0079	0.1431	0.0306	0.0006	0.0014	0.0119	0.0001
Gelephu	Urban	0.0178	0.0055	0.1181	0.0433	0.0067	0.0017	0.0086	0.0001
	Rural	0.0049	0.0015	0.0325	0.0119	0.0018	0.0005	0.0024	0.0000
	Total	0.0038	0.0012	0.0255	0.0093	0.0014	0.0004	0.0019	0.0000
S/Jongkhar	Urban	0.0143	0.0026	0.0730	0.0433	0.0091	0.0018	0.0058	-
	Rural	0.0054	0.0010	0.0277	0.0164	0.0035	0.0007	0.0022	-
	Total	0.0039	0.0007	0.0201	0.0119	0.0025	0.0005	0.0016	-
Monggar	Urban	0.0040	0.0019	0.0552	0.0127	0.0029	0.0005	0.0030	-
	Rural	0.0015	0.0007	0.0211	0.0049	0.0011	0.0002	0.0012	-
	Total	0.0011	0.0005	0.0153	0.0035	0.0008	0.0001	0.0008	-
Bhutan	Urban	0.0399	0.0065	0.2261	0.0381	0.0095	0.0017	0.0116	0.0002
	Rural	0.0243	0.0039	0.1375	0.0232	0.0058	0.0011	0.0071	0.0002
	Total	0.0151	0.0025	0.0855	0.0144	0.0036	0.0007	0.0044	0.0001

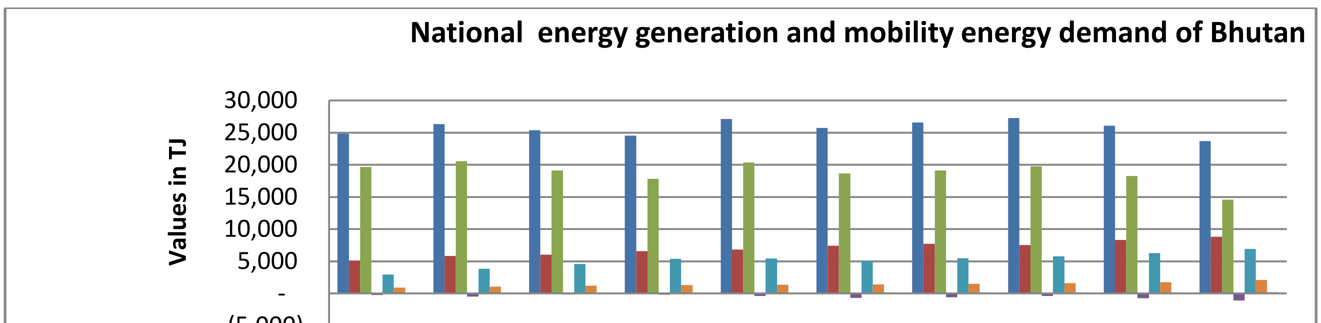
In general the calculated values show that Bhutan has road infrastructure density of 0.472 km/km^2(includes all infrastructure categories), vehicle density of 0.2 km/vehicle(including all vehicle categories) and 0.13 automobiles per inhabitants(including all population group and all vehicle type). There are only 5 aircraft including 1 international and 4 domestic airport. The current status quo is useful for projecting the future mobility scenario of Bhutan, which will be elaborated in chapter 6 in section 6.7.

4.6 Alternative to current mobility

The surface transport development trend elaborated in section 4.3, environment impact calculated in section 4.4, and current status quo analysis in section 4.5 indicate that the mobility system development trend of Bhutan is currently facing the challenge of fuel import dependency accompanied by toxic emission, increasing vehicle population, space limitation influenced by lack of good quality infrastructure and rural accessibility. To address all the above challenges, Bhutan has an opportunity to re-orient the current mobility system development trend. 100% fuel import dependency challenge can be partially or fully waved off if fuel is switched to electrical energy source, as Bhutan has abundant hydro energy [192]. However, they need systemic re-orientation considering the variable list of chapter 3 and mobility scenario in chapter 5 for the successful transition. Alternative to current mobility system development is currently initiated through e-mobility uptake since 2014. E-mobility alternative which can be seen in various literature such as the cost benefit analysis [172], feasibility study by JICA in 2016 [193]and financial support for the low emission urban transport system in 2018 [174] are significant contribution so far. However as of 2019 there are only 112Electric Vehicle (EV) [189] on road and the government of Bhutan with the support of Green Climate Fund (GCF) has started sustainable low emission urban transport with the plan to increase the quick charging infrastructure from 6 to 45 and EV growth from 112 to more than 400 [174]. On the other hand with the support of United Nations Centre for Regional Development (UNCRD), government of Bhutan has also conducted pre-feasibility study on potential for mass transit options using electric train and cable cars in addition to increasing public transport and non-motorized travel behaviour [123]. However, the current status quo analysed in section 4.5 indicates the major challenges faced are infrastructure limitation, vehicle ownership trend and space limitation and rural accessibility although fuel import and environment pollution remain critical situation. On the other hand in-depth mobility research is lacking especially in terms of data availability and fuel qualification as cost benefit analysis is often influenced by political decision [171]. The rational for e-mobility uptake in global context is to increase energy efficiency and environment pollution reduction, which mostly aim to integrate renewable energy sources as mobile energy storage [72]–[74], [79]. Storage options are available in various ways but for mobility requirement, battery and hydrogen are currently known technology. However the fuel choice and qualifying criteria should be based on life cycle assessment for environment pollution control and energy efficiency improvement consideration for the choice according to literature sources [72]–[74], [79], rather than cost benefit analysis [172]. Table 35 shows fuel efficiency from the literature source for different fuel type. The well to wheel efficiency covers the full life cycle fuel efficiency and therefore it is better way to compare the fuel energy efficiency measure. For that purpose fuel efficiency data of diesel, petrol, hybrid petrol and electric, fuel cell for hydrogen and pure electric car is used from Helemers&Marx (2012) and concerning efficiency data of renewable natural gas it is used from Lambert (2018) as shown in table 35 [72], [126]. Both the literature finding is based on real world scenario from the existing market condition. The literature data shown in table 28 revel electrical energy as mobile energy storage in battery as fuel source for vehicle has highest energy efficiency, whereas the Renewable Natural Gas (RNG) has the lowest. It is also important to note that the efficiency comparison is better analysis as against the cost benefit analysis, which is often time influenced by business case [74], [171]. The electrical energy storage in battery is only widely available for small cars for mobility purpose in current market due to vehicle weight added by the battery for use in heavy vehicle, which can be potential future alternative as technologies roll out in the market in future [79].

Table 28: Fuel efficiency for different fuel alternative

Fuel source	Well to wheel	Tank to wheel	Well to wheel	Factor	Source
Diesel	76% - 84%	23% - 28%	18% - 24%	1.75	(Helmers & Marx 2012)
Petrol	79% - 86%	16% -23%	13% - 20%	1.38	(Helmers & Marx 2012)
RNG(CH_4)	34% - 68%	22% -26%	7% - 17%	1.00	(Martin Lambert 2018)
Hybrid (P/E)	79% - 86%	30% - 37%	24% - 32%	2.33	(Helmers & Marx 2012)
Fuel cell(stored H_2)	37% - 53%	50% - 56%	19% -30%	2.04	(Helmers & Marx 2012)
Electric	59% - 85%	73% - 90%	53% -77%	5.42	(Helmers & Marx 2012)



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Electricity Generation	24,832	26,296	25,368	24,521	27,113	25,730	26,574	27,266	26,096	23,666
Domestic consmption	5,092	5,861	6,061	6,581	6,846	7,431	7,712	7,505	8,342	8,836
Electricity export	19,663	20,547	19,116	17,805	20,334	18,645	19,108	19,742	18,247	14,593
Electricity import	-222	-462	-133	-201	-389	-675	-570	-398	-748	-1081
Diesel import	2,971	3,847	4,587	5,382	5,465	5,096	5,466	5,800	6,266	6,921
Petrol import	921	1,072	1,204	1,313	1,356	1,409	1,516	1,622	1,753	2,102
Jet kerosene import	4	60	65	93	141	160	147	147	178	218

Figure 27: Energy generation and fuel import balance since 2009 summery of Bhutan

The efficiency data of table 28 will be used for fuel energy efficiency calculation and to estimate mobility energy demand for fuel switch in Bhutan in future scenario projection. The rational for fuel switch is because of the availability of hydro based electrical energy source, which can be used as mobile energy storage. Figure 27 shows, the energy balance of Bhutan since 2009 in energy unit Terajoule(TJ), which is compiled from the energy data of Druk Green Power Corporation and National Statistical Bureau [139], [169], [170], [192], [194]. As seen in figure 27 hydro energy generation exceeds the national consumption, where on an average 73% of the generation is exported to India. However with the import of mobility fuel (100% fossil) and seasonal generation variation of hydro, the net energy balance shows export has declined from 79% in 2009 to 29% in 2018 a significant impact value of 50%(refer to figure 27). On the other hand the energy export may be diverted and can be used as transport fuel in future, which will be estimated as future mobility fuel energy scenario in chapter 6section 6.7.

The e-mobility uptake in Bhutan is an ad hoc political influence, which triggered the need for immediate cost benefit assessment and feasibility study [171], [172], [193]. Although e-mobility option are seen to be feasible case in global context, other influencing condition such as infrastructure, user behaviour, operational context, economy and future potentials are critical conditions to be considered. All most all the study conducted so far overlooked scientific validation and technical conditions for 100% e-mobility development in Bhutan including the latest action plan report by SAARC [128]. The current focus is only on electric car. For example e-mobility as an alternative to current mobility challenges need to consider all options, such as; heavy vehicle, mass transit, two wheeler, and other alternative fuel shift in future, which is partially or fully missing in all finding. Additionally electrical technical characteristic and infrastructure capacity are overlooked. For example the electric load profile, electricity label, infrastructure capacity and energy system efficiency are very important criteria and are not reflected in the literature. Also due to technical limitation, national standard are very limited for such studies. For example the national grid emission factor reflected in the literatures are 0.8819tCO_{2e}/MWh(IGES), 0.779 tCO_{2e}/MWh(ADB) and 0.889 tCO_{2e}/MWh(WB) that clearly indicate huge data gap for further qualification of e-mobility, which is critical for energy label [175]–[177]. Bhutan's energy share is 100% hydro electricity even if it shares international grid with India. However the current consideration of Bhutan's move for e-mobility is influenced by energy security question rather than environment pollution reduction, which is assumed to be addressed by high sequestration capacity of national forest reserve as seen in section 4.4 [165], [171], [175], [180]. However all emission from vehicle cannot be removed by forest as seen in section 4.4.1 to 4.4.3, which need additional measure. Therefore e-mobility development needs much deeper understanding considering the current situation, infrastructure condition, system optimization options and other variable influencing the mobility system development. So far the mobility status quo of Bhutan is reviewed with the inclusion of historical data, national policies, and environment impact for that purpose. Based on those finding, future projection can now be explored as an alternative options in contrast to current problematic mobility system development trend. The summery result of all the data and national statistics can be seen in the figure 28 & 29. This data is also used to project the mobility system scenario of Bhutan.

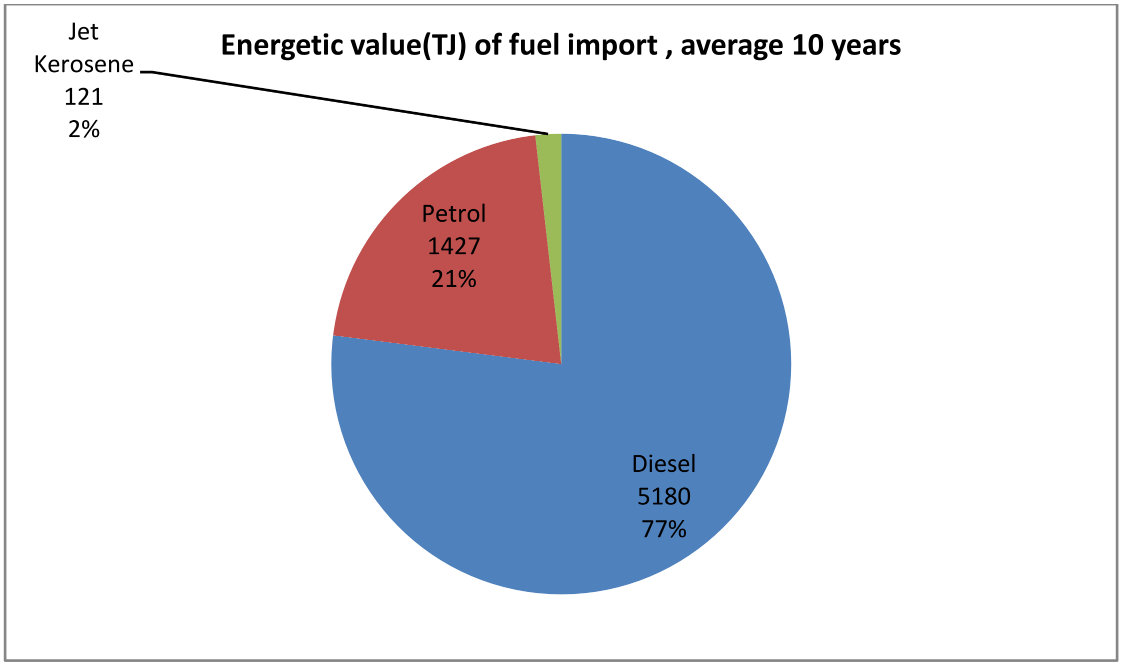


Figure 28: Average national fuel import share since 2009

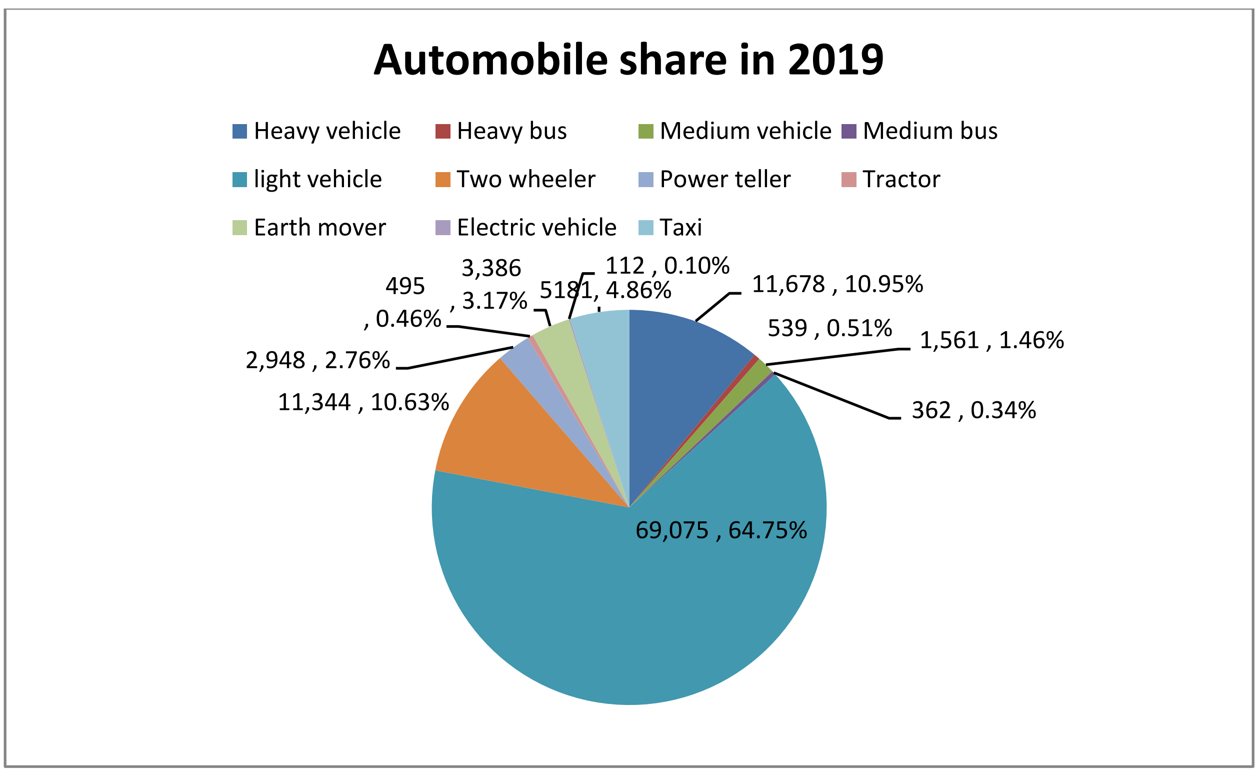


Figure 29: Different type of vehicle in 2019

Figure 28 shows average fuel import share by fuel type in Bhutan since 2008 (refer to table 12 section 4.3 for fuel statistics), which is compiled from NSB data [139], [169], [170]. The current vehicle classification is shown in figure 29, which will be used to estimate the fuel consumption scenario.

The current statistic shows electric car count is only 112 out of 106,681 total vehicles from which 69,075 are light vehicle and mostly run on petrol [189]. To enable the e-mobility growth, Bhutan has a plan to replace 5,181 taxi by electric vehicle, which makes 4% of the total national electric vehicle share and that falls within light duty vehicle category [189]. Vehicle classification of Bhutan is shown in table 29, which is based on vehicle weight [195]. The automobile weighing more than 10 tons is considered as heavy duty vehicle, medium vehicle weight between 3-10 tons and less than 3 tons are classified as light vehicle [195]. On the other hand the passenger vehicle is classified based on weight and passenger capacity. For example passenger capacity of more than 25 people and weighing more than 10 tons are classified as heavy bus, passenger capacity between 13-24 people and weighing between 3-10 tons are considered as medium buses [195]. The taxies fall under light vehicle categories. The automobiles like tractor and power teller are classified as agricultural farm machinery. The two wheelers are not classified, whereas electric vehicle are currently seen as light vehicle.

Table 29: Vehicle classification [195]

Vehicle type	Classification
Heavy	10 ton and above and above 25 passenger buses
Medium	3-10 tons and 13-24 passenger buses
Light	less than 3 tons and passenger upto 12

Figure 29 shows different vehicles types in Bhutan [189]. According to vehicle classification, the vehicle % shares shows, light vehicle is 64.75%, heavy vehicle is 10.95%, two wheeler is 10.63%, taxi is 4.86%, earth mover is 3.17%, power teller is 2.76%, medium vehicle is 1.46%, heavy bus is 0.51%, tractor is 0.46%, medium bus is 0.34% and electric vehicle is 0.11% as shown in figure 29. The fuel mix for this vehicle categories are either diesel or petrol. Since Bhutan's energy supply is 100% based on hydro electricity, the diesel fuel used in transport sector is more or less 100% except for use in backup generator to run emergency power supply during power blackout, which is negligible. Petrol fuel is 100% used for mobility fuel supply. It is also seen that 2% of total fuel demand is accounted for aviation fuel supply. If all petrol vehicles are switched to electric, the net energetic value of fuel share for mobility will remain up to 21%. The fuel shift from diesel to electrical will be used mainly for medium and heavy vehicle including heavy earth moving machineries. The share of fuel demand for heavy and medium vehicle, which mostly run on diesel fuel is approximately 77% as shown in figure 29. However direct use of electricity in heavy vehicles are limited, which need alternative measure. Alternative to such fuel can be hydrogen and Renewable Natural Gas (RNG) or methane as mobility energy storage in future [68]. Based on the above assessment future scenarios can be projected.

5 The variable cybernetics

The variable identification process, the cross-impact analysis and the strategic plot of the variables presented in chapter 3 is a process by which mobility system is defined and this step covers analysis phase of APS [10], [11].The case study of Bhutan reconfirms the empirical evidences concerning variable list and influence factors. The variables show cybernetic behaviour pattern when it is observed from inside and outside of the system. It shows many un-noticed connecting links and they are suitable for imaging the desired vision to enable intended system transformation to sustainable system defined by the critical variables. For example, the variables Mobility service (7), Enabling condition (14) and Economic development (11) occupy the critical region, which are potential system leverage conditions. However, any change in the critical variables is a risky intervention due to many unintended side effect owing to high degree of influence factor to and from other variables, which will have repercussion in the system model if it is not carefully done. This is where the variable's cybernetic and feedback effect play critical role to further analyse as a test model [8], [39].

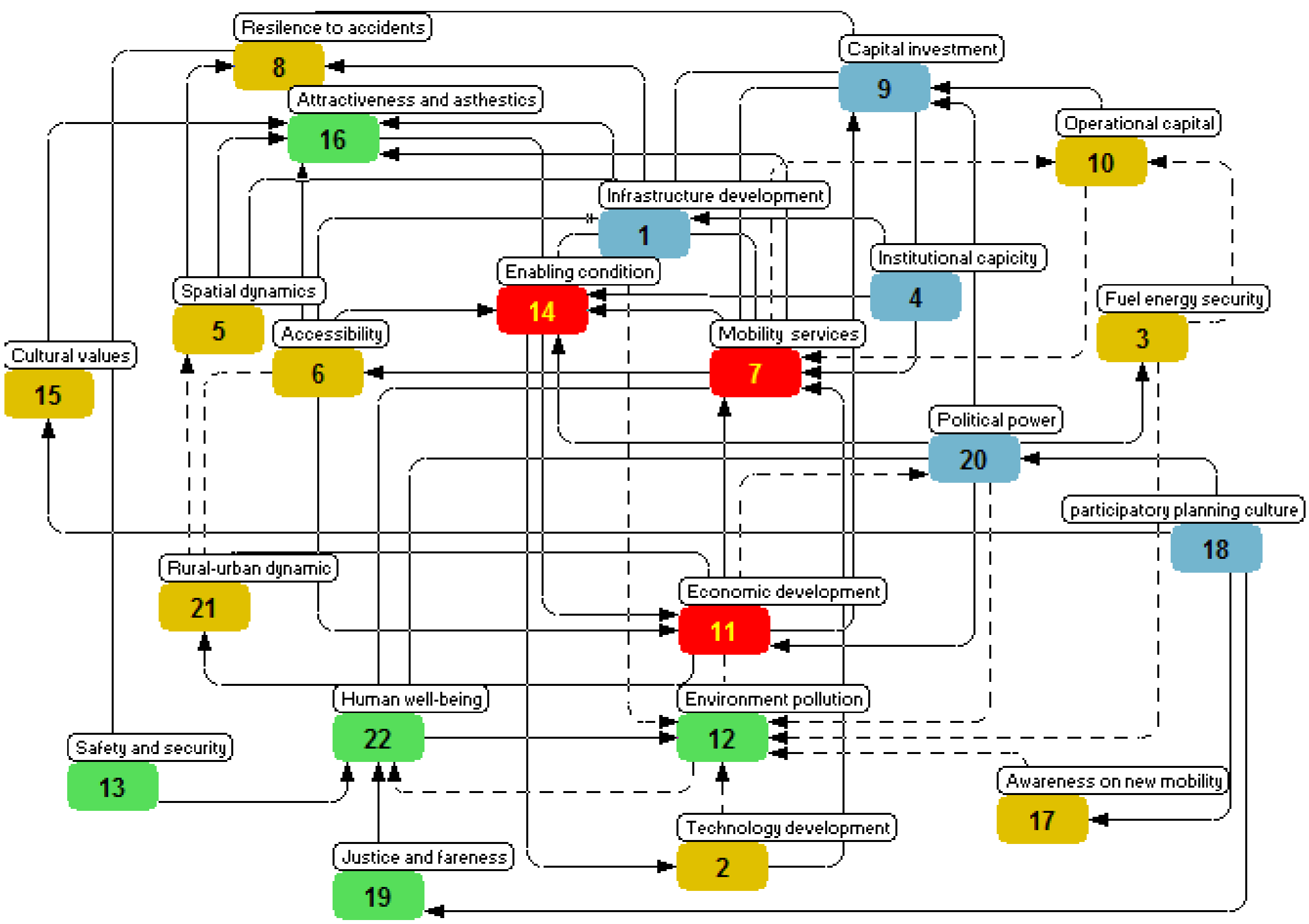


Figure 30: System cybernetic established by the variables, test model construction using Vester Sensitivity Model [39]

The mobility system test model is shown in figure 30, which shows the variables cybernetic effect. The cybernetics of the variables is constructed based on mobility system inquiry with the help of cross-impact analysis in section 3.1.3and the test model is a simplified representation of complete influencing effects [8], [39]. In the test model, the feedback effect can be identified, which will show different scenario fields for their development in the future. The presence of feedback effects show, the system behaves in cybernetic pattern and that indicates the planning complexity for decision making process. Feedback effects are mostly seen in the nature, where auto-correction and growth are controlled by its negative and positive feedback [8], [39]. Negative feedbacks are those cycles that help self-regulation and positive feedback are those that reinforce the growth. The natural system mostly operates on negative feedback, whereas the man-made system needs both positive and negative feedback according to Vester (et al 2007) [8], [39]. In a well-defined stable man-made system, the positive feedback helps to initialize the system functioning and the negative feedback regulates the growth. System stability increases as negative feedback increases [8], [39]. The variables cybernetics exhibit very closely the properties of natural system, when the positive and negative feedback effects are observed, which can be used to describe the self-regulatory dynamics and to define system's future vision based on the theory of feedback effect. Therefore, it can be claimed that the robust system vision can be compared to the nature as a self-regulating and evolving system, which may be called as sustainable system. The service need and built environment is a man-made system, which seems to have not followed the dynamic of natural system and therefore is vulnerable to remain unsustainable [17], [18], [51].Therefore, the man-made system requires heuristic planning process for their success condition [10], [11], [29], [30], [32], [33]. The feedback effect of the system is useful tool for scenario development in the man-made system. The detail analysis of feedback can be observed in the effect system construction shown in figure 30, which is again an iterative process involving heuristic practice that depends on the contextual condition. The analysis of test mobility system model with the preliminary variable list of table 6 and the variables systemic roles in figure 6 shows, there are 119 negative feedbacks and 126 positive feedback cycles (refer chapter 3). This feedback effect identification is very important condition for system to be represented in cybernetic order and to provide negotiable scenario for the desired future vision keeping in mind the transition of mobility system is to be transformed to desirable sustainable system. The detail assessment of the effect system construction will be discussed part by part, which is highly complex and is subject of complex causality among the variables defining the system. Extensive assessment of test model eases an executable planning decision support. The actual executable situation is however outside the scope of this study due to lack of time and financial resources available for further screening, which requires much more time for stakeholder networking and structuring.

The test mobility system model is based on the observer's judgement and in this case the observer have generalised the model based on system analysis represented by figure 6 the mobility system image, table 6 representing cross-impact assessment values and figure 30 representing cybernetic effect system. Figure 30 is alternative way of representation of cross impact analysis, which is very much simplified version and the weak influencing effects are omitted. The cybernetic effect shows dotted and continuous lines with different colour codes. The dotted line shows the opposite influencing effect by the influencing variable to the variable that it gets influenced, whereas the continuous line indicates the equal influencing effect by the influencing variable to the variable that it gets influenced. When these opposite and equal effects are in a closed loop, they give rise to the feedback effect. Odd number of opposite effects give rise to negative feedback and the even number of opposite effects give rise to positive feedback. Similarly, the cycles that contain only equal effect give rise to positive feedback. The presence and absence of these opposite and equal effects define the system's stability [8], [39]. The presence of only equal effect indicates the system is susceptible to collapse at some point of time and therefore it is not sustainable. The presence of only opposite effect shows the system needs initiation, though its development is stable in the further course of time and therefore it is sustainable. More precisely the dominance of opposite effect in the system shows, the system is most likely to be stable [8], [39]. The assessment of the feedback effects are based on the graph theory where the directed graph is considered for construction of test model [131]. The total number of links drawn between the variable is called the network link, which according to Veter (et al 2007) is effect system in Vester Sensitivity Model [8], [39]. The effect system construction is dependent on to the cross-impact matrix data but independent evaluation is done to minimize the possible error. The variables influencing strength determines their construction, which is again a heuristic practice. Therefore, the process of system model construction is an iterative process, which is subject to changes until the satisfactory conclusion is drawn by the involved stakeholders. Based on these fundamental criteria, the total effect drawn between the variables depends on the contextual need. The ratio of total effect to the number of variables present in the system is called the network degree in the graph theory, which is used to describe the system model [131].In the current system model 58 effects are drawn among the variable list in table 6, which shows the network degree of 2.64.With the 2.64 network degree 245 positive and negative feedback effects are established, which can be further screened for contextual need. The detail analysis of the feedback cycles and their development in the future are critical for the test model representing mobility system. This is starting point to define executable model, which may be context dependent for its transition to be sustainable system [8], [10], [11], [17]. The feedback effect is the basis for scenario projection for any system.

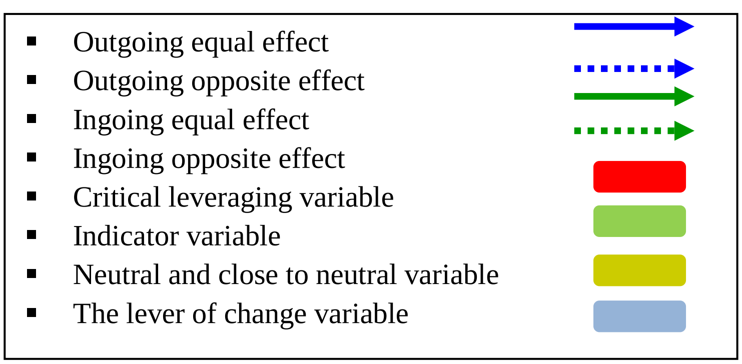


Figure 31: Legend of effect system depicting the influence direction and variable role

The effect system of figure 30 is further explained in detail in section 5.1 with the legend shown in figure 31 for every variable's influencing effect. The detail explanation introduces the influence direction and position of the observer to see the system from different view. The role and goal of the variable changes as the observer position changes in the system. They are critical for understanding the feedback effect and decision support for the design of policy and system planning. The effect system introduces the first step identification process of variable's effect in the system, which is simplified result of cross-impact analysis with possible feedback loop. In the effect system, every effect carries a descriptive reasoning and the influencing effect of the variable to the system and among the variables. Therefore, it is complex analysis for the system test model design, where the unknown connecting threads that are not yet known are recognized [7], [8]. The direction and magnitude of influence of the variable in the effect system determine the development of positive and negative feedback cycles in the system.

The construction of effect system of the variables is based on those values showing the impact matrix in figure 6 in section 3.1.3 (refer chapter 3), where only the direct and strong influences are considered. The influence of the variables is directional, meaning that the influence is possible only in one direction. In the case of variables that tend to influence and will get influence in both the directions, they develop feedback loop. Any change of influencing variable will lead to changes in variable that it gets influenced. The change can be any, the intention of the decision maker to increase or decrease the variable's effect. If the increase in the influencing variable increases the variable characteristics in the variable that it gets influenced, then the effect is called equal effect [8], [39]. Similarly, if the increase in the influencing variable decreases the variable characteristics in the variable that it gets influenced, then the effect is called opposite effect [8], [39]. The effect system therefore has two sets of effects. They are represented by directional line, the outgoing effect, and the other that it gets influenced by the rest of the variables, represented by directional line, the ingoing effect (refer to the legend in figure 31). The opposite effect is represented by dotted directional line and the continuous line shows the equal effect as shown in the legend in figure 31. Different colour code is used to represent the variable role in the system, which is also shown in figure 31, as critical, neutral, leveraging, change lever and indicator. All the variable effect system representation follows the same convention and the legend used in figure 30. In section 5.1 to 5.5 only the critical variables and target variables effect is explained. For more detail on every variable's influencing effect, refer to the annex list at the end.

The critical variables identified from the cross impact analysis are, Mobility service (7), Economic development (11) and Enabling conditions (14). Similarly, the intended target variables are Environment pollution (12) and Human wellbeing (22). The intention of the observer is however not the final conclusion for the successful design of the system. They are subject to further refinement after intensive consultation with the involved stakeholders depending on the context. The mobility system transformation is intended for its transition to sustainable development goal, where environment and social factor play major role. Therefore Environment pollution (12) and Human wellbeing (22) are indented target variables in this study. In section 5.1 to 5.5 the effect systems of these critical and target variables are elaborated, which shows the observer's justification on one to one influence among the variables. The current observation provides an initial stage semantic assessment for the construction of test mobility system model. The test model is generalized version where actual condition can be built from this effect system of the test model by further assessing the real world scenario.

5.1 The effect system of mobility service

The variable, Mobility service (7) is positioned in the critical region in the variable's systemic role in the system image in figure 6 (refer to chapter 3). Therefore, Mobility service (7) has the potential to leverage the system, which is however very risky intervention if not controlled with the feedback measures using other system variables and their influence factor.

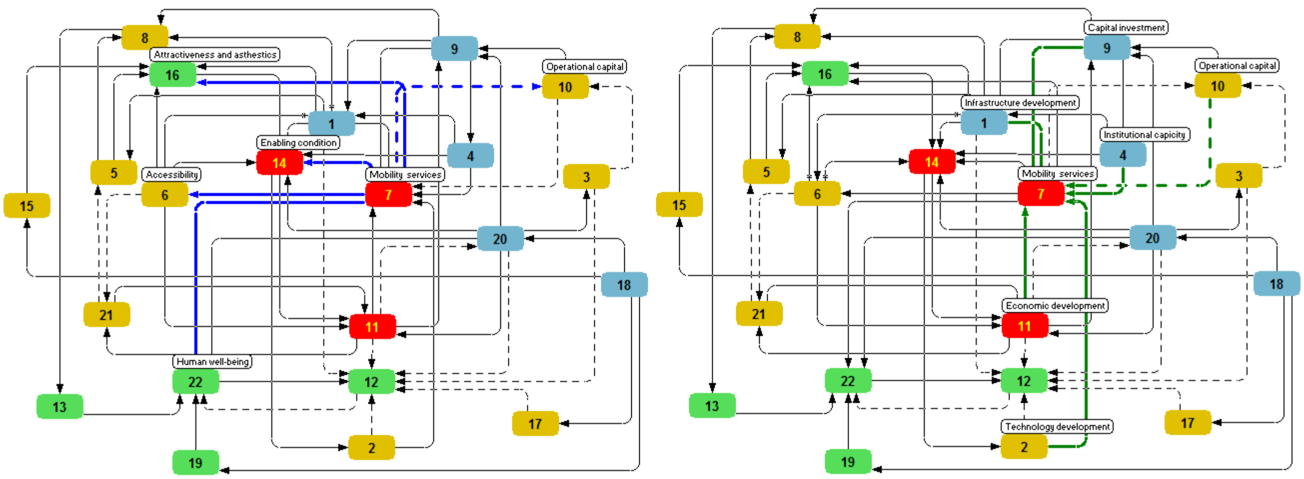


Figure 32: Effect system of mobility service

In the current case the intention of the observer is to leverage mobility system to sustainable development by intervening the variable, Mobility service (7), which is made to influence the variables, Human wellbeing (22), Accessibility (6), Enabling condition (14), Operational capital (10) and Attractiveness and aesthetics (16).The Variable Mobility service (7)is however influenced by, Infrastructure development (1), Technology development (2), Institutional capacity (4), Capital investment (9), Operational capital (10) and Economic development (11) as shown in figure 32. The following can be seen from the effect system of the leveraging variable Mobility service (7).

- $7 \rightarrow 6$ is an effect between Mobility service (7) and Accessibility (6). The alternative options for mobility function, which is based on service development rather than that of product, has the potential to value add to Accessibility (6) for the movement of people and goods alternatively. Therefore, increase in service decreases the need of ownership and increases the functional value of mobility products for motorization, which has the potential to increase the Accessibility (6). Thus, increasing or decreasing the movement function of product consumption to service consumption proportionally increase or decrease the Accessibility (6), which is an equal effect.
- $7 \rightarrow 10$ is an effect between Mobility service (7) and Operational capital (10). Increasing the functional value of mobility product by increasing the usage frequency and by more users has the potential to

increase economy of scale for a single product distributed to different function and consumer categories. Therefore, increase in mobility service (7) has the potential to decrease the daily mobility cost of people and goods. Hence increasing Mobility service (7) decreases the Operational capital (10), which is an opposite effect.

- $7 \rightarrow 14$ is an effect between Mobility service (7) and Enabling condition (14). Availability of multiple services from a single mobility product or technology has the potential to enable diversity and flexibility, which makes the movement function a normal daily service. The increased service of single product increases the enabling environment for user decision support, where availability of diversity and variety play a critical role. Therefore, increasing or decreasing the Mobility service (7) proportionally increases or decreases the Enabling condition (14), which is an equal effect.
- $7 \rightarrow 16$ is an effect between Mobility service (7) and Attractiveness and aesthetics (16). Availability of variety and diversity has the potential to increase the quality, which is dependent on to the service sector development for mobility need for both people and goods movement. The diversity and variety increases competitiveness, which has the potential to decrease the cost. The availability of reliable service is also the key to consumer behaviour change. Therefore, increasing or decreasing the Mobility service (7) proportionally increases or decreases the Attractiveness and aesthetics (16), which is an equal effect.
- $7 \rightarrow 22$ is an effect between Mobility service (7) and Human wellbeing (22). Availability of multiple options, easy and comfortable mobility is one way to improve the living condition. The easy and comfortable mobility option has the potential to enable better access to healthcare for sick people and education for children. Similarly, better Mobility service (7) has the potentials to increase easy access to the daily consumables. Furthermore, easy and convenient mobility service opens a greater degree of social interaction, where visit to friend and family increases. Therefore, diversifying the motorization by use of minimum resources has the potentials to increase the living conditions. Hence increase or decrease in Mobility service (7) proportionally increases or decreases the Human wellbeing (22), which is an equal effect.
- $1 \rightarrow 7$ is an effect between Infrastructure development (1) and Mobility service (7). Although it is desirable to increase quality mobility service consumption instead of product ownership to fulfil the mobility need for the movement of people and goods, their development strongly depends on the availability of relevant infrastructure. Therefore, the infrastructure that enables the shift from product consumption to service consumption is critical. Hence increasing service centric Infrastructure development (1) has the potential to increase the development of more Mobility service (7), which is an equal effect.

- $2 \rightarrow 7$ is an effect between Technology development (2) and Mobility service (7). Availability of quality Mobility service (7) depends on relevant technical support to ease the service development. New and alternative mobility technologies that are developed to fulfil the consumer desire to consume the service instead of technology product have the potential to leverage the transition of mobility industry from delivery of service instead of product to the consumer. Thus, innovation in Technology development (2) has the potential to change the consumer behaviour. Therefore, increasing or decreasing the Technology development (2) proportionally increases or decreases the Mobility service (7) availability, which is an equal effect.
- $4 \rightarrow 7$ is an effect between Institutional capacity (4) and Mobility service (7). Availability of quality Mobility service (7) and the management of the services strongly depend on the role played by the relevant institution to monitor the performance of the service rendered to the consumer by the service provider independently. The performance monitoring requires both technical and management capabilities of the institution responsible for it. Therefore, development of Intuitional capacity (4) further enhances the Mobility service (7). Thus increase or decrease in Institutional capacity (4) proportionally increases or decreases Mobility service (7), which is an equal effect.
- $9 \rightarrow 7$ is an effect between Capital investment (9) and Mobility service (7). The development of mobility as service industry is strongly influenced by the initial Capital investment (9) for service procurement, advertisement, and human resource development for the service function management and initial know how skill sets development. Therefore, it is an investment decision, which will impact on the development of Mobility service (7) industry to fulfil the mobility need for both people and goods. Therefore, increasing the shift from investment decision for service development rather than promoting the mobility product consumption, proportionally increases or decreases the Mobility service (7) development, which is an equal effect.
- $10 \rightarrow 7$ is an effect between Operational capital (10) and Mobility service (7). The development of Mobility service (7) industry is strongly influenced by the existing mobility product-oriented ownership culture, whose transformation depends on competitiveness. Better quality of service depends on higher cost of operation, which has the potentials to weaken the competitiveness. Therefore, increase in Operational capital (10) decreases the consumer preference to opt for the Mobility service (7). Hence increase in Operational capital (10) decreases the Mobility service (7) development, which is an opposite effect.
- $11 \rightarrow 7$ is an effect between Economic development (11) and Mobility service (7). The development of Mobility service (7) industry is influenced by the market availability and consumer preference, which is strongly dependent on the external factor Economic development (11). Mobility function remains inevitable for the Economic development (11). Strong economy demands more mobility need for daily

transaction and logistics flows, where mobility functional cost for both people and goods is important aspect to be considered, which is one of the operational costs for economic performance indicator and will have critical role to play concerning cost optimization. Therefore, better and growing economy, when it opens to the new market for Mobility service (7) industry development, the external influence pushes for the service demand. Hence increase or decrease in Economic development (11) proportionally increases or decreases the Mobility service (7) industry development, which is an equal effect.

The variable Mobility service (7) is a global variable with many indicators defining its role as global mobility system variable, which seems to be system leveraging variable, is subject to many un-intended side effects. In the above list, the one to one effect of Mobility service (7) can be easily analysed and to the greater detail depending on the context, but they still fail to provide complete system image. Even if all the details are reduced to simple solution space for decision support from one to one influence, the side effect is mostly seen in future, when the plan is executed. Therefore, for early correction of the side effects, the network of influencing effects contained in the basic one to one effect needs to be considered for robust system design. The robust assessment can only be seen from the feedback effect developed by the one to one influencing effect, which will be further discussed in section 5.6, the system feedback effect.

5.2 The effect system of economic development

The variable Economic development (11) is an external influence factor for the development of mobility system. The variable Economic development (11) is positioned in the critical region. Therefore Economic development (11), although influences the mobility system from outside, is a critical system variable that has strong system leveraging potentials. The inclusion of Economic development (11) in mobility system planning, unfolds many unknown problem space, which is often time overlooked. The variable Economic development (11) influences other mobility system variables such as; Mobility service (7), Capital investment (9), Environment pollution (12), Political power (20) and Rural-urban dynamic (21), whereas it is influenced by the mobility system variables, Accessibility (6), Enabling condition (14), Political power (20) and Rural-urban dynamic (21). The leveraging variable Economic development (11) overlaps with the variable that it influences, and is influenced by other system variables, which will be discussed further in the feedback effect in section 5.6. Same applies to all the other system variable effect systems. Although it appears the influence factor overlap and seem to repeat, they show unique behaviour if it is observed from different positions of the variable.

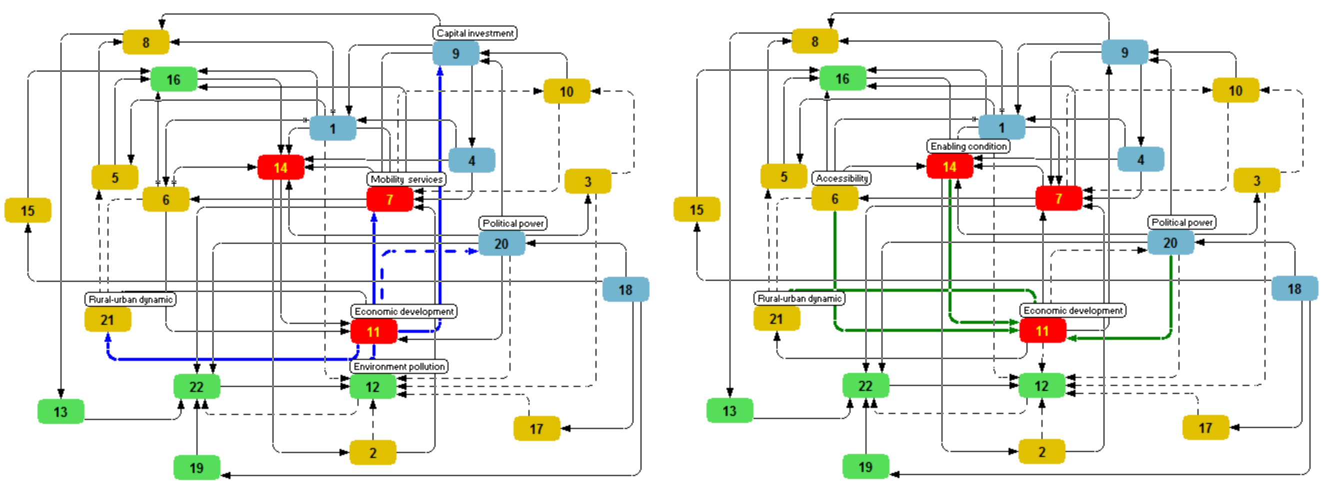


Figure 33: effect system of economic development

The economic system and mobility system are inseparable as both the system exhibit mutual interdependency for the system functioning. The following can be seen from the effect system of Economic development (11) as shown in figure 33.

- $11 \rightarrow 7$ is an effect between Economic development (11) and Mobility service (7). While the choice of economic system determines the type of mobility system, the Mobility services (7) for any economic activities are inevitable. The types of economic system determine the need for mobility of people from different place to carry out economic activities. The goods and service production centre will influence mobility need and settlement pattern of people, which will strongly impact the mobility orientation.

Similarly, the supply of goods and services to the consumer to different locations further determines the mobility requirements to enable the consumer needs. Therefore, the source of consumption and origin of consumables will strongly influence the mobility needs. The Economic development (11) determines the source and origin of the consumables and the consumer. Optimizing the Economic development (11) trend to reduce the mobility requirement, for example the service orientated economy, will proportionally reduce, the need of Mobility service (7), which is an equal effect.

- $11 \rightarrow 9$ is an effect between Economic development (11) and Capital investment (9). The sources of capital assert and financial capital is strongly dependent on the strength of economy. Powerful economy has greater strength to make the availability of capital resources. For the development of good mobility system, the availability of capital resources both in terms of financial capital and human resources are critical. The development of financial and human resources strongly depends on the Economic development (11). Therefore, increase in Economic development (11) has the potential to increase the mobility capital financing and human resources development that increases the Investment capital (9) in general, which is an equal effect.
- $11 \rightarrow 12$ is an effect between Economic development (11) and Environment pollution (12). The better economic growth also has direct impact on the natural capital such as land, air and water. The growth of economy potentially tends to increase exploitation of natural capital. Additionally, the current trend of linear economic growth and increased consumerism decreases the ability of natural capital to replenish easily. On the other hand, increased Economic development (11) pushes for increased need of mobility system to support their growth. Therefore Economic development (11) has negative effect on environment unless alternative resilient economy is adopted. Hence Economic development (11) increases the need of mobility system and thus decreases the natural capital to replenish easily leading to more Environment pollution (12). The positive growth of economy has negative impact on Environment pollution (12), which is an opposite effect.
- $11 \rightarrow 20$ is an effect between Economic development (11) and Political power (20). Economic growth strongly influences the need for mobility thereby weakening the control condition especially the political decision on de-growth requirement. Furthermore, in a strong economy where consumerism is pre-dominant, the political participation is weakened, which has the potentials to push further the economic growth leading to increased need of mobility. The uncontrolled economic growth has the potentials to push the consumerism habit of the people further. Therefore, liberal Economic development (11) has the potential to weaken the Political power (20), which is an opposite effect.
- $11 \rightarrow 21$ is an effect between Economic development (11) and Rural-urban dynamic (21). The choice of people to opt for quality life depends on availability of good jobs and different services for livelihood conditions. The economic growth has the potentials to enable the availability of more jobs and livelihood need. However, the current trend of job availability and livelihood need are perceived to have

developed in the urban environment. The availability of job is dependent on the Economic development (11) and in the current situation it is mostly seen to be in urban area, which is encouraging the rural population to migrate from rural to urban region, especially the young generation in search of job. The concentration of Economic development (11) in urban area has the potential to increase the migration of rural population further to urban environment. The consequence is increase in Economic development (11) in urban area, which increases the population migrating from rural area. Therefore, the current trend of Rural-urban dynamic (21) potentially increases the Economic development (11) unless the control measures are in place to reverse the trend, which is in either direction an equal effect.

- $6 \rightarrow 11$ is an effect between Accessibility (6) and Economic development (11). While the economic growth has the potential to demand more mobility need, the access to mobility system determines the growth of economy. The access to mobility system has the potential for increasing the balanced regional economic growth that has the potential to gross economic value addition. Therefore, the access plays a critical role in economic decentralization. Hence increasing the Accessibility (6) has the potential to balance the economic growth and the access to consumables from multiple source of origin. The availability of diversity and multiple options for consumable has the potential to value add on the gross economy. Thus, increasing or decreasing the Accessibility (6) proportionally increases or decreases the Economic development (11), which is an equal effect.
- $14 \rightarrow 11$ is an effect between Enabling condition (14) and Economic development (11). The alternative options for de-growth development strongly depend on the control conditions. The control conditions influence the behaviour of the consumer. Therefore, not enabling the current economic growth trend and shifting to more resilient economy strongly depend on good enabling environment both economically and politically. Thus, better Enabling condition (14) by design of new control policy has the potential to revalorize the current economic growth trend. Revalorized economic growth trend has the potential to decrease the need of motorized mobility system. Thus, creating good Enabling condition (14) has the potential for de-growth fulfilment of current Economic development (11), which is an equal effect.
- $20 \rightarrow 11$ is an effect between Political power (20) and Economic development (11). While the economic growth has strong influence on the control of political decision, the growth by itself depends on the people's participation. The economic growth initially shows the better livelihood condition but has repercussion effect if not controlled, which lead to increase inequalities and disparity in the society. The increased inequalities and disparity push further the status symbol, which is common trend in the current mobility system development. The inequalities and disparities have the potential for increasing the people's participation in the political system. Thus, increased participation increases the potential for alternative and resilient economy development that also has the potential for removing the status symbol for the need of mobility luxury. Thus, the control by Political power (20) increases development of

alternative economic system. Hence the increase in Political power (20) increases the Economic development (11), which is an equal effect.

- $21 \rightarrow 11$ is an effect between Rural-urban dynamic (21) and Economic development (11). While economic growth influences the migration of people from rural area to urban area, the reverse trend is equally possible if control measures are applied. The urban growth increases the competitiveness, which has the consequence of increased cost of living. Further the uncontrolled urban growth creates the space limitation, which adds to increased living cost and congestion. Although the urban development potentially facilitates economic growth, the cost of economic growth is proportional. The cost of centralized economic growth is shared by the consumer, which will impact the living cost and thereby the shift of urban-rural migration is potentially possible. Urban-rural migration depends on good access to jobs which depend on the Economic development (11). Therefore, reverse trend though not easy is critical for the development of resilient livelihood condition. The reverse trend of Rural-urban dynamic (21) increases with the shift of growth model to decentralized and regional economy, which is desirable for de-growth need. These external influences strongly influence the mobility system development. Increased reverse trend of Rural-urban dynamic (21) is dependent on increased decentralization and regional Economic development (11), which is an equal effect.

To an observer the economic system appears to be much more complicated variables for the design of sustainable mobility system. The economy defines the life style of the people and therefore relevant mobility system requirement is fully dependent on to the behaviour of people, which is dependent on the existing economic characteristics. The urbanization trend for example is systemic property with business goal, which can be easily dismantled if robust decentralization is implemented. From the analysis of one to one effect, it indicates many innovative economies can be created but they do not fully show the side effect of those developments, which require much deeper investigation. The side effect can only be possible with the feedback identification, which will be further discussed in section 5.6.

5.3 The effect system of environment pollution

The variable Environment pollution (12) is positioned in the reactive region in figure 6 (refer to chapter 3). The variable Environment pollution (12) is strong system indicator, which depends on the development of other system variables. The system indicator variables are those variables that potentially do not influence the development of other system variables. Environment pollution (12) is a variable that does not influence easily other variables but it depends on their development. However, the variable Environment pollution (12) influences the Human wellbeing (22) as they are required to mutually co-exist for the system transition to sustainable development. The other variables such as; Infrastructure development (1), Technology development (2), Fuel energy security (3), Awareness on new mobility (17), Political power (20) and Human wellbeing (22) influence the change of variable Environment pollution (12) as shown in figure 34.

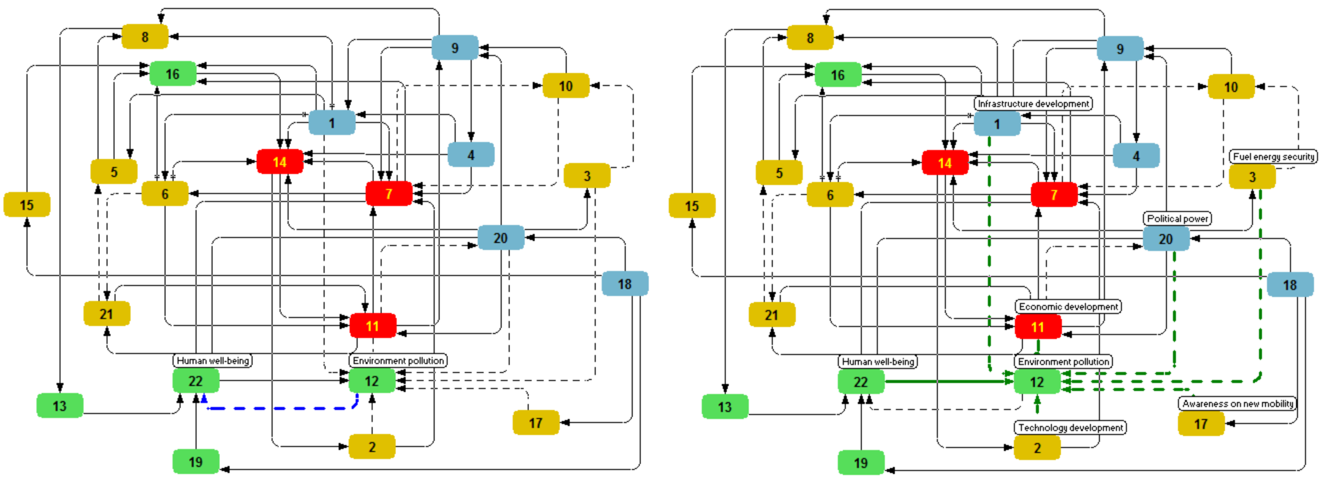


Figure 34: Effect system of environment pollution

The variable Environment pollution (12) is a potential target variable for mobility system's vision definition, which can be used to measure system performance. The following effect can be seen from the effect system of Environment pollution (12).

- $12 \rightarrow 22$ is an effect between Environment pollution (12) and Human wellbeing (22). Good air quality has direct impact on human health. Mobility system is partially responsible for air pollution in both urban and rural environment. Increased level of air pollution has direct effect on climate change, which is a global problem and threatens the human survival. Therefore, the target to reduce air pollution from mobility system potentially increases human health. Health is a strong indicator for the quality and happy life. Therefore, decreasing Environmental pollution (12) increases Human wellbeing (22), which is an opposite effect.

- $1 \rightarrow 12$ is an effect between Infrastructure development (1) and Environment pollution (12). Defining a goal to reduce Environment pollution (12) potentially influences the design and development of infrastructure that is more resilient to environment. The resilient infrastructure influences the mobility behaviour of people and mobility requirement for the movement of goods and services. Therefore, environmental consideration as a priority target will have major impact on the development of resilient mobility infrastructure rather than priority target setting for infrastructure development that enables more motorization. More non-motorized infrastructure tends to develop when Environment pollution (12) control is a primary goal. Thus, increasing environment friendly mobility Infrastructure development (1) decreases Environment pollution (12), which is an opposite effect.
- $2 \rightarrow 12$ is an effect between Technology development (2) and Environment pollution (12). Defining the goal to decouple mobility Technology development (2) from Environment pollution (12) will have strong impact on current trend of motorization. The first priorities of non-motorization strongly influence the development of mobility system that will potentially remain independent to technical solution for movement function. Even if the needs of technology are inevitable, the development of new and alternative mobility technology tends to dominate the mobility services. Therefore Environment pollution (12) reduction as a target goal has the potential to re-orient the technology innovations that are resilient to environment. Thus, increase in alternative Technology development (2) decreases the Environment pollution (12), which is an opposite effect.
- $3 \rightarrow 12$ is an effect between Fuel energy security (3) and Environment pollution (12). Setting target to increase Fuel energy security (3) to reduce the Environment pollution (12) will have major reforms regarding the decision on the fuel price and tax system. The availability of quality fuel determines the emission reduction potential and the choice for alternative source influences the security of supply. Therefore, increasing Fuel energy security (3) potentially decreases the use of fossil fuel, which is the main source of emission and the Environment pollution (12). Hence increase in Fuel energy security (3) decreases the Environment pollution (12), which is an opposite effect.
- $11 \rightarrow 12$ is an effect between Economic development (11) and Environment pollution (12). The influence of external factor Economic development (11) on Environment pollution (12) will have strong influence on mobility system development if goal of economic growth is to decouple Environment pollution (12). Decoupling economic growth from Environment pollution (12) strongly discourages the material and energy intensive mobility development for economic growth. Therefore, decoupling economic growth from environment address the de-growth need, which has the potential to reduce Environment pollution (12). However economic growth is inevitably linked to development that is material and energy intensive, which increases Environment pollution (12). Hence positive Economic development (11) has negative impact on Environment pollution (12), which is an opposite effect.

- $17 \rightarrow 12$ is an effect between Awareness on new mobility (17) and Environment pollution (12). The communication as change enabler is critical for informing user for the choice of mobility that is available. Lack of knowledge is often time seen as communication gap, which is strong component for user behaviour change. Although many different technical and service-oriented mobility options are available these days, they are not fully known by many users. Therefore Awareness on new mobility (17) strongly influences the goal definition and consumer behaviour orientation to new availability. Increase in Awareness on new mobility (17) has the potential to trigger the behaviour change of consumer towards more environment friendly mobility options, which decreases the Environment pollution (12). The increase in Awareness on new mobility (17) decreases the Environment pollution (12), which is an opposite effect.
- $20 \rightarrow 12$ is an effect between Political power (20) and Environment pollution (12). The political commitment strongly influences the environment protection and therefore the mobility system, which is critical considering the uncertain social acceptability for alternative mobility options that are available. Setting environmental target especially the action to climate change mitigation will strongly influence the development of new and alternative mobility option. Further the political decision strongly depends on the power of ruling government to control the reforms in the national policy and target setting. Thus, strong and stable Political power (20) has the potential to align mobility system development that is more environment friendly, which potentially decreases the Environment pollution (12). Therefore, increase in Political power (20) decreases the Environment pollution (12), which is an opposite effect.
- $22 \rightarrow 12$ is an effect between Human wellbeing (22) and Environment pollution (12). The duality of consumerism and de-growth need is strongly dependent on goal definition, which can be mobilized through middle path goal, where Human wellbeing (22) and Environment pollution (12) are balanced. Increase in Human wellbeing (22) has the potential to increase the consumerism behaviour, where luxury and ownership trend tend to dominate the mobility system development, which is not desirable considering the current state of the environmental health. Increasing Human wellbeing (22) without the limit condition will lead to increased use of natural capital, which increases the Environment pollution (12). Therefore, increase Human wellbeing (22) increases the Environment pollution (12), which is an equal effect.

Environment pollution (12) as a mobility system variable acts as system control and mostly leads to development of opposite effect. The opposite effect has the potential to enable system self-regulatory dynamic, which can however be seen as a chain of influencing effect in feedback effect that will be elaborated in section 5.6.

5.4 The effect system of enabling condition

The variable Enabling condition (14) is positioned in the critical region in figure 6 (refer to chapter 3). The variable is a subject of collective agreement, which will define the intention of the observer for system transformation to sustainable development. The national policies and strategies will define the variable's role as strong system leverage condition. The variable Enabling condition (14) strongly influences Technology development (2) and Economic development (11), which actually determines the development of mobility system. Enabling condition (14) however depends on other system variables such as Infrastructure development (1), Institutional capacity (4), Accessibility (6), Mobility service (7), Attractiveness and aesthetics (16) and Political power (20).

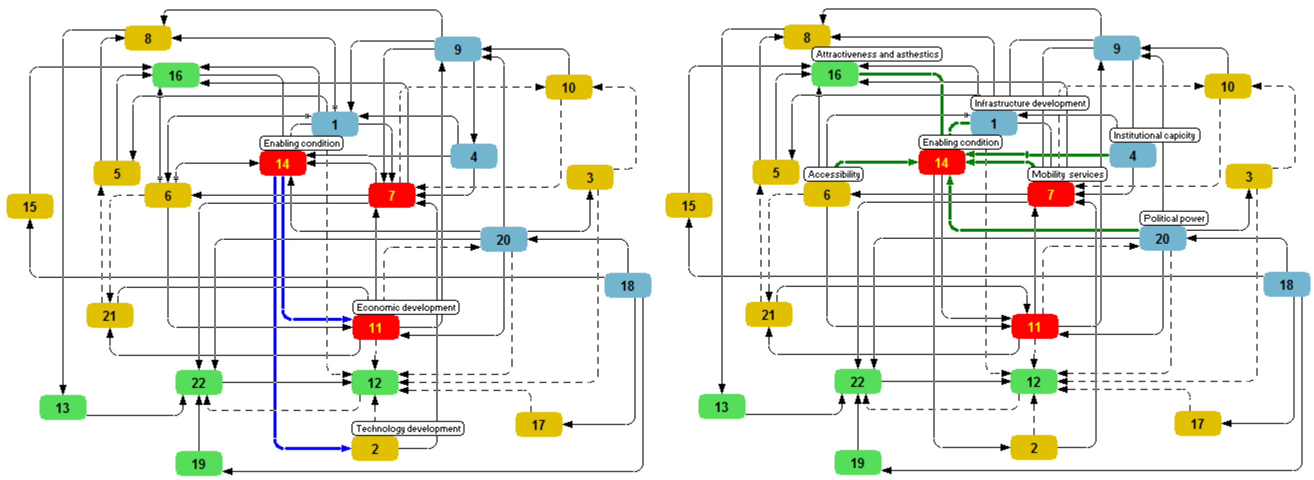


Figure 35: effect system of enabling condition

The variable Enabling condition (14) is a soft but strong control lever of the system for goal definition. It is a complex process for common agreement to align mobility system to sustainable development, where many interconnected effects need to be considered. Following are one to one effects of Enabling condition (14)

- $14 \rightarrow 2$ is an effect between Enabling condition (14) and Technology development (2). The enabling policy for the rollout of alternative technologies are necessary as the new development is always faced with the challenge of market monopoly and the built infrastructure that it is not so easy for the penetration of new alternatives in the existing system. The control of technology development is depending on the need assessment, which is strongly influenced by the control condition, where consumer requirement is properly taken care. The mobility technologies are those that attempt to ease the movement function by motorization. Creating more Enabling condition (14) for motorization potentially increases the Technology development (2). On the other hand, uncontrolled technology development tends to push further the system growth requirement, which is not the desired vision for sustainable development of the mobility system. Therefore, growth minimization and optional Enabling condition (14) has the potential to increase the alternative to fossil fuel Technology development (2), which is an equal effect.

- $14 \rightarrow 11$ is an effect between Enabling condition (14) and Economic development (11). The control of external influence factor Economic development (11) is necessary for desirable mobility system development. The free and liberal conditions are key element to competitiveness for the economic growth, where the quality control is determined by the competitiveness. However uncontrolled growth has the potential to increase the consumerism, which is fully dependent on the economic development trend. Increased economic growth increases the demand for more mobility requirement if not carefully monitored. Therefore, good Enabling condition (14) potentially increases the Economic development (11), which is desirable to some extend but not beyond the required need. Hence increase and decrease of Enabling condition (14) has proportional effect on the Economic development (11), which is an equal effect.
- $1 \rightarrow 14$ is an effect between Infrastructure development (1) and Enabling condition (14). Although soft leveraging variable Enabling condition (14) is critical for the control of mobility system as a whole, it strongly depends on availability of relevant Infrastructure development (1), which has the push pull effect. Defining the Infrastructure development (1) policy that aligns to sustainable development of Infrastructure development (1) has the potential to optimize the Enabling condition (14). Therefore, resilient Infrastructure development (1) potentially depends on the policy support that creates Enabling condition (14), which is an equal effect.
- $4 \rightarrow 14$ is an effect between Institutional capacity (4) and Enabling condition (14). Although soft leveraging variable Enabling condition (14) is necessary for the system to function as desired, it strongly depends on the availability of competent human resources. On the other hand, the human resource development is strongly influenced by the need to optimize skill capacity. Therefore, the influence of Institutional capacity (4) determines the initial goal or the target definition of the system, where the needs of relevant skill sets are identified. Increasing the Institutional capacity (4) through relevant policy support creates Enabling condition (14) that supports the need criteria, which are subject to the goal and target setting on contextual basis. Therefore, increase in the Institutional capacity (4) potentially increases the Enabling condition (14) that supports holistic system goal definition. Hence the influence is an equal effect.
- $6 \rightarrow 14$ is an effect between Accessibility (6) and Enabling condition (14). The mobility access plan/design/policy for mobility need influences strongly the Enabling condition (14). However, it depends on the need assessment that enables the access requirement. Therefore Accessibility (6) depends on the guiding policy. Access to different services can only be optimized with strong enabling support conditions. The current mobility system is faced with the challenge of lack of equitable access

to mobility services to different population categories that will require strong policy support, which creates an Enabling condition (14). Thus, increase in Accessibility (6) through regulatory intervention potentially increases the Enabling condition (14), where the enabling condition requires appropriate and unbiased access need assessment. Hence, increase in policy supporting the Accessibility (6) creates increased Enabling condition (14), which is an equal effect.

- $7 \rightarrow 14$ is an effect between Mobility service (7) and Enabling condition (14). The choice for mobility product or service consumption depends on the availability of either of them. The current trend of mobility system development dependent on mobility product consumption, where the ownership culture dominates the consumer behaviour. The desired mobility system aims to increase Mobility service (7) development, which is dependent on the policy supporting them that creates the Enabling-condition (14). The development of service curtails the inclusion of strong policy that enables the service development, where quality service requirement by the consumer remains unchanged. The influence of leveraging variable Mobility service (7) and influenced variable Enabling condition (14) require independently separate goal definition for their development. The variables open an alternative goal option on a contextual basis. Increase in Mobility service (7) proportionally increases the Enabling condition (14), whereas the reverse conditions are applicable depending on the contextual need. The influencing factor generates uncertainty condition for decision support, which needs careful consideration including the feedback effect. In any case the influence is equal and therefore they exhibit an equal effect.
- $16 \rightarrow 14$ is an effect between Attractiveness and aesthetics (16) and Enabling condition (14). Attractiveness and aesthetics (16) determine the user reaction on the availability of convenient mobility options. The convenient mobility option for people and goods are the desired dream and wishes of the user, which is depended on to availability of quality mobility services. The quality of the service is defined by the user centric service development. In the current trend of mobility system development, the status symbol of owning the mobility product dominates to fulfil the same mobility function especially for the movement of people. De-coupling the ownership culture strongly depend on Enabling condition (14) with relevant supporting policies that has the potential to remove the stigma of mobility product ownership as status symbol. Increasing Attractiveness and aesthetics (16) has the potentials to de-couple the current trend of mobility product consumption by the user that create Enabling condition (14) to shift the consumer behaviour. Therefore, increase in Attractiveness and aesthetics (16) increases the Enabling-condition (14) to de-couple mobility product ownership culture, which is an equal effect.
- $20 \rightarrow 14$ is an effect between Political power (20) and Enabling condition (14). The external and internal influence factor Political power (20) strongly influences the Enabling condition (14) requirement for the development of desirable mobility system, which depends on power structure and regulation. However, the goal definition of the system that creates Enabling condition (14) is critical.

The political support is necessary for the control condition, where reforms in mobility system policy and regulation will potentially control the development of desirable sustainable development vision. The strength of stable and strong Political power (20) will potentially create strong Enabling condition (14) for the development of desirable mobility system policy. Hence increase in Political power (20) increases the Enabling condition (14), which is an equal effect.

The variable Enabling condition (14) is a complex and contextual power dependent, which can actually control rest of the mobility system variable development. This is where linear and biased control condition is mostly seen in the design of mobility system. The Enabling condition (14) is critical for system target and vision setting. However, they are overlooked and the real contextual need is often undermined for holistic system design. Although the power plays critical role, the power itself is dependent on many other systems. Therefore, for the power struggle it requires participatory approach, where holistic world view is critical. The effect system construction indicates that the Enabling condition (14) has different role to play, when observer shifts its position from one variable to the other. The complete system influence and side effect is still missing in one to one effect, which can be seen from the feedback effect in section 5.6.

5.5 The effect system of human wellbeing

It is the intention of the observer to enable mobility system to sustainable system development, where human agency plays a critical role for that target intention. The complex dimension of sustainable development is resting on the so called human factor, which can neither be analysed nor easily changed. Therefore, Human wellbeing (22) is considered to be a system indicator. The variable Human wellbeing (22) expresses the mobility need to fulfil quality of life, which is an important system indicator. The variable Human wellbeing (22) is positioned in the reactive region in figure 6 (refer to chapter 3).The variable Human wellbeing (22) is therefore a target variable, which can be an ideal condition for defining mobility system vision, where the desired mobility system that expresses the dream and wishes of the user can be addressed. The variable Human wellbeing (22) does not easily influence other system variables but is mostly dependent on them. However, the dream for quality of life influences Environment pollution (12), which is where the push and pull factor or growth and de-growth is relying on. On the other hand, Human wellbeing (22) depends on almost all the mobility system variables and the direct one that influence quality of life are, Mobility service (7), Environment pollution (12), Safety and security (13), Justice and fairness (19) and Political power (20).

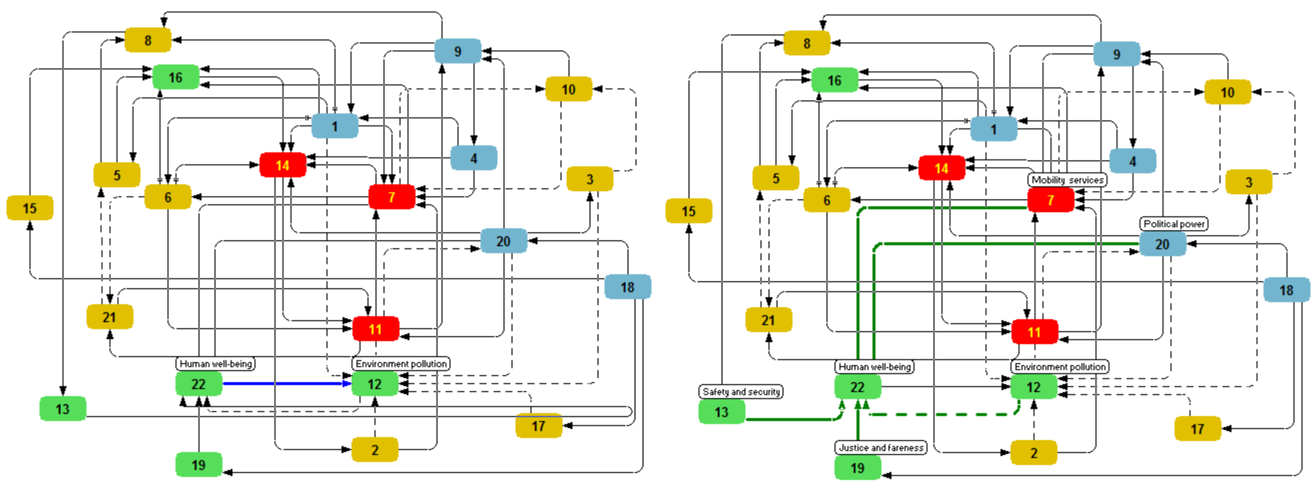


Figure 36: effect system of human wellbeing

The effect system of Human wellbeing (22) is an intended target variable for mobility system vision definition, which is context dependent. The following can be seen from the effect system of Human wellbeing (22) as shown in figure 36.

- $22 \rightarrow 12$ is an effect between Human wellbeing (22) and Environment pollution (12). Human wellbeing (22) is an aspiration that expresses the need for better quality of life. The basic philosophy of better quality of life is influenced by those conditions that fulfil the need of the body and the desire of the mind. They fundamentally depend on individual, community, society, organization and built environment. Mobility system is among many others, the built environments that influence the quality of life. The need of built environment for movement function to fulfil the aspiration of people is unlimited, which directly influences limited natural capital, the surrounding environment. Thus, increasing Human wellbeing (22) by promoting uncontrolled desire and wishes to enable movement function increases the consumerism behaviour especially the motorization trend, which causes exploitation of the natural capital found in the environment. Hence the motorization trend that increases the consumerism habit of people in the pretext of increasing Human wellbeing (22) has the potential to increase Environment pollution (12), which is an equal effect.

- $7 \rightarrow 22$ is an effect between Mobility service (7) and Human wellbeing (22). While the Mobility service (7) influences the quality of life, it strongly depends on the limit condition and the desired mobility requirement for the functioning of social system. Therefore, enabling Mobility service (7) by defining the systemic goal that addresses Human wellbeing (22) is critical. Mobility service (7) has the potential to take any form if not controlled leading to behaviour change of the user for the basic movement function, which will impact quality of life. Thus, increase in Mobility service (7) in general increases the Human wellbeing (22), which is an equal effect.
- $12 \rightarrow 22$ is an effect between Environment pollution (12) and Human wellbeing (22). The availability of good quality air, water and land will have direct influence on the Human wellbeing (22). The need for better quality of life however depends on basic requirement for movement activities, which will fulfil all the daily needs. On the other hand, increasing dependency on motorized mobility behaviour for daily activities especially based on ownership culture as status symbol is not sustainable approach. The consequence of increased motorization potentially increases the Environment pollution (12). Thus, increase in Environment pollution (12) decreases Human wellbeing (22), which is an opposite effect.
- $13 \rightarrow 22$ is an effect between Safety and security (13) and Human wellbeing (22). Safety and security (13) has direct influence on the desired mobility system development and therefore Human wellbeing (22). Enabling mobility system with the inclusion of early precautionary measures and human error avoidance increases the level of satisfaction for the user. Satisfaction enables the physiological aspect of quality of life. Thus, increase in Safety and security (13) increases the Human wellbeing (22) by fulfilling the user aspiration to be more satisfied to avail mobility services, which is safe and secure. Hence increase in Safety and security (13) proportionally increases the Human wellbeing (22), which is an equal effect.
- $19 \rightarrow 22$ is and effect between Justice and fairness (19) and Human wellbeing (22). Justice and fairness (19) addresses equality, which defines quality of life and therefore collective Human wellbeing (22). Inclusion of Justice and fairness (19) for mobility system design addresses the requirement of different income categories, population groups, and service choice by all involved in the system as actors. Therefore, defining the goal to improve quality of life is important condition for Human wellbeing (22)

improvement, which will have to be based on equal distribution of mobility services to all population categories in contextual basis. Hence increase in Justice and fairness (19) has the potential to increase Human wellbeing (22), which is an equal effect.

- $20 \rightarrow 22$ is an effect between Political power (20) and Human wellbeing (22). The external and internal influence factor, the Political power (20) is critical for the control of the system and their functioning, which is also applicable for mobility system development and therefore Human wellbeing (22). Peace, prosperity, economic growth and freedom of expression are key requirement for innovation and system transition to desired need. Stable political system strongly influences the quality of life. Aligning the political goal to consider Human wellbeing (22) is therefore an important system change lever, which is applicable for the development of desired mobility system. Thus, increasing the strength of Political power (20) potentially supplements the desired mobility system development that enhances Human wellbeing (22), which is an equal effect.

The variable Human wellbeing (22) expresses the system's long-term vision and is the intention of system observer to define it, as holistically as possible, with the influencing effect from other variables present in the system. The goal addressing sustainable development depends on sustainable society formation, which is a complex dynamic and requires much deeper understanding of human environment interaction. Sustainable society can be built when complete system transformation is fully executed. The mobility system might be an approach to locate the problem area and can be potential area for system re-orientation for sustainable development.

The current effect system construction of all the variables identified so far is however initial semantic for identifying the network of influencing effect, called as the feedback system, which will be discussed in more detail in section 5.6.So far, the variables are observed with observer position changed for every variable and they represent the variable´s causality in the system, called as system cybernetic. The result of cross-impact analysis is simplified further in the process of cybernetic effect system construction, which is an alternative representation of system test model. They are however highly context dependent and differ from the observer position in the system. The satisfactory system image can only be possible, when every variable is fully assessed by involving stakeholders who are system actors. However, the process requires much more debate and organizational setting, which is beyond the scope of this study considering the time limit. The test model however is an initial step for actual system model projection. The system model is therefore a rough image, which is subject to further reduction for executable plan on contextual basis. Moreover, only five of the variables effect is shown in the above analysis. The influencing effect of other variables can be found in the annex list at the end. Note that the effect system construction is very similar approach to mathematical model but here the major focus is given to semantic building block and linguistic norms and values to inquire the system. Furthermore, this type of semantic of variable based system construction is often time not available in literature sources because major focus of the research so far is on empirical deduction of predefined problem situation concerning one to one causality of variable effect and not the full system image, which is critical for system transformation.

The effect system of the mobility system test model is a representation of variable's one to one effect within the system that enables the identification of first stage influencing effect. When all the effect established by the variables in the system are observed together, they show much more complicated network of influencing effects, which will be elaborated in the following in the feedback-effect analysis.

5.6 Feedback effect

In sections 5.1 to 5.5 one to one effects of the variables are analysed, which shows the variables causality. The integration of one to one effect of the variables leads to the formation of complete system, which is the actual system that is normally functional. The complete system can now be used for executable purpose. It has to be noted that both one to one effects and integrated version of the cybernetic effect of the variables is the intention of the observer to enable how the system ought to function, where it is the intension of observer to transform to sustainable system. Therefore, the system can take any functional image depending on the context and the intention of the observer, which depends on how the system is adjusted. The corrective measure and success condition of the system is dependent on the cybernetic deduction of the system, which requires extensive debate to arrive at the common agreement among the actors of the system. Neither the statistical parameters nor the observer's intension determine system functioning. The system functioning depends on the push and pull factors influenced by the feedback effect present in the system, which provides logical justification for common agreement on specific scenario from many available options.

The feedback can only be seen when one to one effects of the variables are integrated together to form functional system. The system without feedback effect is a linear and isolated system, which is almost non-existent in the real-world functional system[8]. The functional systems are mostly an open system[8]. The cybernetic effect of figure 30is an open system. When one to one effects are integrated and observed carefully, the network of effects shows feedback among the variables. This feedback effect shows varying degree of uncertainty and contradiction as well as multiple alternatives that shows, how the system is made to behave, which depends on possible vision imaging that tends to transform the system and behave sustainably. For that purpose, system requires vision definition which is free from uncertainty and contradiction. The presence of feedback effect in the system shows the problem of control for the system's vision definition and uncertainty of leveraging variable, which is critical for the desired leverage condition. For the mobility system transformation to sustainable system, the observer identifies indicator variables, which are positioned in the reactive region in the variables systemic role. These can be used to state a potential system's vision that can be influenced by leveraging variables. The indicator variables and the leveraging variables are both subject to cybernetic deduction, depending on the feedback effects established by them. The leveraging variables that influence the indicator variables with the presence of only positive feedback indicate the system is tending to uncontrolled growth, which is potentially subject to collapse, whereas the system with only negative feedback will tend to oscillate and will not initialize own its own[8]. Every indicator variable is subject to different influence factor and their future development is unpredictable that depends on the control of the feedback effects. The feedback effect will take different orientation owing to different influencing effect as noticed in one to one effect of the variables in section 5.1 to 5.5.The contextual consideration of feedback orientation determines the level of success and failure for the defined vision, which can be further analyzed for functional system design [17], [30].

The maximum possible leverage potential that the leveraging variables can exert on the system is equivalent to the number of influencing effects the leveraging variable can exert on the system variables, which are potential for system vision definition. On the other hand the leveraging variable, although it shows leverage potential to an observer, is subject to many uncertainties [30]. The uncertainties arise due to the length and total number of positive and negative feedback effects established by them with the other system variables. The feedback length determines the potential side effects in future and the number of feedback cycles determines the potential uncertainty. The maximum possible length of the feedback effect is n+1 where 'n' represents the total number of variables in the system, whereas the minimum length is a pair of variables in a loop [8]. The minimum length of feedback effect indicates the immediate effects, whereas the longer feedback effect indicates the effects that will potentially develop in the future. The contradiction free system vision can be defined from the system indicator variables that are free from feedback effect. Therefore, defining system vision depends on uncertainties and contradiction sorting of the leveraging variables as a control measure, which depend on the power struggle among the actors of the system [9]–[11], [30]. Based on the control condition, multiple futures can be visualized from the system model as potential future scenarios. Scenarios that are potentially developed with equal number of positive and negative feedback effects indicate the system is more likely to be sustainable, whereas the system that contains only the positive or negative feedback effects will indicate the system is less likely to be sustainable [8]. The feedback effects of the variables in the system are critical for the design of sustainable mobility system, which is optional and context dependent. The vision definition of the system and power struggle process can be justifiable with the help of feedback control. Therefore feedback effect plays a central role for decision making process, which is debatable [8], [30].

The integration of one to one effects of the variables into the effect system leads to formation of complete mobility system, which generates two sets of feedback effects. The one that influences system growth called as positive feedback and the other that tends to control the growth called as negative feedback. The number of feedback effect development is dependent on the construction of influencing effect, the cybernetic of the variable in figure 30. They are potential for cybernetic deduction and can be further simplified in cybernetic order. In the cybernetic effect in figure 30, there are 245 feedback effects including 119 negative feedbacks effect and 126 positive feedback effects. Although it is an ideal case to continuously analyze all the feedback effects for the design of functional mobility system, the consideration of all feedback effects is beyond the scope for one research project due to time limitation. The feedback effects can be used further for alternative future research project. They can be additional research problem situation, which can be used as an alternative research hypothesis for mobility system analysis. The list of 245 feedback effects can be found in annex list at the end. Only the main feedback effects and few examples are explained in section 5.6.1 to 5.6.4, which are used as a basic building block for mobility system vision definition and scenario projection in this study.

5.6.1 Positive feedback effects

Positive feedbacks are identified when equal effects and even number of opposite effects established by the variables in the effect system develops a loop during the process of one to one effect integration in section 5.1 to 5.5. The influencing effect of positive feedback is a continuous growth loop. The positive feedback effects are necessary for the system to initialize the change process. Once the system is initialized, their growth has to be monitored with the control condition, which can only be seen in negative feedback effect. The system initiation and control is not dependent on the intention of the observer but is dependent on the variables orientation that determines their development. On the other hand, the variable orientation is the result of one to one variable influencing effect consideration during the process of effect system construction, which is context dependent. Therefore, the system remains flexible and highly complex, which is subject to iterative and cybernetic deduction for desired development.

The positive feedback effects of the variables can be seen from the effect system in section 5.1 to 5.5 and those in annex list. The variables are represented by serial numbers in the order 1 to 22 as listed in chapter 3 and they follow the same number representation in the feedback effect. The positive feedback effect list 'a' to 'm' is main feedback, which will have multiple deviations, and the choice of feedback effect for system initiation depends on observer choice and intended vision. The feedback effect also shows many alternative paths to initialize the system for the change process. In the ideal case digging deeper in the entire feedback effect path is the best choice. However, the push and pull factors involved in the assessment process are never ending, which is where identification of complexity involved for decision making process can be based on feedback choice. This also indicates that there is not a single but many options available for initializing the system transformation to sustainable development, which determines how system is made to behave. The following feedback effects provide alternative decision support, which are subject to stakeholder consultation and are context dependent.

a. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 6 \rightarrow 11 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
c. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
e. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
g. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
h. $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$
i. $5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5$

j. $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7 \rightarrow 6$

k. $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7$

l. $11 \rightarrow 21 \rightarrow 11$

m. $7 \rightarrow 10 \rightarrow 7$

The feedback effects 'a' to 'm' are positive, which is the effect representing continuous growth that influences the behaviour of mobility system. In the positive feedback effect, when the effect between one variable is increasing, the variable that it influences will also increase and the process continuous till the influencing effect returns back to the influencing variable with magnified impact. Such growth orientation is unsustainable and therefore needs control mechanisms, which will be further elaborated in negative feedback effect in section 5.6.3. For example, in feedback effect 'a', if the intention of an observer is to enable system growth by making an intervention on Infrastructure development (1), the magnification of the influencing effect is much higher than that it has initially influenced the variable Spatial dynamic (5) due to magnified impact from the feedback loop (see feedback effect 'a' for the chain of influencing effect). Therefore, the intervention in any one variable in the system will have cascading effect on the system variable if such feedback effects are not monitored. There are also potential path deviations and alternative options available in the above list from the effect system of individual variable in section 5.1 to 5.5 and that are in annex list. In view of such complex problem situation, the cybernetic representation is reduced to network of influencing effects and the variables represented with number and influencing arrow sign for further analysis with the legends as shown in figure 37.

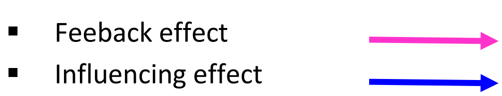


Figure 37: legend representing feedback effect and influencing effect

The legend shown in figure 37 is used to represent the influencing effects and cybernetics of the variables in the mobility system test model. The mobility system model represented in the cybernetic effect system is first step system analysis process for decision support. The detail path deviation and multiple feedback effects of all 22 variables although show the deeper understanding of the mobility system, the analysis process requires much more time and therefore only few selected feedback effects can be used for defining mobility system scenario for system initiation to transform mobility system to sustainable system. For holistic scenario projection positive feedback effect 'c' from the above list that is the feedback cycle $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ is used in this study. Therefore,only possible path deviation and multiple options for the chosen feedback effect is elaborated in section 5.6.2. The other feedback effects can be seen in annex list. However thesystem's feedback effect development is still dependent onstakeholder agreement and logical reasoning in addressing the contextual need. Therefore the intention of observer is not the final decision.

5.6.2 Example of positive feedback effect

The feedback effect $1 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows multiple alternative paths deviation in the effect system of variables Accessibility (6), Economic development (11), Enabling condition (14), Political power (20) and Rural-urban dynamic (21) as shown in figure 38. Also note that the effect system of variable Accessibility (6) is only shown in figure 38.

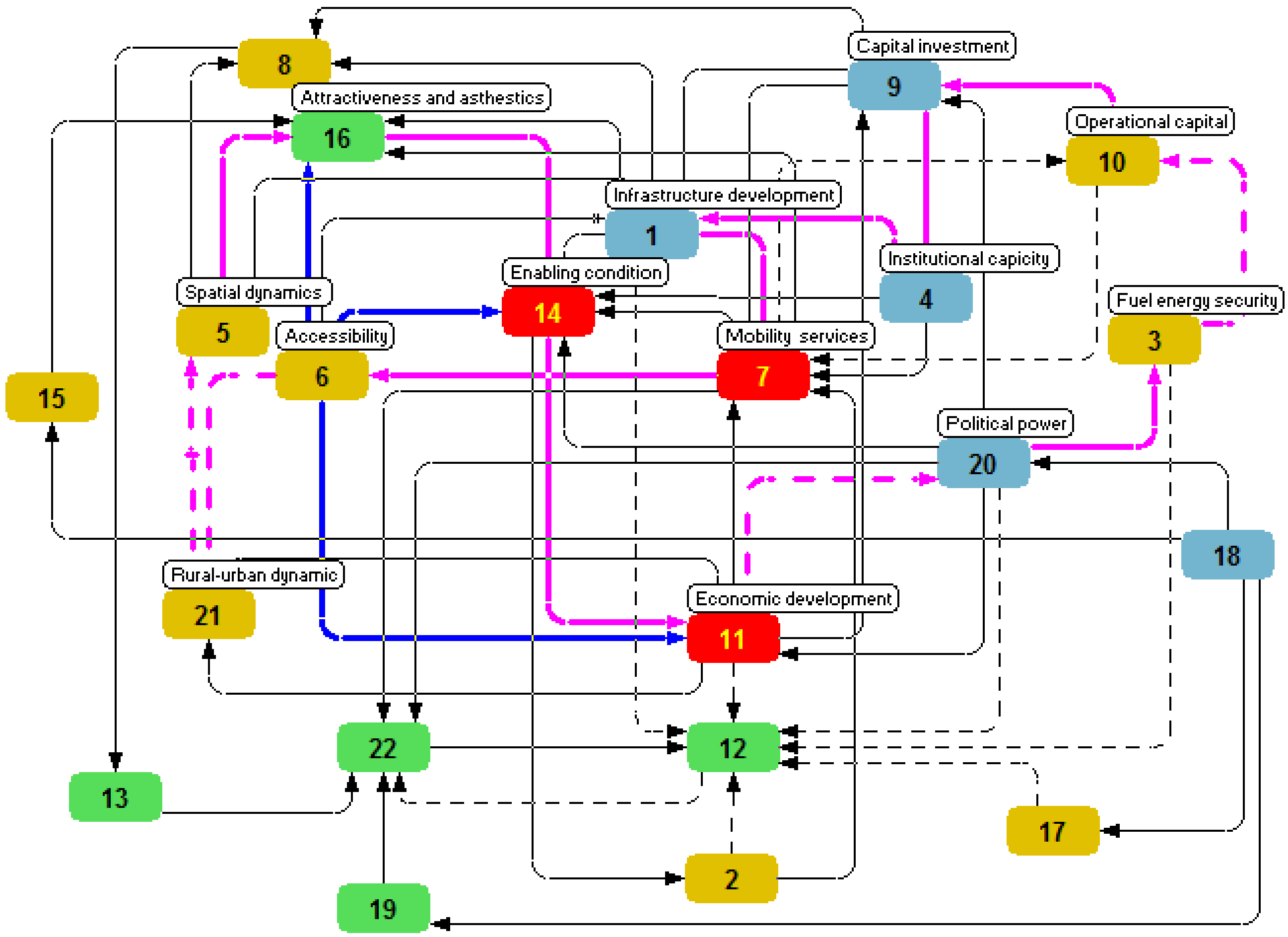


Figure 38: Feedback path deviation in Accessibility

a. $1 \to 7 \to 6 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
b. $1 \to 7 \to 6 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
c. $1 \to 7 \to 6 \to 11 \to 9 \to 4 \to 1$
d. $1 \to 7 \to 6 \to 11 \to 9 \to 1$
e. $1 \to 7 \to 6 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
f. $1 \to 7 \to 6 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
g. $1 \to 7 \to 6 \to 14 \to 11 \to 9 \to 4 \to 1$
h. $1 \to 7 \to 6 \to 14 \to 11 \to 9 \to 1$

i. $1 \to 7 \to 6 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
j. $1 \to 7 \to 6 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
k. $1 \to 7 \to 6 \to 16 \to 14 \to 11 \to 9 \to 4 \to 1$
l. $1 \to 7 \to 6 \to 16 \to 14 \to 11 \to 9 \to 1$
m. $1 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
n. $1 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
o. $1 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 9 \to 4 \to 1$
p. $1 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 9 \to 1$
q. $1 \to 7 \to 6 \to 21 \to 11 \to 20 \to 9 \to 4 \to 1$
r. $1 \to 7 \to 6 \to 21 \to 11 \to 20 \to 9 \to 1$
s. $1 \to 7 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
t. $1 \to 7 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
u. $1 \to 7 \to 14 \to 11 \to 9 \to 4 \to 1$
v. $1 \to 7 \to 14 \to 11 \to 9 \to 1$
w. $1 \to 7 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
x. $1 \to 7 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
y. $1 \to 7 \to 16 \to 14 \to 11 \to 9 \to 4 \to 1$
z. $1 \to 7 \to 16 \to 14 \to 11 \to 9 \to 1$

The feedback effect $1 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows 26 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore, the intervention on any one of the variables in the system leads to growth or de-growth of mobility system.

The feedback-effects a, b, e, f, i, j, m, n, o, p, q, r, s, t, w and x from the above list shows it is a decreasing effect due to the presence of even number of opposite effects, where the re-enforcing effect of de-growth can be seen from these feedback effects. Therefore, the system initialization for growth orientation from this feedback effect is useless. The feedback effect c, d, g, h, k, l, u, v, y and z from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effects. Therefore, system can be initialized from these feedback effects on a contextual basis for their growth development. However, it is important to note if the vision for mobility system is to slow down their development then the feedback-effect paths a, b, e, f, i, j, m, n, o, p, q, r, s, t, w and x are very useful. Therefore, it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for de-growth development is determined by Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as they show strong opposing effect in the effect system. However, all the control condition is subject to conditional scenario for future projection.

5.6.3 Negative feedback effect

When positive feedback effect was explained in section 5.6.1, it was concluded that the control condition is needed for growth limit. The control condition should be made optional with the influencing variables. That is to say the orientation of cybernetic effect and control justification is dependent on negative feedback effect, which is again potential for cybernetic deduction [8]. It is the intention of the observer to provide this control condition based on the influencing effect for its development in future as self-regulating options. The negative feedback effects can be recognized by observing the feedback cycles, which show the odd number of opposite effects, when one to one effects of the variables are integrated to form a complete system [8]. Negative feedback effects are critical for control condition in any system [8]. System without any negative feedback effect is potential to collapse in either case of growth and de-growth [8]. The same principle is applicable for the control of mobility system growth and de-growth. Also, it is important to note that for the system to be sustainable, the system will have to obey the principles of negative feedback for system self-regulation. Following main negative feedback effects are seen from the effect system of section 5.1 to 5.5 and those listed in annex list.

a. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
c. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
e. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
g. $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
h. $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4$
i. $5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5$
j. $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$
k. $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7$
l. $11 \rightarrow 20 \rightarrow 14 \rightarrow 11$
m. $11 \rightarrow 20 \rightarrow 11$
n. $12 \rightarrow 22 \rightarrow 12$

The negative feedback effect list 'a' to 'n' are potential feedback cycles for the control of the growth of positive feedback effect. The growth control can be done in many alternative ways but understanding the side effect of the growth control has to be aligned to the initialization of the growth, which is subject to the choice of positive feedback cycle on how to control them. Therefore, it is not the new intervention that addresses the growth control but more from the internal system correction based on variables orientation in the feedback effect. The critical condition for new intervention can also be seen from the control identification from the positive feedback effect. Hence the negative feedback effect plays a major role for design of the system. The design is however influenced by the vision definition, which can also be controlled depending on the negative feedback effect. The control measure based on negative feedback effect provides a holistic approach on sustainable development vision definition, which can have cybernetic effect and is context dependent. Therefore, any system initialization with the help of positive feedback effect needs to be accompanied by the negative feedback effect for the control condition and system self-regulation potential, which is often time missing in system planning and policy design.

The negative feedback effect resembles the self-regulatory dynamic of control measure seen in the natural system, which is self-sustainable [8]. The natural system is however different from the man-made system, which is highly complex owing to many influencing effects and above all the behaviour correction is critical for the intention of the observer. Therefore, the control conditions are context dependent and should be made optional for multiple choices. It has to be noted that even if the new and alternative mobility system is proposed, without the change of behaviour, system tends to function in normal way. Therefore, the control of all the influencing effects that tend to align to the dream and wishes of the actor are important criteria, which has to be optional[8]. Understanding the functional value of the system that shapes the lifestyle will require collective changes in the influencing effect, which depends on cybernetic effect and feedback choice. The intention of observer here is to make the visibility of those conditions, which are not yet networked in the thinking process of the decision maker. For example, the feedback effect 'a' is contextual and the control intervention can be made in any variable. In this case the observer's intention is to pinpoint the Spatial dynamic (5) as control influencing effect and cybernetic deduction based on that condition. The limitation of space is an argument for control measure requirement and the entire variable following after that need cybernetic orientation based on the limit condition defined for meaningful adjustment.

Although in the ideal case all the control conditions and influencing effects can be re-oriented but due to time limitation, it is not feasible to complete all the feedback effect control. Therefore, the choice has to be made on which negative feedback effect can be used for the control of the growth initiating positive feedback. In section 5.6.2 the selected positive feedback effect is elaborated and for that the control negative feedback effect will be elaborated in section 5.6.4. It has to be noted that the positive and negative orientation of the feedback effect is dependent on the observation made by the observer and accordingly the orientation of selected control variable to align to that control dynamic. The other negative feedback effect list, which is not reflected in the main text, can be seen in the annex list.

5.6.4 Example of negative feedback effect

The example of positive feedback effect is shown in section 5.6.2, which can be used for system initialization to transform the mobility system to sustainable mobility system. However, the positive feedback effect alone is not enough for the system transformation. The transformation needs balancing effect with control measures. The control condition can only be found in negative feedback effect, which is context dependent and negotiable. The feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$ is a negative feedback for the example positive feedback effect in section 5.6.2 and the variables present in it can be used for control condition, which is context dependent and how it is made to behave. It has to be noted that this feedback effect has multiple path deviations, which leads to optional control conditions. The multiple paths are seen in the effect system of the variables Mobility service (7), Accessibility (6), Rural-urban dynamic (21) and Economic development (11) as shown in figure 39.

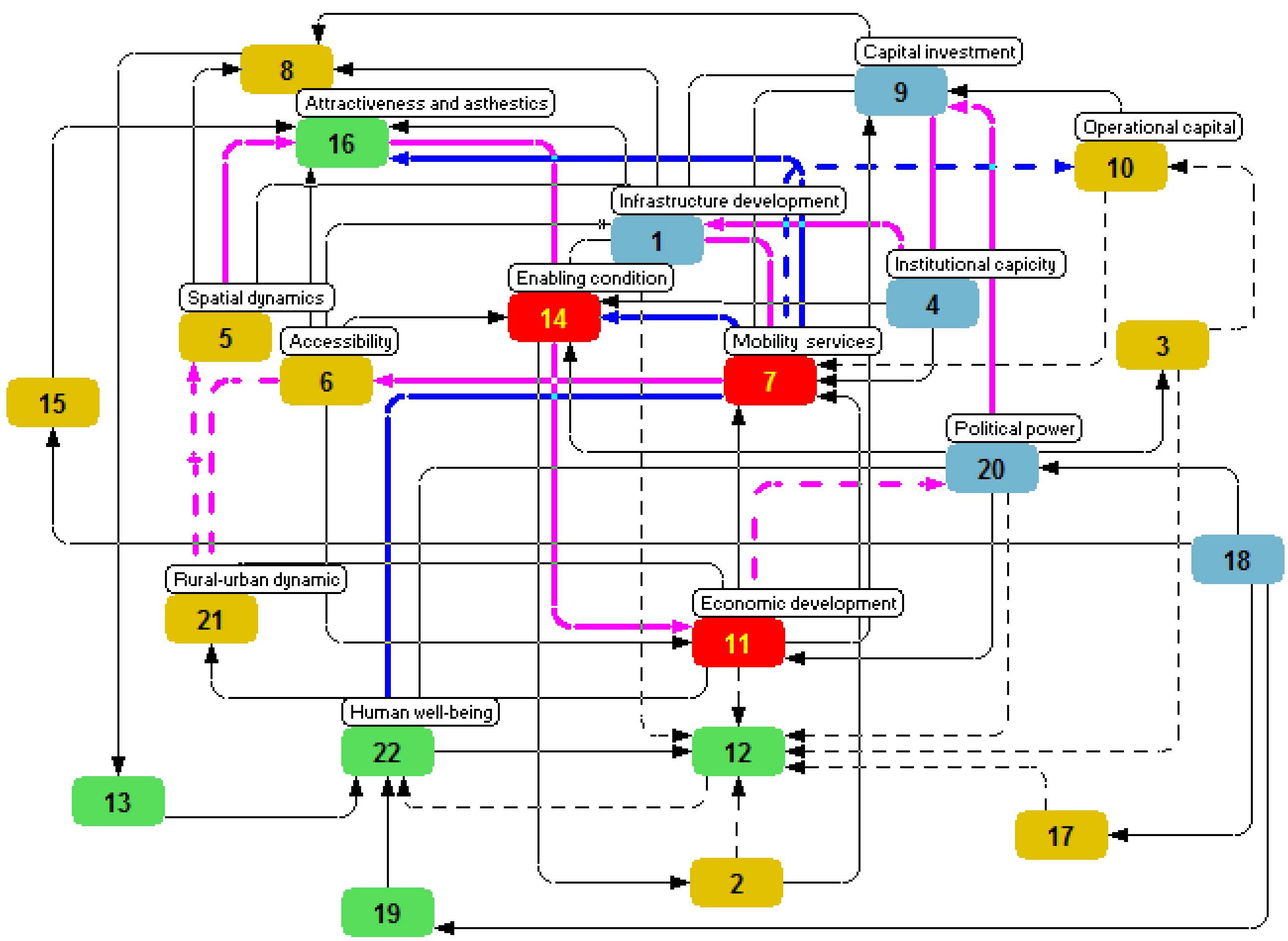


Figure 39: Feedback path deviation in Mobility Service

a. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$

c. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
j. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
k. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
l. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 1$
m. $1 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
n. $1 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
o. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
p. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
q. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
r. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$

The control feedback $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows 18 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore, any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list, which provides multiple options. It also indicates that there is not one single control condition but multiple options are available, which can have cybernetic effect. Similar to that in section 5.6.2, the feedback effect a, b, c, d, e, f, o, p, q and r from the above list show Economic development (11) and Political power (20) as strong control variable for system stability and their sustainability. In feedback effect g and h the control variables are Spatial dynamic (5), Accessibility (6), Economic development (11), Political power (20) and Rural-urban dynamic (21). In feedback effect i and j the control variables are Fuel energy security (3), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11) and Political power (20). The control variables in feedback effect k and l are Accessibility (6) and Rural-urban dynamic (21). The control variables in 'm' and 'o' are Mobility service (7) and Operational capital (10). Identification of these control variables is critical for designing a system that tends to self-regulate in future. While the choice of the negative feedback effect depends on the system vision and the initializing positive feedback effect, the control condition is strongly dependent on the identified control variable in the negative feedback effect. Thus, designing a sustainable system will follow three uniquely defined steps on a contextual basis. The first step starts with the identification of system vision, the second step the choice of positive feedback to initialize intended development and the third the control variable that regulates the system for it to be sustainable in future.

5.7 Summary of cybernetic effect system

The cybernetic analysis of the mobility system indicates that the system is highly interconnected and cannot be treated in isolation. The variables consideration, their influencing effects, the network of influence and the feedback effects are dependent on how the system is made to behave. Even if the intention of observer influences the system transition, their cybernetic behaviour will continue to normalize future development. For example the current idea to enable de-growth strategy of economic system and other systems influenced by it is to de-couple consumerism behaviour and reduce human ecological foot print, which seems to be an outcome of industrial revolution after Second World War [1]. The major drawback of early industrial growth progress was mainly influenced by linear system identification mostly with the predefined single goal, where the cybernetic effects are not considered. New discoveries of technology seem to have pushed many growth models that are inter-connected and cannot be treated in isolation any more. Same is true for mobility system, where mobility system growth is heavily influenced by motorization. Even now when the de-growth strategy addresses current systemic challenges, without the knowledge of cybernetic effect, the system will tend to re-generate new problems. For example, in the pretext of sustainable urban design, the urbanization has already become the major focus, which will without doubt lead to problem of space constraints and associated human behaviour influencing the new problem. The massive infrastructure, space utilization and human behaviour to adapt to the change are where current de-growth orientation need cybernetic deduction. However, the growth control based on cybernetic effect is missing for vision definition for any system, which is highly interconnected. Even if the empirical results with fine-tuned data sets are agglomerated, the fundamental problem of systemic failure will continue to grow. System correction requires behaviour correction and contextual scenario projection for the success condition for the desired system.

The 22 variables set identified for mobility system and their cybernetic effect analysis so far is roughly the useful system image for further scenario projection, which is context dependent and are cybernetic in nature [10], [11], [29], [30]. If the influencing effects are closely viewed, they tend to show complex behaviour pattern that depends on how the system is made to behave. On the other hand, when the influencing effects are combined together to form a cybernetic effect, they tend to show many unintended side effects. The side effects and influencing effects cannot be easily quantified with formal scientific methodology that requires set of pre-defined problem statements to be answered, which influence and tend to reduce the complex systemic problem to a linear object. However the systemic problem is irreducible , which cannot be reduced to simple isolated system to address the complex problem situation [17], [18], [51]. The process requires much deeper understanding of influencing effects that the system is challenged with multiple cause and effect matrix. The influencing effects depend on the variables defining the system. Hence the process is iterative and there are no fixed fit for all rules for how system is made to behave. It is purely based on the stakeholder's need and system stability condition. Therefore, stakeholder engagement for user centric negotiation process is critical criteria for system analysis. However due to the time limitation in this study the system assessment is limited to scientific stakeholders, which needs further communication with system experts. The test mobility system model can be used for next stage communication for executable system.

6 Problem of control: Target variable identification

The functioning of any system depends on the defined vision that influences the mission, goal and objective [132]. Defining system's vision is to visualize the future of the system in present situation, which is challenged by many uncertainties [9], [30], [32]. However, the vision definition tends to obey the hierarchical order influenced by the power structure. To avoid such biased decision, it is critical that system be cybernetically explored with the involved actors [24]. Actors are those stakeholders involved for the design of the system and those that use the system [8]. Therefore, the cybernetics of the variables enable meaningful stakeholder engagement platform for vision definition and to locate potential uncertainty. The first uncertainty is dilemma on the choice of system's variables that potentially leverage the system to desired vision. The second uncertainty is about the influence of system variables on the leveraging conditions and the third uncertainty depends on the effect system of the leveraging variables. The effect system of the leveraging variable is inevitably linked to multiple target variables that it can influence system's future and therefore can be potential system vision. However, all the target variables influenced by the leveraging variables cannot be realistic system vision. Furthermore, the variables that represent the system's vision should be free from the feedback effect to show clear future path and it should fulfil the required function of the system, which is future oriented [132].The target variables that are identified for vision definition are often time the system indicator variables. Therefore, defining the system vision is a future planning challenge, which is influenced by many uncertainties that will require fulfilling the contextual need [8]–[11],[30], [32]. Therefore, robust system vision definition can be made easy by cybernetic deduction of effect system in a heuristic order on how system is made to behave. For that reason, the system variables, effect system and feedback effects analysed so far enable the vision definition, which is iterative process.

The variables position and the systemic role played by the variables in the system is shown in chapter 3 and the cybernetic effect system of the variables is seen in chapter 5, which is useful for vision definition of the mobility system, uncertainty shorting and what if conditional scenario assessment. The positioning of the variables in the system image and the role played by them in the system shows Mobility service (7), Economic development (11) and Enabling condition (14) are potential system leveraging variables, positioned in the critical region in the system from the list of 22 global variables (refer to figure 6 in chapter 3 for system image). The first leveraging variable Mobility service (7) leverages the mobility system from inside, whereas the variable Economic development (11) leverages the mobility system from outside of the system. The leveraging variable Enabling condition (14) leverages the system with the opposing and equal effect for control requirement from external and internal influence in the system and enabling positive and negative feedback effect development. The effect system of these leveraging variables will indicate potential variables for system visions definition, which can be further projected. However, the feedback effect established by the leveraging variables with other system variables are also subject to uncertainty, which will generate multiple options to arrive to the desired target variable for system vision definition. The process is highly complex and context dependent and therefore it requires a participatory process involving the actors of the system in cybernetic order.

The leveraging variable *Mobility service (7)* influences the variables Accessibility (6), Operational capital (10), Enabling condition (14), Attractiveness and aesthetics (16) and Human wellbeing (22) as seen in the effect system in chapter 5, which is the result of one to one effect system construction. It may be possible that the one to one variable causality will require empirical verification if the system does not fulfil the required need of the actors involved in the system and the process is iterative. Therefore, at a first glance there are potentially 5 possible variables for mobility system visions. However, for the system vision to be sustainable and future oriented, the target variable influenced by the leveraging variable should be free from the feedback effects and also it should represent as system indicator to avoid power struggle. The presence of feedback effect in the target variable will not provide clear future path and therefore contradicts with the system vision as it develops in the future, which is not desired for the success of sustainable mobility system development. The variable Accessibility (6) shows 80 negative and 90 positive feedback effects, which also indicates the variable does not have clear future path and therefore not suitable for mobility system vision. Similarly, the variable Operation capital (10) shows 53 negative and 54 positive feedback cycles, which also indicate weak variable for mobility system vision. The Enabling condition (14) is itself the leveraging variable that it can have its own vision and it has 91 negative and 102 positive feedback effects, which is again a very weak variable for mobility system vision. Similarly, the variable Attractiveness and aesthetics (16) shows 53 negative and 60 positive feedback effects indicating a weak variable for system vision. Therefore Human wellbeing (22) with clear future path with only 1 negative feedback effect is a potential target variable for mobility system vision for the leveraging variable Mobility service (7). The vision to improve Human wellbeing (22) by intervening in the variable Mobility service (7) is subject to multiple uncertainties due to feedback effect, which are potential future scenario for the mobility system. Also it has to be noted that Human wellbeing (22) was initially assumed as a target variable for the design of sustainable system. What is more critical from cybernetic effect is that even the variable that are potential for vision definition is part of the feedback cycle, which needs to be sorted cybernetically. The leveraging variable Mobility service (7) shows 96 possible control feedback and 93 possible system initializing feedbacks on a contextual basis, which can be used for scenario projection.

Similarly, the leveraging variable *Economic development (11)* influences the variable Mobility service (7), Capital investment (9), Environment pollution (12), Political power (20) and Rural-urban dynamic (21) as seen in the effect system in chapter 5. Therefore, at a first glance the leveraging variable Economic development (11) shows 5 potential variables for mobility system visions. The influence of Economic development (11) on the target variables also face uncertainty challenges due to the presence of feedback effect making the variables weak for mobility system vision. The first target variable Mobility service (7) is by itself a leveraging variable beholding its own unique vision with 96 negative and 93 positive feedback effects. Therefore Mobility service (7) as a variable for mobility system vision definition is very weak because it has multiple uncertainties contained in it indicating unclear future path. Similarly the variable Capital investment (9) shows 106 negative and 111 positive feedback effects leading to multiple future uncertainties, which also indicate weak variable for mobility system vision. The variable Political power (20) shows 70 negative and 63 positive feedback effects leading to multiple uncertainties, which also indicates the variable is weak for mobility system vision. The variable Rural-urban dynamic (21) shows 42 negative and 34 positive feedback effects indicating weak variable for mobility system vision. Therefore, the target variable Environment pollution (12) is potential for mobility system vision that is influenced by the leveraging variable Economic development (11) with only 1 negative feedback effect. Note that Environment pollution (12) is also an assumed target variable. The vision to reduce Environment pollution (12) is however subject to uncertainties condition as seen from the feedback effect of the leveraging variable Economic development (11). The leveraging variable Economic development (11) shows 101 control feedback effect and 120 possible system initialization feedback effects on a contextual basis, which can be used for scenario projection.

The leveraging variable Enabling condition (14) influences the variable Technology development (2) and Economic development (11) as observed from the effect system in chapter 5. Therefore, the leveraging variable Enabling condition (14) potentially has 2 possible variables for mobility system visions. However, both variables show feedback effects contained in it with multiple uncertainties. The variable Technology development (2) shows 38 negative and 31 positive feedback effects and the variable Economic development (11) shows 101 negative and 120 positive feedbacks. Therefore, the leveraging variable Enabling condition (14) shows very weak system vision from its target variable for the mobility system vision and scenario projection in the future. Thus, the leveraging variable Enabling condition (14) is potentially not suitable for mobility system vision definition. The Enabling condition (14) remains as a strong system control variable for the development of mobility system to the desired vision to remain sustainable in future.

It has to be noted that the target variables defined above are based on the intention of the observer for system transformation to sustainable system, which is subject to further assessment on a contextual basis. The leveraging variables from the above assessment show, there are two possible strong target variables for mobility system visions for the mobility system to be sustainable in the future. The first vision originates from the leveraging variable Mobility service (7) influencing the target variable Human wellbeing (22) and the second vision originates from the leveraging variable Economic development (11) influencing the target variable Environment pollution (12). The potential mobility system vision from the target variables Human wellbeing (22) and Environment pollution (12) is an intervention expected to be made from inside and outside of the system, which is broad and future oriented to define sustainable mobility as a complete system image. Therefore, it can be concluded that the design of sustainable mobility system depends on both internal and external correction. Thus, the reforms in the mobility system will require the reforms in the economic system for positioning the robust mobility system vision as an alternative development. Reforms in either one in isolation will have insignificant impact for future of mobility system development.

Leveraging the mobility system by intervening in the leveraging variable for the desired vision is however not as simple as it is expected to be due to the presence of many other system variables that influence the leveraging variables. To achieve better Human wellbeing (22) by intervening in the leveraging variable Mobility service (7) is subject to contextual scenario based on the feedback effect established by it, with the other system variables. Similarly, to reduce Environment pollution (12) by intervention in Economic development (11) is subject to contextual scenario based on the feedback effect established by it, with the other system variables. For example, the Mobility service (7) shows 96 negative and 93 positive feedback effects that lead to possibly multiple future alternatives to achieve the vision of better Human wellbeing (22). Similarly, the Economic development (11) shows 101 negative and 120 positive feedback effects that lead to multiple future alternatives to achieve the vision to reduce Environment pollution (12). The choice of system initializing positive feedback and the system control negative feedback depends on different condition that suit the needs of the users in general and the capacity of the system implementer. Further the variables effect and the causality in the effect system that leads to the development of positive and negative feedback effect strongly influences the development of feedback effect that causes those initialization and control conditions. Therefore, recognizing control variables is very important for the design of sustainable mobility system. The target variable Human wellbeing (22) and Environment pollution (12) envisioned for the development of two possible mobility system vision also require addressing the vision that fulfil the dual target. Therefore, envisioning the system vision and their future development depend on contextual scenarios.

Cybernetic effect system of chapter 5 shows both positive and negative feedback, where the system growth, de-growth and control condition can be observed. The presence of multiple alternative feedback paths also indicates the leverage of the system can have multiple scenario fields. From the positive feedback effect the growth potential are seen when the relation between the variable in the feedback loop show equal effect, whereas for the de-growth development, the even number of opposite effects in the feedback loop are seen. The system's vision initialization for either growth and de-growth depends on the choice of these positive feedback effect (equal effect). The system with only positive feedback effect is however not sustainable in either case of growth and de-growth development [8]. Therefore, the role of negative feedback effect is critical for control condition. Negative feedback effects are developed based on the control variable that influences the system's self-regulation with its opposing effect[8]. These control variables observed in chapter 5 are Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) for different alternative feedback effect path. Among this control variables Mobility service (7) and Economic development (11) has the system leveraging potential and therefore unique future scenario can be established from them.

The alternative future scenario from the leveraging variables can be chosen from the feedback effect established by the leveraging variables with the other system variables for either growth or de-growth development [30]. The choice of the feedback effect depends on the desired vision. The leveraging variable Mobility service (7) shows 93 positive and 96 negative feedback effects for growth or de-growth and control condition for the mobility system vision to enable better Human wellbeing (22). Similarly, the leveraging variable Economic development (11) shows120 positive and 101 negative feedback effects for growth or de-growth and control conditions for the mobility system vision to enable the control of Environment pollution (12). The choice of feedback effects for future scenario projection however depends on the choice of control variables. The scenarios projection from the defined vision, their intended development and control condition are therefore called as plural future alternatives envisioned in the present situation [30]. Therefore, it can be concluded that the future of a system is dependent on the desired vision, which is cybernetically connected within the system [8], [18], [132]. Hence, even if the scenarios are different they are influenced by the defined vision of the system. For the mobility system vision, detail and careful analysing indicates variable Environment pollution (12) and Human well-being (22) as robust and future oriented target variable for mobility system vision definition, which can be leveraged by intervening in variable Mobility service (7) and Economic development (11).

6.1 Cybernetic simplification: Initiating and control variables

The shortest feedback effect with the leveraging variable and potential target variable that define system's vision is the best way to initialize the system and to identify the control conditions, which is however irreducible. The network of influence can only be agreed upon depending on the context as an initial condition for further projection. The mobility system model developed from variable identification in chapter 3 and variable's cybernetic effect system in chapter 5, shows the inclusive pairs $11 \rightarrow 20 \rightarrow 11$, $12 \rightarrow 22 \rightarrow 12$, $7 \rightarrow 10 \rightarrow 7$ and $11 \rightarrow 21 \rightarrow 11$ as a shortest feedback effects shown in figure 40. The strong causality of the global variable that forms inclusive pair in the system is developed based on the observation of the current situation, which is context dependent and are interconnected with other variable. These feedback effects give first hints for system initialization for either growth or de-growth development and control condition for self-regulation.

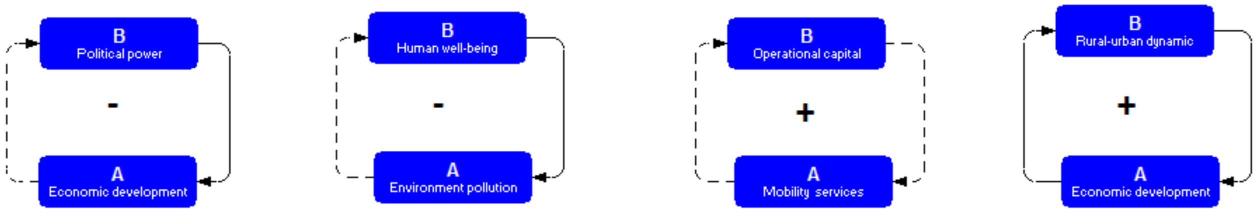


Figure 40: Feedback effect of inclusive pair shortest cycle [39]

The shortest feedback effect can be found when one to one effect of the variable forms a loop. The shortest loop formation has the potential for unintended side effect development in the cybernetic effect system. Therefore, the push-pull factor involved in the system design due to the feedback effect development is a first step decision making complexity. Hence, the one to one effect of the variable forming a loop is foundation for system design. The variables pair Political power (20) and Economic development (11), and the variables pair Environment pollution (12) and Human wellbeing (20) show negative feedback cycle, whereas the variables pair Mobility service (7) and Operational capital (10), and the variables pair Rural-urban dynamic (21) and Economic development (11) show positive feedback cycles. For the positive feedback effect, the inclusive pair Mobility service (7) and Operational capital (10) it has the potential for de-growth development due to the presence of even number of opposite effects, whereas the inclusive pair Economic development (11) and Rural-urban dynamic (21) it has the potential for growth development due to the presence of only equal effect. On the other hand, the variables in negative feedback-effect acts as a system control variable for self-regulation due to the presence of odd number of opposite effects. They are the feedback-effect Human wellbeing (22) and Environment pollution (12), which is potential for system vision, whereas the feedback-effect Political power (20) and Economic development (11) is potential system's external influence for control. Therefore, it has to be noted that the mobility system's vision is inter-dependent to both external and internal influence. Since this two feedback pairs are potential for the mobility system vision definition, which is acting as a self-regulating negative feedback effect, the control variable for the vision can be either one of them depending on the choice of the system's vision from the two. That is to say if better Human wellbeing (22) is intended for system vision, the control variable is Environment pollution (12). On the other hand, if the system's vision is intended to decrease Environment pollution (12), then Human wellbeing (22) is the control variable. These shortest feedback effects are however influenced by other system variables and are not independent from the cybernetic effect system of chapter 5. The variables at this stage only show the global effect of the mobility system, which in general show similar trend in every geographic location. The influence factors can be interpreted in many different ways but the influence of variable on the system as a whole is more or less the same even if the context differs. The role-play, characteristics and influence of feedback effect $11 \rightarrow 20 \rightarrow 11$, $12 \rightarrow 22 \rightarrow 12$, $7 \rightarrow 10 \rightarrow 7$ and $11 \rightarrow 21 \rightarrow 11$ are as shown in table 30. The role play, characteristics and impact determine the behaviour of the system.

Table 30: Effect of inclusive pair in the system

Feedback	Role play	Characteristics	Impact
$11 \rightarrow 20 \rightarrow 11$	External influence	Control the system from outside	Balancing effect
$12 \rightarrow 22 \rightarrow 12$	Vision control	System vision definition	Balancing effect
$7 \rightarrow 10 \rightarrow 7$	System initiation	Internal system corrective measure	Initialize de-growth
$11 \rightarrow 21 \rightarrow 11$	External influence	External corrective measure	Initialize growth

The first negative feedback effect $11 \rightarrow 20 \rightarrow 11$ in table 30 shows the global trend to stabilize the system by controlled corrective measure. The Political power (20) has strong influence on the Economic development (11), where the strong political system enhances the economic growth initially. As soon as the economic growth is achieved, the willingness of people to take part in the politics will weaken the political power. The economic power that weakens the good political system will face the challenge of growth control. Therefore, people's participation for de-growth development will become critical. This is what we see in the Club of Rome findings on de-growth strategies [1], [2]. The end of world wars indicates the development of stable political system which enhanced the industrial revolution and therefore economic growth. Today the economic power dominates the control of growth where the people's participation is critical for the de-growth development. This can always be true for the control of mobility system transition from the current state of uncontrolled high share of motorization and ownership culture, which can only be solved by people's participation by increasing service sharing culture to leverage the system.

The second negative feedback cycle $12 \rightarrow 22 \rightarrow 12$ established between the variables Environment pollution (12) and Human wellbeing (22) shown in table 30, regulates the mobility system by de-coupling quality of life by exploitation of the environment. Both the variables are system indicator and are potential system vision, which influence the mobility system by indicating how the system vision control transforms the mobility system. While fulfilling the functional need of mobility is critical for improving the quality of life, the higher demand for mobility need further increases the environmental stress such as land use change and air pollution, which threatens the quality of life when it comes to the availability of free space and human health [14], [58], [125]. Therefore, the tendency to increase quality of life has the potential to decrease the environmental health. The feedback effect balances the mobility system, in which it is intended to de-couple the mobility need from the environmental pollution. The control mechanism can have strong influence on use of mobility fuel, infrastructure and travel behaviour. Use of bio-fuel derived from bio-waste, algae, and energy crops that do not compete with food supply are important fuel substitute. The infrastructure planning and the integration of renewable electricity as a source of mobility fuel will have potential value addition to environment protection [72]–[74]. The urban and rural planning where the encouragement of non-motorized travel-behaviour will have significant environmental value addition. Therefore, the overarching goal of avoid, shift and improve strategy play critical role for the development of environment friendly mobility services that has strong positive effect on Human wellbeing(22) [25].

The positive feedback effect $7 \rightarrow 10 \rightarrow 7$ shown in table 30, unfolds the mobility system from inside, where the re-enforcing opposite effect between Mobility service (7) and Operational capital (10) is strongly influenced by the service centric business development. The feedback cycle initializes the mobility system transformation from ownership-based mobility service to service centric mobility system. The positive feedback effect indicates the need to shift the consumer behaviour from mobility product consumption to mobility service consumption [15]. The possible options are increasing the affectivity of mobility service by creation of more jobs while service quality is enhanced, decreasing mobility service cost by use of ICT enabled service and promoting liberal competitive market in mobility service sector. Such alternatives are strongly influenced by the consumer behaviour and the availability of quality service [15], [18]. The mobility service extends far more than public transport service. They range from basic travel service to shift in shared motorization with the engagement of bank and insurance company co-operating with service provider and mobility industry. Mobility as a service industry instead of vehicle ownership combined with other mode of travel options such as public transport and rental scheme are possible structural transformation alternatives to reduce mobility cost and to combat the negative environmental impacts. The feedback effect is a de-growth initializing positive feedback effect.

The positive feedback effect $11 \rightarrow 21 \rightarrow 11$ in table 30, established between the variable Economic development (11) and Rural-urban dynamic (21) is an external influence affecting mobility system. The feedback effect also indicates strong leverage condition for current mobility system development. The influence of economic growth strongly influences the increased mobility of people and goods, which further enhances the economic growth. The feedback effect is growth initializing in which the control of de-growth is not so easy. The balance between rural and urban development are critical for mobility system to remain stable especially in terms of space usage and availability of services. The current trend of urbanization and shrinking rural population is global problem which needs alternative measures [6], [12]. They are linked to many different aspects for quality of life measurement apart from mobility system. The major mobility system consideration as of today is on urban development and less on the rural mobility need. The rural economy addresses the vital source for agricultural consumables, whereas the urban economy is mostly based on service sector and industrial growth. However, the mobility challenges remain the same in both rural and urban region, where the connectivity plays critical role for the control conditions.

The role play, characteristics and impact defined in table 30 are important building blocks for design of sustainable mobility system. The cybernetic effect can be alternatively simplified based on the fundamental behaviour of the variables influencing the development of mobility system. It has to be noted that the basic feedback effect is not the conclusion for the design of the sustainable system. This basic effect influences the development of larger cybernetic effect system shown in chapter 5, which can of course be adjusted depending on the context. The contextual justification and cybernetic deduction process does not depend on the statistical parameter for making generalized fit for all prediction [8], [9], [11], [24], [30], [32]. Therefore, a conclusion can be drawn based on this limitation that the statistical evidence does not provide meaningful transformation, which requires extensive integration of cause and effect relation. In this context, making a decision depends on how the system is made to behave without disturbing the self regulatory dynamic of the system. Changes in statistical parameter should not influence the transformation of the system, but should be based on the network of influencing effects between the variables defining the system, which is complex and cybernetically well-established.

6.2 Role of control variable

The control variables are those variables that develop opposite effect during one to one effect construction in the cybernetic effect system, which is adjustable depending on the context. Depending on the result of desired adjustment, the variable are made to enable the control in the network of influencing effects as negative feedback effect, which is necessary for system self-regulatory dynamic [8]. The systemic roles of the variables in the system image of chapter 3 in figure 6shows, the variables Enabling condition (14), Mobility service (7) and Economic development (11) have strong leveraging effect. However, the leveraging variables tend to influence each other and are in the positive feedback cycle $7 \rightarrow 14 \rightarrow 11 \rightarrow 7$ as shown in figure 41, unless they are externally controlled. The control condition can only be seen in the negative feedback that tends to influence the identified positive feedback. For example, Political power (20) has strong control potential in the system, which can be seen in the feedback cycle $11 \rightarrow 20 \rightarrow 14 \rightarrow 11$ developed between the variables Economic development (11), Political power (20) and Enabling condition (14). The variables Enabling condition (14), Political power (20) and Economic development (11) are interventions from outside of the system whereas the Mobility service (7) is internal mobility system leverage condition.

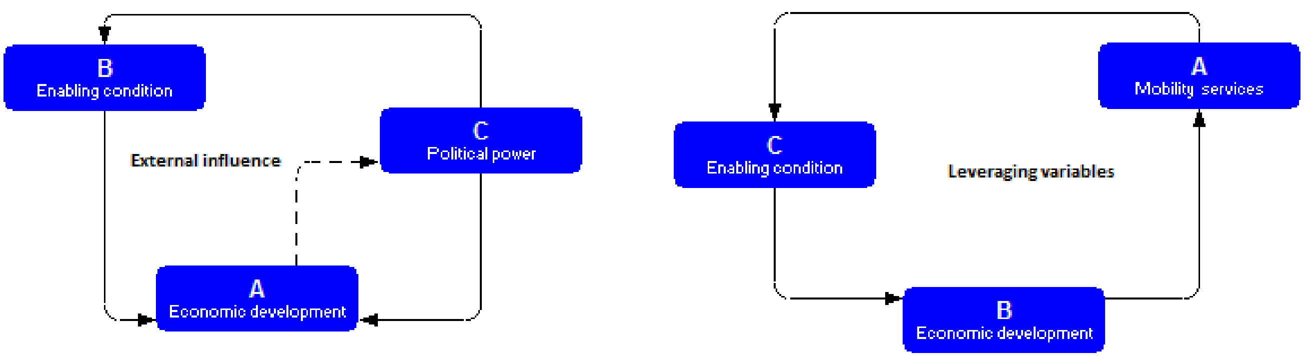


Figure 41: Critical and lever of change variables effect in the system

The left-hand side of figure 41 shows the external control variable Political power (20), which behaves as strong system control variable for feedback effect $7 \rightarrow 14 \rightarrow 11 \rightarrow 7$. Strong and stable political system tends to shape the economy initially and as economy is fully developed, the political influences seem to depend on power of economic growth [1], [2]. Therefore, strong political power enhances the economy by creating Enabling condition (14) for growth but the strong economy weakens the Political power (20). As the economic growth falls back, the voice of the people tends to increase. However, the domination of economic power weakens the control measure. This is where the behaviour of consumer is expected to change who allow the change process to be supported by shifting their consumption habits [15], [18]. Therefore, the influence of Political power (20) on consumer behaviour can have value addition, where the commitment to reforms of system policy as a system change agent is very necessary.

The right-hand side of figure 41 show, the positive feedback cycle with the internal mobility system leveraging variable, where the better Mobility service (7) is the key to Economic development (11) in which the economic transactions demand for more mobility services. As mobility services are improved, they create better Enabling condition (14) for further economic growth, unless external intervention is used to control the growth cycle. Since this is a positive feedback effect with only the equal effect, it is a continuous growth situation. Although the cycle seems to initialize the Mobility service (7) growth development, it is not self-regulating in long-term future and therefore the system potentially collapses [8].For this reason, a negative feedback effect is required to control the system by identifying the control variables in it. From the previous feedback effect, it is realised that the external influencing variable Political power (20) as system controller is required to self-regulate the service growth of the mobility system.

The feedback cycles in figure 41 unfold the condition of current trend of urbanization and the mobility system development. Even if the mobility function is transformed from product consumption to service consumption, the influence of economic development and weak enabling condition will create mobility system to remain inevitably unstable [15], [18]. The condition for mobility system to be stable will depend on strong political support that depends on people's participation, which will determine the control variable enabling the system leverage conditions in a participatory approach [8], [21]–[24]. Further they are subject to stabilising negative feedback effect with the rest of the variables in the system that defines the internal mobility system development for design innovation [15], [18]. The uncertainty condition of the leveraging variable enforces the system to depend on optional alternative for the system to transit from unstable state to stable state, whereby the mobility as a system remains sustainable in the future with the defined system vision. Therefore, defining alternative options from the leveraging variable is subject to control condition, which can be visualized as a conditional future scenario from the defined vision of the system in the present situation.

From the above control factors that are involved in the mobility system, affecting the leveraging variable in the positive and negative feedback effect shows, it is impossible for the system to remain in stable state without the help of control variables. Therefore, the identification of multiple future scenarios is the only option for those possible control conditions to enable the system self-regulation for the defined vision. Hence scenarios are critical for future development of the mobility system. From the identified variables for system vision that tend to enable better Human wellbeing (22) and Environment pollution (12), the entire mobility system can be controlled by the control variables Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11), Political power (20), Rural-urban dynamic (21) as they tend to develop opposite effect with other variables on a contextual basis as observed in chapter 5. Therefore, conditional scenario can be projected for these control variables.

6.3 System vision: Future image projection

Defining system vision is influenced by identification of contextual future scenarios and they are unpredictable[9], [32]. Unpredictable future can however be identified from the cybernetic effect, which is complex and time consuming process as seen in chapter 3 and 4. Therefore cybernetic characteristics of the variables defining the system and their influencing effects enable contextual scenario identification and they represent future scenario [8], [10], [11]. Based on this property of the system, the future scenario is defined as an intelligible description of a possible situation in the future that depend on complex network of influence factors [8], [11], [28], [30], [133]. In this context scenario analysis is future projection as seen in Gausemeier's scenario logic, system analysis by Vester and Quattro Stagioni logic for a conclusive deduction of cybernetic effects [8], [20], [30], [133], [134]. The future scenario can be best identified by combining all three method in APS approach that integrates all three method [10], [11]. The scenario processes are as follows;

1. Scenario preparation: Scenario preparation depends on scenario base identification. The scenario base is an assessment of decision field in its mandatory situation [30]. This phase of scenario resembles the system vision definition from the analysis phase of mobility system with the help of Vester's Sensitivity Model [8], [39]. The two possible visions are identified in the beginning of this chapter. They are Environment pollution (12) control and improving Human wellbeing (22). This two decision fields can be used to project the possible goals of system from either one of them as system visions.
2. Scenario field analysis: Scenario field analysis is a process of key factor identification[30]. The key factors are characteristics that play great role in determination of scenario-field. This phase can be compared with the critical variables identification in the Vester's Sensitivity Model that tends to leverage the decision field [8], [39]. From the Vester Sensitivity Analysis, Mobility service (7), Economic development (11) and Enabling condition (14) are identified as a key factor for system leverage.
3. Scenario prognostic: Scenario prognostic is a process of projecting at least three possible developments of key factors in the future [30]. The future of the defined decision field in step 1 is followed by these projected possible goals from the key factors. The positive and negative feedback effect from the Vester Sensitivity Analysis opens for the possible development and control conditions based on the what if logic [8], [39]. From this step follows the future projection.
4. Scenario-development: Scenario development is intelligible description of possible situation in the future, based on complex network of influence factors [8], [11], [28], [30], [133]. Range of possibilities is described in this process from the key variables and their possible development. This is where alternative options and contextual need can be defined for the desired decision field.
5. Scenario-transfer: Scenario-transfer is the process of developing a strategy for the desired decision field in the future [30]. This is a final step where analytic decision support for future planning of the system is

explored in the current situation. Therefore, this final step is a recommendation for system planner and decision maker to implement the transformation process of the decision field by modifying the possible future through the key factors.

From the above five steps for scenario development, the Vester Sensitivity Analysis already covered the first and second phase and partially the third phase. That is to say 1 to 3 from the above steps is fully or partially covered. So far, the system´s variables description and defining their systemic role in chapter 3& 4, variables cybernetic effect system in chapter 5 and target variables for system's vision definition in the beginning of this chapter are known from the analysis of mobility system. The vision of the system can potentially be defined by exploring possible future goals and the multiple influence factors observed in the effect system and feedback effect in the system analysis is further projected. The critical variables enable the leverage of the potential target variable for system's vision definition. Therefore, system transformation is dependent on the definition of system's vision, mission, goal, strategy, objective and action plan, which is fully influenced by the complex interdependency of the global variables list in chapter 3 until the beginning of this chapter.

System vision: Target variables identified in the beginning of this chapter that are influenced by leveraging variables are potential for system's vision definition, which has clear future path for system transition to sustainable development. Leverage condition of the target variable depends on the feedback effect contained in the leveraging variable that influences the target variable as observed in the beginning of this chapter. From the entire analysis of the mobility system, the variables Human wellbeing (22) and Environment pollution (12) is reconfirmed as a potential target variable for mobility system vision, which has the potential for system transition to sustainable development. Although there can be many scenarios for the success potential for the defined mobility system vision, the vision of mobility system is single and roughly clear future image. It has to be noted here that, it is the intention of observer to transform mobility system into sustainable mobility, considering the cybernetic effect of the system defined by a set of 22 global variables. Therefore, defining mobility system vision potentially rests on many target variables, which can be further projected. The current cybernetic deduction justifies that the variables Human wellbeing (22) and Environment pollution (12) exhibit clear future path and have the potential to capture all variables systemic role, which are at stable equilibrium due to their tendency of co-existence as negative feedback effect as seen in chapter 5. Therefore, mobility system vision can be defined from this negative feedback effect as follows;"*Improve human wellbeing by providing safe, equitable and environment friendly mobility services*". To achieve this system vision, mobility system can have multiple goals and strategies to overcome their development challenges in future. They can be explored in the cybernetic effect system from the Vester Sensitivity Analysis and scenario development approach to visualize future image of mobility system [8], [20], [30], [133], [134].The vision statement, which is based on the target variable identification, is dependent on the system leveraging variables Mobility service (7), Economic development (11) and Enabling condition (14) as potential leveraging variables to enable Human well-being (22) and the control variable Environment pollution (12) for system self-regulation. Therefore, from this broad system vision, possible system goals and strategies to develop them depend on the effect system and feedback effect on a contextual basis. For example, the internal system leverage potential can be explored through the variable Mobility service (7) and its positive and negative feedback effects. The leverage potential of the mobility system by external influence can be explored from the variable Economic development (11) and the conditional control variable to enable their development can be explored from the variable Enabling condition (14). These three critical variables, also called as the key factors, play significant role for mobility system transition to sustainable development, which enable potential future scenario projection as an alternative and multiple system goal for the desired mobility system vision.

It has to be noted here that it is the intention of the observer to transform the mobility system to sustainable mobility system, based on the cybernetic effect of variables forming mobility as a roughly complete system, which is however adjustable depending on the context. Therefore whole system can be extensively communicated for different contextual need and depending on different geo-political situation and does not limit to one single fit for all strategy defined by the associated goal to reach to the intended development. However, the executable system depends on the entire condition explored so far in the test model and also additional hidden scenario field, which needs further research. The cybernetic effect system of chapter 5 already indicates multiple possibilities that depend on how system is made to function. Therefore, the context, decision field, scenario and vision definition depend on the desire of system user rather than that of the intention of system observer, which can only be realised through heuristic decomposition of the test model with all the involved actors of the system [8], [11], [20], [30], [133], [134]. The heuristic decomposition in this study is conducted involving students, academic experts and general mobility system experts, but the actual context has not yet been tested for different contextual need. However the empirical evidences are explored taking into account the mobility situation of Bhutan as a case study, which can be seen in chapter 4 and in sections 6.7.

6.4 Goals: possible situations

The defined vision of mobility system is contextual and therefore will have multiple future options, which determine the success potential for the system transition to sustainable development [11], [18], [29], [30], [51]. The defined vision to "*Improve human wellbeing by providing safe, equitable and environment friendly mobility services*" is the desired mobility system transformation from the result of mobility system analysis by the observer. For the system to be leveraged to the defined vision, critical variable identified so far are Mobility service (7), Economic development (11) and Enabling condition (14). Projection of these key variables will give the range of possible options in the future for the success of defined vision through each one of them. The feedback effect of chapter 5 will play critical role for the projection of key variable to reach to the desired vision. The network of influencing effects seen in the positive and negative feedback effects that enable the system's growth or de-growth and control conditions will follow in every scenario of key variable projection.

Considering the feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ as a status quo of the mobility system in the current state from the feedback effect of chapter 5, it indicates de-growth requirement for the mobility system to be sustainable. For the system's self-regulation from the above feedback effect, identification of control variables from the corresponding negative feedback effect is necessary. For this feedback effect the system control variables for system's self-regulation are Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21). It is also important to note that the key variables Mobility service (7), Economic development (11) and Enabling condition (14) are interdependent to each other at different stage of their development from the above feedback effect. Furthermore, it is also important to note the choice of this long feedback effect from the list of 126 positive and 119 negative feedback effects. Being the longest positive feedback effect it gives more or less the complete status quo of current situation. Therefore the projection of key variables to at-least three possible future alternative will have to be explored based on the influence factors of the variables present in the feedback effect [30].

The key variable Mobility service (7) influences the demand side internal scenario field, whereas the key variable Economic development (11) influences the supply side external scenario field. The key variable Enabling condition (14) influences soft control condition and will have control scenario field for either one of the key variables. Each one of the key variable responses to the system's general vision "Improve human wellbeing by providing safe, equitable and environment friendly mobility services". The key variables will have a range of possible futures and among others the most critical ones are business-as-usual scenario, shift from product centric business model to service centric business model, and shift from motorization to digitalization of mobility system. The three scenario fields of demand-side, supply-side and control condition for either one can enable transformation of the mobility system to desired vision.

6.5 Cross consistency analysis

So far the system variables are screened for vision, goal and associated scenario projection, which is however dependent on the indicator defining the critical variables identified. The approach can be seen in General Morpological Analysis (GMA) and is applied as further assessment to weedout the constraints [29]. The GMA principles are extensively used for potential future scenario projection [30].

Table 31: cross consistency assessment

Cross consistency of target variable and leveraging variable 1 =Total inconsistency 2 = Partial inconsistency 3 =Neutral or independency 4 = Consistency 5 = Strong consistency		Environment pollution(12)					Human wellbeing (22)				
		Air pollution	Waste generation	Noise pollution	Space utilization	Lubricant and fuel spillover	Quality of life	level of satisfaction	Health and safety	Freedom of choice	Reduced financial burdens
Mobility services(7)	Multimodal public transport	3	1	1	2	1	3	4	1	5	4
	Car rental scheme	3	1	1	4	1	4	4	1	5	3
	Online booking system	1	1	1	1	1	4	1	1	3	1
	Local and regional connectivity	1	1	1	1	1	3	3	1	1	1
	Maintenance services	1	2	1	1	4	1	1	1	1	1
	Regular training	1	1	1	1	1	1	1	1	1	1
	Home office scheme	4	1	3	3	1	3	1	1	1	3
	Incentivized parking facilities	1	1	1	4	1	1	2	1	3	4
	Ownership free driving incentives	1	1	1	1	1	2	4	1	5	3
Economic development(11)	Type of businesses	2	3	1	2	1	5	4	1	1	4
	Financial flow	1	1	1	1	1	1	1	1	2	5
	Service sector	1	1	1	1	1	5	3	1	1	1
	Production center	5	4	2	1	4	1	1	4	1	1
	Consumption center	1	5	1	1	1	4	4	4	1	1
	Transaction Type	1	1	1	1	1	1	1	1	3	3
	Tourism and recreation	4	4	4	1	1	3	1	1	1	1
Enabling condition (14)	Tax holidays	1	1	1	1	1	2	2	1	3	5
	Incentives	3	1	1	1	1	3	1	1	1	4
	Performance award schemes	4	3	1	1	1	1	4	1	2	1
	Law and policy reforms	5	4	2	3	1	1	1	1	1	1
	Reliable and affordable options	1	1	1	1	1	3	3	1	3	5

The cross consistency using GMA approach has two objectives that are the parameters defined by system variable and values defined by indicator of the variables to give more detail on internal influencing effect and the removal of inconsistent values. Table 31 shows these internal influencing effects of leveraging variable and the target variable. Both leveraging variable and indicator variables are adjustable and therefore the expectation of system user determines their development. The intention of observer in this study is to analyse how can system be sustainable and what are the potential scenarios for their development. Additionally, it has to be noted that the internal influencing effect is connected with the other system variable, which makes the goal and vision definition an iterative process. Cross consistency assessment of table 31 enables more detail definition on how system 'ought to be' and how the system 'is' for the desired vision visualization. Since this is an irreducible systemic property, the scenario developments are descriptive and follow normative values justification. For this purpose, the variable's influencing effect including that of its values pinpoint, the problem space and how system ought to be and how system is, can be projected. Additionally, the change requirements are necessary for the desired transformation to be visualized more clearly in the scenario field.

Variable's values that are defined in chapter 3 are once again reflected in cross consistency table 31 for further assessment to check, how consistent are the variable's values in the influencing effect by which 'is and ought to be' scenario justification can be projected. With these steps the large cybernetic effect system is reduced to small size that can inform many decision-making fields for other variables. The leveraging variable Mobility service (7) has 9 values defining its role in the system. They are: Multimodal public transport, Car rental, Online booking system, Local and regional connectivity, Maintenance services, Regular training, Home office scheme, Ownership free driving incentives (loan/company offer) and Incentivized parking facilities. The leveraging variable Economic development (12) has 7 values defining its role in the system. They are: Type of businesses, Financial flow, Service sector, Production centre, Consumption centre, Transaction type, Tourism and recreation. The leveraging variable Enabling condition (14) has 5 values. They are: Tax holidays, Incentives, Performance award schemes, Law and policy reforms, Reliable and affordable options. Similarly, mobility system target variable Environment pollution (12) has 5 values. They are: Air pollution, Waste generation, Noise, Space utilization and Lubricant and fuel spill over. The target variable Human wellbeing (22) has 5 values. They are: Quality of life, Level of satisfaction, Health and safety, Freedom of choice and Reduced financial burdens. The consistency check for leveraging variable and the target variable based on their values is what is called here as consistency matrix as shown in table 31. The variable's values can be further broken down in normative format for their development in the future for 'is' and 'ought to be' justification.

The influencing effect of leveraging variable Mobility service (7) with its 9 values can be verified based on three conditions such as: how the system is in the current situation, how should the desired system look like and what change is required for transformation. For example, the value Multimodal public transport is neutral with Air pollution and Quality of life but is consistent with the Freedom of choice, Level of satisfaction and Reduced financial burden. Multimodal public transport service in the current situation is limited to public transport service, which has the potential to improve the quality of life of the commuter. It also has the potential to address the Level of satisfaction and possibly decreasing Financial burden for the commuter. Similarly, the Rental option for driving a car gives freedom of choice for the user, which is at the moment fully dominated by ownership culture. Mobility maintenance service for example has strong consistency with the Environment pollution such as Oil and lubricant spill over control measure, which is often time unnoticed for projection of future scenario. The value Home office service has strong consistency to reduce travel and therefore reduce Air pollution. The value Incentivised parking facilities has strong consistency to enforce the parking regulation and therefore the Space use optimization. Finally, the Ownership free driving is an ambitious goal, which intends to shift the complete mobility industry to sell services instead of products, which has the potential to optimize the product value. Thus from the leveraging variable Mobility service(7), the direct impact on the target variable can be found in Air pollution, Freedom of choice and Space usage, which require strong alignment of other system variables to those conditions. The fundamental transformation requirement can be influenced by behaviour correction of the user, which can be influenced by other system variables.

The leveraging variable Economic development (11) with 7 values follow the same question of how is the system in current situation, how should it look like in the future and how can it be transformed. The variable's value Type of business is consistent with the Quality of life and Reduced financial burden. Type of business influences major changes in the life style of people, which needs much more transformation for the desired vision to transform the mobility system to sustainable system. The value Financial flow strongly determines many hidden aspects of Financial burden to the user, which is normally seen as profit marginalization rather than the end value creation. The strong consistency can also be observed in service sector economic growth to enable the development of service consumption and increasing the product value, which can be dominated by product durability concept of product development for business continuity [110]. The most important value influencing the mobility system is seen from Production centre and Consumption centre, which determine the travel distance requirement for goods and service flow. The travel distance is directly linked to the Air pollution. Therefore, the leveraging variable Economic development (11) has strong influence for mobility requirement and the target value influenced by them are Air pollution and Financial burden to end user. The basic consideration recognizes the need of decentralization of production and consumption centres. However, they are strongly influenced by other system variables to enable the desired development.

The leveraging variable Enabling condition (14) with its 5 values can potentially enable the system transformation. The leveraging variable's values enable the change requirement for how the mobility system is in current situation and how the system should look like. The value Tax holiday has strong consistency with the target value Reduced financial burden. The Financial burden tends to weaken the success potential of both transformation of Mobility service (7) and Economic development (11) defined by their values to the target variable's values. In the current situation profit-oriented market competition has pushed the mobility system to fully motorized travel behaviour. The value such as Performance award scheme has strong consistency to enable Air pollution control enabling non-motorized travel behaviour. Similarly, the values such as Enabling reliable, Affordable and Alternative mobility options have strong consistency on Reduced financial burden. Thus, the variable Enabling condition (14) strongly influences the target variable's values Level of satisfaction, Air pollution control and Reduced financial burden. The variable´s values are descriptive about, how the normative orientation of variable Mobility service (7) and Economic development (11) should be facilitated with regulatory and non-regulatory norms.

The variables values and their cross-consistency indicate that the service orientation of economy and the mobility of both product and goods is fundamental condition for transformation to sustainable mobility system. However, the service orientation is strongly dependent on the change requirement addressing user behaviour. The behaviour change is therefore the major influence factor for mobility system transformation to sustainable mobility system. The observer's verification based on variables normative values about how the system is and how should it look like can now be simplified as business as usual case, which is how the current system is offering the mobility service and further projection of alternative options. The alternative options can be seen as service orientation of the leveraging variables Mobility service (7) and Economic development (11), where variable Enabling condition (14) enables user behaviour change requirement. The service orientation can be potentially enabled through virtual services and shared mobility options [45]. Therefore, three potential goals can be projected, they are: business as usual case, service orientation and system digitalization for scenario field analysis to leverage the system with the help of critical variables and the target variables. It has to be noted that the other system variables strongly influence any changes made in the leveraging variables. Therefore, step by step process is necessary for goal definition and scenario field consideration. We will see this process in section 6.5.1 to 6.5.3 with the inclusion of feedback effects for goal definition, which can be bundled further as scenario. Furthermore, the process is highly context dependent, which is subject to iterative process. Thus, there is nothing like one fixed goal and fixed value proposition. It is fully dependent on the contextual scenario, variables and their values influencing the transformation process. The current projection is however focused more to service orientation of mobility system for transformation to sustainable mobility system. It has to be noted that, although principles of General Morphological Analysis and cross-consistency enable scenario management , it does not necessarily follow the strict rules about the principles of GMA and clustering technique as the proposition of values and scenario are normative and is adjustable keeping in mind the large system image will remain un-distorted [8], [10], [11], [18], [29]. The context here is therefore to address demand projection, supply projection and control measures with the help of the above-mentioned leveraging variables and their influencing feedback effect considered initially.

6.5.1 Demand side management

The demand side management refers to how the mobility requirement is and how should it look like for the desired vision defined earlier. The demand side management can be explored in the critical variable Mobility service (7) as seen in section 6.5, based on the cross-consistency analysis for the desired vision to "Improve human wellbeing by providing safe, equitable and environment friendly mobility services". The goals that will target the defined vision depend on the control strategies for the worst-case scenario to the best-case scenario as summarized in table 32. In the worst-case scenario the business as usual development is in any way possible even without any intervention in the system. The moderate scenario, which is widely known but not yet been able to implement it fully, is to shift the mobility function from product to service orientation [45]. The more ambitious scenario, which is less known, is to digitalized mobility system where the growing development of artificial intelligence plays a critical role to support its development [46].

Table 32: The possible options for mobility service

Mobility service	Business as usual demand (worst case)	Service demand (better)	Digitalized mobility (best case)
Infrastructure development	Infrastructure growth	Optimize infrastructure	Digitalized infrastructure
Fuel energy security	Conventional fuel	Alternative fuel	E-mobility
Institutional capacity	Product design	Service design	Innovation design
Spatial dynamic	Increase congestion	Control congestion	Decrease congestion
Accessibility	Motorization	Non-motorization	Virtual platform
Capital investment	Low investment	Moderate investment	High investment
Operational capital	High operation cost	Moderate operation cost	Low operation cost
Economic development	Product focused	Service focused	Digitalized services
Enabling condition	Competitive market	Preferential market	Regulated market
Attractiveness and aesthetic	Highly preferred	Attractive alternative	Inexperienced field
Political power	Very weak control	Need control measure	Require strong control
Rural urban dynamic	Rural-urban migration	Urban-rural migration	Neutral

While the identification of three possible developments from the key variable addresses goal for the system vision, the strategy to address them depends on the network of influence factors from the effect system and the current choice of feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ from chapter 5 on a contextual basis and the cross-consistency analysis in section 6.5.

<u>Business as usual:</u> In the business as usual case the mobility service is mostly based on the product and technology development as witnessed in the current situation. The Infrastructure development (1) will potentially grow to enable the Mobility service (7). However, the motorization trend will dominate the access requirement connecting rural and urban areas for the movement of both people and goods. Although rural-urban

access can be improved, daily commutation will be heavily influenced by personal car ownership. More importantly, if regulatory measures are not put in place, the public transport service will face the challenge of lack of passenger and logistics operator will face the challenge of lack of business for goods transport. The consequence of such development leads to disadvantaged population group to shift to urban areas for jobs and business search. In such situation the variable Rural-urban dynamic (21) will potentially exhibit migration of rural population to urban area. The rural-urban migration and increased motorization trend for access lead to congestion of settlement area and disturbances in the free flow of the road transport. Thus, the variable Spatial-dynamic (5) leverages the system to behave as if space growth is virtual requirement. However, the space expansion is impossible, which tends to make the mobility system less attractive for movement of both goods and passengers. On the other hand, the consumer behaviour will not change despite system being leveraged too unattractive for user. Therefore, the variable Attractiveness and aesthetics (16) will require a better Enabling condition (14). There are two possible chances for creating attractiveness for the consumer. The first being the internal correction where Technology development (2) plays critical role and the second the external influence factor Economic development (11). For the Technology development (2) the feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ will address positive growth, which will enable alternative product design, where the size of passenger car can be redesigned that creates lesser space demand. For the variable Economic development (11), competitive market will continue to dominate the mobility service requirement. In this scenario the Economic development (11) exhibits the role of business growth outside of mobility system and is least bothered to influence the mobility system unless the control interventions are made. The consumerism trends continue to increase the product centric economic growth. What if the Political power (20) influences the consumer behaviour through policy reforms? However, the controls are very weak due to the economy dominating the market force. Possible reforms are to liberalize fuel import tax and strengthen international trade. Alternatively, the possible development is also to be expected on environmental standards requirement for mobility choice and fuel standards to address that development. Thus, the variable Fuel energy security (3) will indicate the need for a change. The influence of the fuel standard aligns with the environment standard also has the potential to address the mobility cost by lowering the Operational capital (10) through the incentives scheme on high standard fuel and emission reduction target setting. However, such development will have strong impact on Capital investment (9) and Institutional capacity (4). Both variables will face the bottleneck situation, if it is an underdeveloped country with lack of skilled human resources. Thus, in the business as usual scenario, although the control measures are made, they tend to behave differently. The desire of improving Human wellbeing (22) will be fulfilled for short time with all those interventions and the system is once again leveraged to unsustainable growth. Therefore, for such development goal 1 influences the system development.

Goal 1: Enhance mobility growth through adoption of existing best practice to achieve better quality of life

Service centric mobility: In the service centric mobility, the product durability and quality improvement will target the increased service development by optimized product usage. Therefore, product's active life will become a key control condition for business growth. Consumer behaviour tends to shift from quality product consumption to quality service consumption. This type of mobility option can be compared to smart phone demand by the consumer on monthly payment rather than one-time investment to fully use the best smart phone, which is otherwise expensive. Same applies to mobility system where the automobiles durability and quality will have to be improved for multiple uses and ride sharing culture encouraged. In such a scenario the Infrastructure development (1) will require up gradation and maintenance for quality requirement rather than the growth demand to enable Mobility service (7). Although the consumer behaviour for motorized mobility will continue to grow, the mobility function will demand for more service growth in which demand for convenient rental scheme increases due to consumer behaviour change. On the other hand, the public transport services are increased and ride sharing cultures are enabled through consumer corporative for the mobility needs in the community. In such a scenario the consumer behaviour is influenced by multiple service options for both goods and passenger movement. Access to the mobility will be influenced by the consumers, which potentially increases the service demand. Such kind of development in economic sense is a competitive market, where consumers determine the demand based on the availability. Therefore, service centric business will potentially increase the Accessibility (6). The multiple service access for different population categories will have major turn over where more people are willing to stay in the regional community for both good quality life and to take up the service business. Therefore, the variable Rural-urban dynamic (21) will exhibit the slow migration of congested urban area to rural area because of the availability of services that are equivalent to urban centres. Due to the reverse migration and ride sharing services, the congested urban settlement and disturbances in the road traffic will potentially improve. The Spatial dynamic (5) which is seen to be constant will be reorganized, where the space availability will appear to virtually increase. What if logic from Vester's partial scenario can also be explored in such change process. For example, what if the service centric business influences the consumer behaviour shift from ownership to ridership completely for mobility demand? The negative feedback effect $6 \rightarrow 21 \rightarrow 11 \rightarrow 7 \rightarrow 6$, which tends to self-regulate the mobility system will have strong role to play for system stabilization. That is to say the behaviour change of the consumer influences the shift from centralized economic growth to decentralized economic growth, where the Mobility service (7) demand increases instead of product demand. Therefore, the variable Attractiveness and aesthetic (16) will show sharp rise for mobility demand with more service options that address better quality of life for movement function for both passenger and goods. The mobility system is regulated by the consumer behaviour based on the availability of services, which will have cascading implication on the need for better Enabling condition (14) for economic reforms and also for technology durability and quality assurance. The positive feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ will face increased demand for product durability and quality improvement. Furthermore, the consumer decides the market development that literally addresses the people's voice to enhance Political power (20), where Economic development (11) will be decentralized by people's participation. The political control for fuel quality and cost will also strongly influence the consumer decision on service choice. Therefore, the Fuel energy security (3), which is widely known to be a problem, will potentially become an opportunity. Alternative fuel for mobility can potentially be adopted. Further the service Operational cost (10) and Capital investment (9) requirement will influence the need for human resources capacity development to address behaviour change of the consumer. Therefore, the social norms and value system expressed by the variable Cultural values (15), which is not yet fully linked to the mobility system, will increasingly become important. Thus Institutional capacity (4) requirement will be based on the consumer decision on the choice of service quality and user friendliness, where service innovation is key assert for institutional growth. Based on those scenario conditions the vision of Human wellbeing (22) improvement will be more sustainable than that is addressed in the product centric business as usual scenario. However, the key control for system transformation will depend on service quality and consumer behaviour. Therefore, goal 2 can be formulated to reach to the vision statement.

Goal2: Increase service demand by behaviour shift of the consumer to achieve better quality of life

Digitalized mobility: The scenario, in which the mobility system is digitalized, is a condition where consumer behaviour is strongly influenced by the technology. In such a scenario mobility system is fully or partially digitalized. Mobility system is fully dependent on ICT technology and system automation. This scenario is comparable to the increasing consumer dependency on social media platform for communication and transaction at various levels including many executive decisions. In such a system Infrastructure development (1) is transformed to digital system to enable virtual Mobility service (7). The consumer tends to depend on virtual platform for movement function such as online services. Thus, the Accessibility (6) is strongly influenced by access to ICT network for the mobility requirement. Due to the presence of virtual platform, it can be anticipated that the mobility need will be potentially reduced. Consumer demand for home office tends to increase wherever physical mobility is unnecessary. Such options have the potential for consumers to move away from the congested urban areas and perform the task online as much as possible from the native home towns, which are often time rural areas. Therefore, the variable Rural-urban dynamic (21) seems to exhibit urban to rural migration for better quality of life. The myth of urbanization is illusive in relation to Human wellbeing (22), where the truth of quality of life is relative. In the current state the growing stress factor seen in the behaviour of busy urban dwellers, the better quality life is expected to be found in rural areas especially in native home towns. The behaviour of the consumer that manifests the reverse movement will have the potential for reorganized space and land use change. Thus, the variable Spatial dynamic (5) exhibits the decongestion and increases Attractiveness and aesthetic (16) for movement function. The consumer behaviour is however enabled by Technology development (2). Thus, the variable Enabling condition (14) tends to enable Technology development (2) as a main control factor. The positive feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ will play important role for enhancing service development by technology innovation. On the other hand, the ICT based automation will fully dominate the economy, where the virtual business world can be expected. The variable Economic development (11) is expected to influence and leverage mobility system for growth development, which is not the desire of the consumer. Therefore, the controversial questions on the developing artificial intelligence will have to be regulated by Political power (20). Unless the control conditions are applied in the technology enabled behaviour of the consumer, the growth is inevitable as it was witnessed in the industrial era after the Second World War. On the other hand, the consumer behaviour can also be fully influenced for alternative fuel source. E-mobility that is seen to face market penetration challenge today will be easily integrated in the digital mobility system. Therefore, the variable Fuel energy security (3) is expected to align more towards consumer opting for automated driving, which indicates e-mobility as a choice by the consumer. However, the system will demand for very high Capital investment (9) to fulfil the wishes of the consumer. The business scenario in such case indicates low Operation capital (10) for mobility system enabled through efficiency improvement for the system operation. In such a scenario skill demand for ICT operation and maintenance is critical. Therefore, the variable Institutional capacity (4) will have to orient the skill development to fulfil digital services for movement requirement. Hence it can be envisioned in the digitalized mobility mode, the Human wellbeing (22) is expected to improve but also the virtual platform will continue to dominate the social values. Therefore goal 3 can be projected for the desired vision.

Goal 3: Increase service demand by technology innovation to achieve better quality of life

From the demand side response of the leveraging variable Mobility service (7) it indicates, the future of mobility system can take any one of the following possible goals. Note that goal 2 and goal 3 are closely related and their development tend to show gradual shift for consumer behaviour correction.

1. Goal 1: Enhance mobility growth by adoption of existing best practice to achieve better quality of life
2. Goal2: Increase service demand by behaviour shift of the consumer to achieve better quality of life
3. Goal 3: Increase service demand by technology innovation to achieve better quality of life

Either one of the above goals and / or all of them in partial form can address the vision to "Improve human-well-being by providing safe, equitable and environment friendly mobility services". To assign the goal to the desired vision, same goals have to be aligned to the system´s influencing variables from outside and control requirement for both of them. In the demand side management it expresses the commuter/consumer desire and wishes for movement requirement. Note that the demand side management through value free goal definition is somehow linked to the consistency analysis in section 6.5, whereas in this step other system variables are integrated in the process. Therefore, the process is iterative and context dependent, which is still cybernetic in nature. The future of sustainable mobility is seen in service development.

6.5.2 Supply side management

The supply side management refers to how external influence is influencing the mobility system and how it should look like for the desired vision to transform mobility system to sustainable mobility system. The supply side response can be explored from the critical variable Economic development (11) as a leveraging variable for the desired vision to "*Improve human wellbeing by providing safe, equitable and environment friendly mobility services*". The goals that will target the defined vision depend on the control strategies for the worst-case scenario to the best-case scenario as summarized in table 33. Similar to the demand side management in the worst-case scenario, the business as usual development is in any way possible without any intervention in the external system that influences mobility system development. The moderate scenario which is widely applied in utilities and service economy is not yet fully valued, the role of mobility industry for the mobility demand fulfilment by implementing business shift from product centric growth to service centric growth. Well-established but not yet fully applied in mobility system is the digitalized mobility system, where the business growth potential for mobility industry depends on artificial intelligence to fulfil the demand requirement of autonomous mobility especially mobility as energy storage options.

Table 33: The possible options for economic development

Economic development	Business as usual case(worst)	Service centric business(Better)	Digitalized mobility mode(Best)
Infrastructure development	Growth potential	Optimization potential	Saving potentials
Fuel energy security	Increase dependency	Reduce dependency	Increase resiliency
Institutional capacity	For business	For people	For technology
Spatial dynamic	Increase urbanization	Increase free space	Optimized space use
Accessibility	For business	For people and service	Network based
Mobility service	Product development	Service development	Technology development
Capital investment	Increase investment	Reduce investment	Optimized investment
Operational capital	Increase cost	Decrease cost	Revenues source
Enabling condition	Preferential	Normative condition	Regulated conditions
Attractiveness and aesthetic	Profitability	Reliability	User friendliness
Political power	Business controlled	Consumer controlled	Technology controlled
Rural urban dynamic	Centralized growth	De-centralized growth	Neutral

While the identification of three possible development from the key variable addresses the goals for the system vision, the strategy to address them depends on the network of influence factors from the effect system and the current choice of feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ from the system analysis phase in chapter 5.

<u>Business as usual:</u> In the business as usual case, the economic growth is mostly based on the product and technology development as witnessed in the current situation. Therefore, the economic growth will influence the

mobility system growth. The Infrastructure development (1) will potentially increase to enable the Economic development (11). On the other hand, the mobility industries continue to grow by mass production of automobiles to facilitate the movement of both people and goods. Thus, the variable Mobility service (7) depends on the supply of automobiles. The access requirement for various economic services is an opportunity for mobility industry. However, the access demand is facilitated by personal car ownership. In such business model the industrial growth challenges are transferred to the consumer, where the burden of product ownership is consumer daily responsibility for access need. Thus, the variable Accessibility (6) will enhance the growth of automobiles production by the mobility industry. More importantly if alternative measures are not put in place the massive market manipulation encourages the ownership culture as a status symbol. The consequence of such development leads to disadvantaged population group to shift to urban areas for better jobs and business search, where manufacturing and production is the major job market and business options. Due to economic factor the manufacture and production industry are mostly located in a strategic location and are centralized, which is often times very close to urban centres. In such situation the variable Rural-urban dynamic (21) will potentially exhibit migration of rural population to urban areas for job and business search. The rural-urban migration and growth of manufacturing and production industry is expected to increase the congestion of settlement areas and disturbances in the free flow of the road transport in the region of strategic location. Thus, the variable Spatial dynamic (5) leverages the system to increased urbanization, facilitating production and manufacturing industry's growth. The variable Attractiveness and aesthetics (16) will require better Enabling condition (14) for urbanization and land use change. Thus, the mobility system in such scenario tends to influence the economic growth. The external control negative feedback $11 \rightarrow 20 \rightarrow 14 \rightarrow 11$ will behave differently than it is expected. The economic growth tends to dominate the Political power (20), where the economic growth will be prioritised. The demand for automobiles will tend to increase with the massive market manipulation. The influence of Political power (20) for environmental standards requirement for mobility system tends to shift the mobility product standards development. In such situation the ideas of clean fuel, fuel standards and mobility eco-labelling tend to influence the business; the approach will potentially push the mobility industrial market growth alternatively. However, the whole purpose of system de-growth vision is strongly manipulated. It is possible to witness growth of alternative fuel technology for mobility demand requirement. Thus, the Fuel energy security (3) potentially exhibits the shift from one fuel source to another. However, the dependency continues to increase for their development. Alternatively, market competition for Investment capital (9) and Operation capital (10) requirement will potentially face alternative fuel technology development challenges unless strong regulations are imposed on the market growth. In such a situation the Institutional capacity (4) development tends to impose market barrier through increased regulation on the conventional fuel technologies, which will potentially enable public service development especially for passenger movement. On the other hand, consumerism trends continue to increase the product centric economic growth. What if the Political power (20) intends to influence the industrial growth through policy reforms, where alternative fuel is preferred? However, the controls are very weak due to the economy dominating the market force. In such a scenario even if the regulatory measure influences the alternative mobility development, the business behaviour of the industry will remain the same. That is to say the economic growth is still based on increased manufacturing and production of alternative mobility technology. Thus, in the business as usual scenario, although the control measures are made, they tend to obey the growth development. The desire of improving Human wellbeing (22) will be fulfilled for short time with the support of economic growth, which will potentially leverage the mobility system to behave unsustainable growth trend. Therefore, for such development goal 4 influences the mobility system development.

Goal 4: Enhance economic growth through adoption of alternative mobility to achieve better quality of life

Service centric business: In the service centric business, the economic growth depends on product durability and quality improvement, which will target increased service development by optimized product usage. Therefore, product's active life will become a key control condition for economic growth. Industrial manufacture and production behaviour tend to shift from product quality improvement to increase the service business. The business scenario can be compared to utility company providing regular service to household by owning the utility asset such as electric grid, drinking water supply and internet and TV network operator. Same applies to mobility system where the automobile industry owns the asset such as automobiles, fuel system and partly the infrastructure. In such a scenario the Infrastructure development (1) will become collective responsibility of industry and public holdings for the growth demand to enable Mobility service (7). Although the product development continues to dominate the market demand for mobility functional requirement, product life plays a critical role for business growth of industry. On the other hand, the public transport services are liberalized where the quality development influences their market growth, which will further enable industrial competitiveness for quality services. In such a scenario the industrial growth is influenced by access to multiple service options for both goods and passenger movement. Access to the mobility facilities will be influenced by the mobility industry, which will potentially shift the business model of industry, from product market to service market. Such kind of development in economic sense addresses resource efficiency strategy, where material demand for manufacturing and production is decreased by multiple use of product over longer service life. Therefore, increased Accessibility (6) service increases the service market for industry. The multiple service access for different population categories will have major turnover of franchises service business development in regional community, where service decentralization becomes critical for business operation for the mixed consumer. Therefore, the variable Rural-urban dynamic (21) will exhibit the slow migration of congested urban areas to rural areas because of the availability of more jobs in the decentralized service industry. Due to the reverse migration and increased mobility services, the urban road traffic density will potentially improve. The variable Spatial dynamic (5), which is seen to be congested, will potentially be converted to more recreational centres, facilitating mobility service development. The variable Attractiveness and aesthetic (16) tends to influence the market competitiveness for mobility industry· The mobility system is regulated by the availability of quality services, which will have cascading implication on the need for better Enabling condition (14) for economic reforms and also for technology durability and quality assurance for the industrial competitiveness. The positive feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ and the negative feedback effect $11 \rightarrow 20 \rightarrow 14 \rightarrow 11$ tend to obey how the system ought to be, where product durability and quality improvement are strongly supported by mobility system policy. Furthermore, the quality service development decides the market growth opportunity that literally addresses the enhanced Political power (20), where Economic development (11) will be decentralized by industrial participation. The political control for fuel quality and cost will potentially be shared by the public holding and mobility industry. Therefore, the Fuel energy security (3), which is widely known to be a problem, will potentially become an opportunity for mobility industry. Industrial growth can also be aligned to alternative fuel development as new line of business options. Further the service Operational capital (10) and Capital investment (9) requirement will potentially influence the capacity development of industry in service sector business. Therefore, the industrial norms and value system enhances the economic value creation rather than linear growth model. Thus Institutional capacity (4) requirement will demand human-resource capacity, which will have the potential for service innovation and the key asset for industrial growth. The industry owned training institution is likely to take the market leadership. Based on these scenario conditions the vision of Human wellbeing (22) improvement will be more sustainable than that is addressed in the product centric business as usual scenario. However, the key control factor for system transformation will depend on service quality and industrial business model reforms. Therefore, goal 5 can be formulated to reach to the vision statement of the mobility system.

Goal5: Enable service economy development in mobility industry to improve quality of life

Digitalized mobility: The scenario, in which the mobility mode is digitalized, is a condition where industrial growth is strongly influenced by the ICT technology and system automation. In such a scenario mobility system is fully or partially digitalized. Industrial competitiveness is fully dependent on to ICT technology and system automation. In such a system Infrastructure development (1) is transformed to digital system to enable automated mobility. The infrastructure includes ICT network inclusive to the existing road and other form of physical infrastructure. The infrastructure has potential to integrate mobile energy storage through the introduction of smart grid network. Multiple options for mobility function can be enabled through the ICT infrastructure. Therefore, mobility industry and ICT industry play critical role for mobility system optimization for both movement of passenger and goods. Apps based service automation plays a critical role for increasing market demand of mobility industry to facilitate the access requirement. Thus, the Mobility service (7) is available on virtual platform. System automation has the potential for service efficiency improvement and potential for resource saving. Service ownership is shared by mobility industry and ICT service provider. Thus, the variable Accessibility (6) depends on the quality and reliability of ICT service providers and industrial automation. Due to the presence of virtual platforms, industrial competitiveness depends on innovation optimization through mobility system integration with banking services and public and private administration. While the industrial innovation shift from driver to driverless ride can be expected, the ICT innovation has the potential for opening new home office jobs. Therefore, the variable Rural-urban dynamic (21) seems to exhibit urban to rural migration for better quality life. The myth of urbanization is illusive in relation to Human wellbeing (22), where the truth of quality of life is relative. In the current state the growing stress factor seen in the behaviour of busy urban dweller, better quality life is expected to be found in rural areas especially in native home towns. Therefore, the service innovation depends on decentralizing the digital market services, where industrial competitiveness can be expected for extending the digital network coverage. Thus, the variable Spatial dynamic (5) seems to exhibit virtual growth, enabling Attractiveness and aesthetic (16) for movement function through digital and online services. However, the industrial competitiveness depends on Technology development (2). Thus, the variable Enabling condition (14) tends to enable technology innovation as a main control factor for industrial growth. The positive feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ will play important role for enhancing business growth of mobility industry. On the other hand, the industrial automation has the potential to dominate the economy, where the virtual business world can be expected. The variable Economic development (11) is expected to influence and leverage consumer behaviour, which is dependent on technology innovation. Therefore, the controversial questions on the economic growth based on artificial intelligence will have to be regulated by Political power (20). Political intervention for industrial growth value addition can be seen by enabling energy policy for smart management. The control of self-driving autonomous e-mobility will potentially be strong market share in urban areas. The variability of renewable energy management can value add to mobility fuel demand especially in urban centres as mobile energy storage. Therefore, the variable Fuel energy security (3) is expected to enhance fuel saving potential. Capital investment (9) and Operational capital (10) requirement tend to become part of service business models for mobility industry and ICT service providers, which increases system resiliency even at the cost of high investment requirement. In such a scenario, skill demand for ICT operation and maintenance is critical for industrial growth. Therefore, the variable Institutional capacity (4) development will be part of business opportunity for mobility industry. Therefore, in general mobility industry will operate the service business in co-operation with the ICT service providers. Hence it can be envisioned that in the digitalized mobility mode, the Human wellbeing (22) is expected to improve but also the virtual platform will continue to dominate the industrial values. This can be addressed by goal 6.

Goal 6: Increase industrial competitiveness through system automation to achieve better quality of life

From the supply side management of the leveraging variable Economic development (11), the future of mobility system can influence the mobility system vision with following defined goals:

1. Goal 4: Enhance economic growth through adoption of alternative mobility to achieve better quality of life
2. Goal5: Enable service economy development in mobility industry to improve quality of life
3. Goal 6: Increase industrial competitiveness through system automation to achieve better quality of life

Either one of the above goals and / or all of them in partial form can address the vision to "Improve human wellbeing by providing safe, equitable and environment friendly mobility services". To manifest the goal to the desired vision, same goals have to be aligned to the system´s influencing variables from inside and control requirement for both of them. In the supply side management it expresses the industrial desire to transform the mobility business model. So far, the supply side management has been weak in almost every manufacturing and production industry. The business model and economic growth are linear, where the increased consumption influences the increased manufacturing and production. Therefore, shift in business model of industry for industrial competitiveness can be seen in service sector development, where both resource consumption and service value seem to avoid wasteful behaviour of industry and consumer. Similar to that of demand side management, the supply side management is a normative value proposition, which is context dependent and original system cybernetic is still intact. More importantly the external factor that influences the internal scenario development is critical consideration one may recognize from this goal definition. The goals are subject of further adjustment depending on the context. The argument in this study is orientation of economic growth through service centric development facilitating the movement function.

6.5.3 Control measure by policy

Control measure by policy refers to the control measure for both internal and external factors influencing mobility system and how should it look like for sustainable mobility system development. The control is required for both internal and external influence, which can be seen in Mobility service (7) and Economic development (11) in section 6.5.1 and 6.5.2. The control measure for the critical variable that will potentially transform the mobility system can be observed from Enabling condition (7) as a leveraging variable for the desired vision to "Improve human wellbeing by providing safe, equitable and environment friendly mobility services". The goals that will address the defined vision depend on the leveraging conditions that the controls of worst-case scenario to the best-case scenario development are adequately addressed is summarized in table 34. The demand side management and supply side management, where the business as usual case development is in any way possible even without any control measure in the internal and external system that influences mobility system development and can be addressed through existing policy. However, the transition from product centric to service centric development needs the control through alternative policy enforcement. Similarly, the system digitization and automation depending on artificial intelligence technology and is relatively unknown and it is not fully tested in the real world, which need strong control policy for their development.

Table 34: The possible option for enabling condition

Enabling condition	Business as usual case(worst case)	Service centric business(better)	Digitalized mobility mode(best case)
Infrastructure development	Enable growth	Enable optimization	Enable innovation
Fuel energy security	Enable import access	Enable alternative fuel	Enable system efficiency
Institutional capacity	Business centric	Consumer centric	Service centric
Spatial dynamic	Enable land use change	Enable conservation	Enable optimization
Accessibility	Enable public control	Enable de-regulation	Enable virtual platform
Mobility service	Industrial growth	Logistic growth	Innovation growth
Capital investment	Enable profitability	Enable value addition	Enable ICT access
Operational capital	Tax revenue	Service revenue	Service revenue
Economic development	Free market	Preferential market	Regulated market
Attractiveness and aesthetic	Less preference	Multiple options	Alternative options
Political power	No control	Moderate control	Strong control
Rural urban dynamic	Enable urbanization	Enable regionalization	Enable network access

While the identification of three possible development from the key variables address goals for the system vision, the strategy to address them depends on the network of influence factors from the effect system and the current choice of feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ from chapter 5 for the control strategy, which will indicate how system policy should look like for the transition to sustainable mobility system.

Business as usual: In the business as usual case the mobility service is mostly based on the control of product and technology development as witnessed in the current situation. Product standard, prove of technology, environmental standards and market control are commonly applied control strategies. The product development will in any way continue to dominate consumer demand. The control of Infrastructure development (1) will depend on the control of Mobility service (7) demand. The Infrastructure development (1) policy tends to accommodate the growing traffic volume and human settlement pattern. Various options for access requirement will potentially address the multi-modality for movement function. The control of de-motorization tends to face the challenge of behaviour change, due to the market force dominated by automobiles for the access requirement, connecting rural and urban areas for the movement of both people and goods. Even if the access control policy enables the availability of public services, daily commutation will be heavily influenced by personal car ownership due to the consumer behaviour influenced by market force. Thus Accessibility (6) will potentially become challenging for consumer. Enabling conditions are required for public services through various incentives to change the consumer behaviour. Mobility system tends to exhibit as if too much of regulation is imposed on both the consumer and the mobility industry. The consequence of too much of regulatory measure leads to poor access for disadvantaged population group, where rural-urban migration can be expected for access to jobs and business search. Although the control policy may be deployed, the variable Rural-urban dynamic (21) will potentially exhibit migration of rural population to urban areas even in a controlled condition. The positive feedback effects $7 \rightarrow 14 \rightarrow 11 \rightarrow 7$ and $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ influence the mobility system development in such condition, where growth seems to be an enabling control condition. The variable Economic development (11) and Technology development (2) seem to leverage mobility system resiliency for better Mobility service (7). Thus, the variable Spatial dynamic (5) leverages the system to behave as if urbanization is the ultimate requirement for control conditions. The system tends to further grow to create better conditions. Therefore, the variable Attractiveness and aesthetics (16) seems to obey the growth model, where Technology development (2) influences the Economic development (11) and enabling system policy tends to align to their development. Although not desired, the enabling mobility system policy tends to promote consumerism behaviour due to the product centric external market force. In such scenario the variable Political power (20) influences the consumer behaviour through policy reforms, where product selectivity and environmental standards are imposed on the consumer and mobility industry. However, the controls are very weak due to the economic growth dominating the market force. Possible control measures are to regulate the fuel import tax and de-coupling the economic growth from mobility demand. Alternatively, the possible control measures are also to be made on environmental standards requirement for mobility choice and fuel standards to address their developments. Thus, the variable Fuel energy security (3) will indicate the need for energy policy reforms, where the alternative fuels are incentivised. The influence of the incentivised fuel alternative through energy policy reforms is still system growth fulfilment, which is more align to the environment standards and leverages the variable Operational capital (10) to adopt incentives scheme on high standards fuel and emission reduction target setting. However, the control policy will face high Capital investment (9) challenges and their development is growth oriented, which will depend on the external economic growth. Thus, the Institutional capacity (4) development is inevitably linked to mobility system growth that tends to align the system to better standards as a control measure. The control policy will face increase of mobility system development cost. Thus, in the business as usual scenario, although the control measures are made, they tend to face the resistance from consumer as well as mobility industry. The desire of improving Human wellbeing (22) will be fulfilled for short time with all those interventions and the system is once again leveraged to unsustainable growth. Therefore, for such development goal 7 influences the system development.

Goal 7: Enable economic growth through improved mobility services for better quality of life

Service centric business: In the service centric business, the control policy that enables the product durability and quality improvement will target the increased service development by optimized use of product. Therefore, key control condition for business growth is influenced by the policy supporting the service development in mobility industry and increase consumer behaviour shift from ownership to ridership. The success of control policy is measured by the quality service offered. The service centric business control policy can be compared to utility management policy such as electricity supply, TV and internet service and smart phone rental scheme. Same control strategy applies to mobility system business growth where the automobiles durability and quality will have to be improved for business competitiveness. In such a scenario the Infrastructure development (1) control condition will require up gradation and maintenance for user centric service growth development that will potentially enable Mobility service (7) development. The policy enabling the increase in recreational facilities for service user, which is much more comfortable, compared to personal car user is critical requirement. Same applies to service development for goods delivery to home and home office services. The mobility policy that enables the industrial competitiveness for the sale of service and development of franchise logistic market also enhance the mobility service growth. De-regulation of public transport service enabled through alternative service option for movement function, which opens a new service market for mobility industry are key innovation in business model design. The role play of public service provider is to monitor the service quality and tariff regulation for the service. Therefore, the multiple service options for both goods and passenger mobility are innovation option for the mobility industry. Policy enabling incentivised operation in unprofitable route and unprofitable regional location enables better service access. Multi-modal option for access requirement will demand more enabling environment. Enabling condition for service demand growth can be potentially optimized through service reliability on a competitive basis rather than long-term fixed service market. Therefore, the industrial competitiveness depends on service quality and reliability. Thus, enabling service centric business will potentially increase the Accessibility (6). Enabling service sector development for access, through incentivised policy favouring service growth, increases the likelihood for increased logistic service business development in rural areas. Therefore, the variable Rural-urban dynamic (21) will self-regulate, where the reverse migration is enabled through services that are equivalent to urban centres based on de-regulated, competitiveness, and preferential service market development. Enabling the service growth will have the potential to de-congest urban settlement and disturbances in the road traffic movement. The variable Spatial dynamic (5) tends to stabilize, where the movement function is enabled through less land use requirement. In service centric mobility service development, one automobile enables increased functional value through multiple use and ride sharing alternatives. Enabling the service centric business development for mobility requirement potentially enhances the economic reforms. The negative feedback effect $6 \rightarrow 21 \rightarrow 11 \rightarrow 7 \rightarrow 6$ tends to enable the self-regulatory dynamic of mobility system, which will have the potential to decentralize the economy. That is to say the enabling service growth regionalizes the economic base, where the Mobility service (7) demand increases instead of product demand. Furthermore, enabling service growth influences the variable Attractiveness and aesthetic (16) as key control lever for market manipulation for movement function for both passenger and goods. The positive feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ will influence the industrial product design and development strategy, where product durability and quality improvement enhances the service quality improvement. Thus, technical innovation is key success control factor for mobility industry. The product durability influences the Technology development (2), which then is internal business secret for the market competitiveness and de-growth development. In a scenario where system growth is influenced by quality control, the variable Political power (20) potentially influences Economic development (11), which has the potential for de-growth control, enabled through high quality low impact policy design for industrial competitiveness. When the mobility industry controls the service growth, the control over Fuel energy security (3) is business opportunity for mobility industry, which otherwise would face low market competitiveness. Fuel energy security (3) will potentially have high environmental standard requirement for Mobility service (7) attractiveness for service provider. Furthermore, standardizing the service enables easy control over the service tariff package unlike the situation in which automobile service is personal business such as taxi services. Thus, Operational capital (10) and Capital investment (9) requirement will be industrial business secret where tariff is regulated by the public authority. Increasing dependency on insurance companies for safety and risk reduction is a key driver for the control of investment and operation costs. Thus, enabling Institutional capacity (4) development for service growth will potentially demand human resources for system auditing and quality control management to monitor the consumer rights. Based on these control conditions for service enabling policy development, the vision of Human wellbeing (22) improvement will tend be more sustainable than that is addressed in the product centric business as usual scenario. However, the key control for system transformation will depend on innovative public policy that enables industrial role play for service quality development to fulfil the dreams and wishes of the consumer. Therefore, goal 8 can be formulated to reach to the vision statement

Goal8: Enable mobility service growth through industrial competitiveness to achieve better quality of life

Digitalized mobility: The scenario, in which the mobility system is digitalized, is a condition where mobility system policy enables the Technology development (2) as strong control condition. Mobility system is fully dependent on ICT technology and system automation, where ICT technology dominates the service development by deploying virtual platforms. The policy enabling the development of artificial intelligence and autonomous mobility tends to transform Infrastructure development (1) to digital system to enable virtual Mobility service (7). In such situation, policy enabling the home office and work package system rather than routine daily task will strongly reduce mobility need. On the other hand, the ICT infrastructure development policy will have to be strongly aligned to online systems and remote monitoring systems. Thus, the development of autonomous mobility and virtual platforms are strongly dependent on the ICT capacity. Further the Accessibility (6) is fully controlled by access to ICT network, which determines the need of travel to work. In such a system many alternatives are also to be witnessed, such as telemedicine for access to health care system, YouTube learning tutorials, and home service delivery for grocery etc. Due to the presence of virtual platform, it can be anticipated that the mobility need will be potentially reduced. However, they all depend on the enabling condition and nature and type of job an individual is responsible for. The myth of urbanization is illusive in relation to the Human wellbeing (22), where the truth about the quality of life is relative, which is fully conditioned by the enabling policy that influences livelihood and perception of an individual. The enabling policy that supports online jobs has the potential for behaviour change of the consumer, which will potentially manifest the bi-directional migration in which the variable Rural-urban dynamic (21) tends to remain neutral. In such situation policy controlling the de-congestion of urban region will have to be strictly regulated. Only in the regulated condition the variable Spatial dynamic (5) exhibits the decongestion and increases Attractiveness and aesthetic (16) for movement function. Attractiveness such as basic service requirement will play a critical role for the online and digital system. For example, the home office job for working mothers, driverless cars for people who cannot drive, and emergency services for health and other accidents. The positive feedback effect $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$ will play an important role in enhancing service development enabled through technology innovation. Thus, in a system that is fully technology dependent, the economy is heavily in need of ICT systems, where distributed network and service centric development tend to regionalize the economic growth. However, the enabling conditions are necessary for regionalising the economic growth, such as availability of school, health care and recreational facilities. In a regulated condition Economic development (11) is expected to influence and leverage mobility system for de-growth development, where regional economic value addition can be anticipated from the virtual home office jobs. The virtual platform will be dominated by the deployment of artificial intelligence for both mobility service and economic services, which is the strategy to optimize resource efficiency. However, such development is not yet fully tested in the real-world social system. Therefore, the controversial questions on the developing artificial intelligence will have to be enabled and regulated by Political power (20), where normative value systems are protected. The policy enabling technological innovation will have the potential for e-mobility development, which tends to face the market monopoly in current situation. The enabling control condition for the growth of e-mobility will potentially have an opportunity for autonomous vehicle in urban or densely populated settlement. The e-mobility development enables the variable Fuel energy security (3) to shift the fuel source to electricity. The renewable energy sources that face seasonal variation can have the potential for mobile energy storage. However, the enabling conditions are necessary for electric grid network and technology redesign. Incentives for alternative technology development are key condition for system change, which tend to leverage Capital investment (9) and Operational capital (10) requirement for the desired system transformation. For enabling the mobility system to transform to digital system seem to offer many optimization options, although initial change and future development are very uncertain. The levels of uncertainties are increased if Institutional capacity (4) for digital and virtual platforms is weak. Therefore, strong enabling policy and resource allocation for ICT capacity development will be the key condition for autonomous system development. Hence it can be envisioned in the digitalized mobility system, the Human wellbeing (22) is expected to improve but also the virtual platform will continue to dominate the social values, which needs strong regulatory measure. Therefore, goal 9 addresses the mobility system vision.

Goal 9: Enable technology innovation to improve mobility service for better quality of life

The control measures from the leveraging variable Enabling condition (7), responds to the future of mobility system vision through following possible goals.

1. Goal 7: Enable economic growth through improved mobility services for better quality of life
2. Goal8: Enable mobility service growth through industrial competitiveness to achieve better quality of life
3. Goal 9: Enable technology innovation to improve mobility service for better quality of life

Either one of the above goals and / or all of them in partial form has the potential to address the vision to "Improve human wellbeing by providing safe, equitable and environment friendly mobility services". To address the desired system vision, the goals have to be aligned to the demand side management and the supply side management for the control requirement of both of them. The control measures foresee enforcement mechanism, where the public intervention is needed for system regulation.

6.6 Projection : possible scenarios in future

Scenario is an art of projecting an image, such as mental map, stories, mental models, narratives, pictures, indicators and change processes [133]. So far mobility system is observed in a formalistic approach, which is defined based on variables consideration and cross-consistency analysis [8], [11], [30]. The two approaches have adequately addressed the cybernetic assessment, where critical variable identification, vision formulation and goal definition based on the result of alternative future perspective of mobility system are defined by variables and their normative values [10], [11]. The 9 goals defined in section 6.5.1 to 6.5.3 resulting from critical variables Mobility service (7), Economic development (11) and Enabling condition (14) have been identified as system leverage potential. The main argument for goal definition was based on 'is' and 'ought to be' justification for sustainable development, which shows three possible ranges [21], [22], [24]. The 'is' and 'ought to be' is simplified to business as usual case, service centric development and system digitalization. These formalistic scenarios defined through the goals are still contextual and subject to further projection and synthesis for meaning purpose. This decomposition is dependent on the gross system and therefore representation of the gross scenario field influencing the formalistic scenario is critical for the successful transformation to sustainable system. Transferring formalistic scenario to normative value proposition can be derived from the Quattro Stagioni logic [11], [20]. The Quattro Stagioni logic is simplification of meaningful and workable scenario that one can imagine, which can be positioned through the key variable identification process in Vester's system analysis and scenario management logic through cross-consistency matrix that actually depend on morphological field defined by variable's values [8], [28]–[30], [33]. The question of how to combine these formalistic tools and image creation of the future can be clarified with the help of Analysis-Projection-Synthesis(APS) approach [11]. Thus, the Quattro Stagioni logic is the comprehensive summary result of extensive adjustment considered so far for future image creation of the system. We have selected three variables from the Analysis phase and projected 9 different goals based on three possible future considerations (business as usual case, service centric development, fully digital world). The three variables considered for this purpose are Mobility service (7), Economic development (11) and Enabling condition (14). The Quattro Stagioni logic defines plausible quadrant formed by the two most important variables and their orthogonal axes crossing to indicate the possible divergence of the variable in future [134].Among the three critical variables defined, Mobility service (7) and Economic development (11) represent, how the system is and how should it look like for sustainable development, where the Enabling condition (14) is a potential control lever to monitor the extreme development of the Mobility service (7) and Economic development (11). In figure 42 the possible divergence of the variables Mobility service (7) and Economic development (11) is shown, which is the final stage of defining the actual scenario from Analysis phase. This step is therefore the future projection of normative scenarios from the result of system analysis phase so far considered.

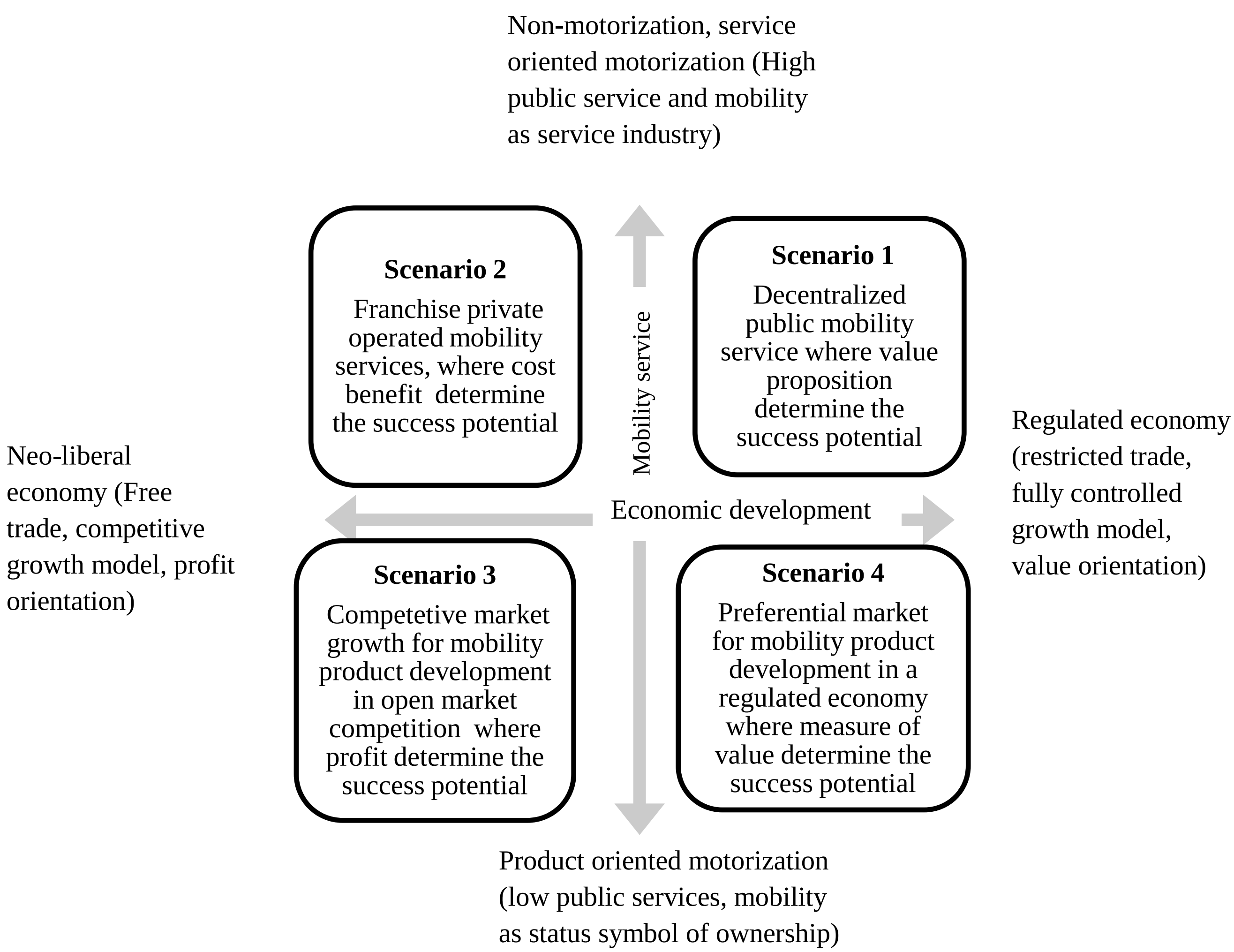


Figure 42: Quattro Stagioni representation of Mobility system

The first variable Economic development (11) has two possible divergences, the one that is fully controlled growth and the other fully liberal growth. It has to be noted that the Economic development (11) cannot be easily defined by growth and its measuring value gross domestic product but in real sense economy can be defined by purchase of power ideology normatively [135]. It is much easier to explain economy with the purchase of power ideology than that of profit and growth projection. The behavior of economic model formalized based on demand, supply and growth can be fully influenced by the power [135]. Capture of market, creation of dependency, consumer behavior manipulation, control policy, and demand-supply orientation are some aspect by which the purchase of power ideology can be defined [135]. Therefore, power will play major role for the economic divergence, whether it is national economy or global economy. The control of power, which we may call an Enabling condition (14) is how the system is made to behave. The greater uncertainty is the control of power, even if the enabling system may define their development. Based on this fundamental fact, the Economic development (11) has the potential to diverge from fully regulated to fully liberal, which is represented by horizontal axis in figure 42. In the regulated economy the top down Enabling condition (14) can be witnessed, where strong enforcement mechanism tends to shape the economy [136]. On the other hand, the liberal economy obeys the bottom up approach to create Enabling condition (14) that will shape the economy [137]. Both approaches are fully controlled by the flow of power structure. Western economic model may be considered to be liberal economy, where the freedom is regarded as main condition for increasing the Human wellbeing (22). The more conservative economic model can be found in Asian economy, where the consumer freedom is fully or partially controlled to enable the Human wellbeing (22). The question is how and who execute the power in both regulated and liberal economy is determining condition, which will define the possible scenario field in four quadrants as shown in figure 42. These scenarios will be further elaborated in section 6.5.5 to 6.5.8.

Similarly the second variable Mobility service (7) has two possible divergences, the one that is fully product oriented and the other fully service oriented [16], [45]. The vertical axis represents this possible situation in figure 42. In both cases the purpose is to provide the movement function. The movement function can be best explained by service value proposition [110]. Service value is a qualification of what is made to move and how does it move. The production center and consumption center and their transaction type determine the need of Mobility service (7). The public transport services, courser industry, automobile industry, aviation industry and settlement orientation will influence the movement function, which is dependent on how economy is made to function. The service orientation and product orientation indicate the possible condition for system efficacy. The idea of shared values and owned values therefore will shape the system efficacy. The development of shared values and owned values can be controlled through Enabling condition (14) for their development in the future. In shared values ideology the product responsibility is fully controlled by the service provider, whereas in the owned values ideology the product responsibility is born by the consumer. Both the ideology is strongly influenced by the consumer behavior and Enabling condition (14) available to them. The question on shared value and own value ideology is determined by how the service is made available and who makes those availability, which gives scenario field as shown in figure 42. These scenarios will be further elaborated in section 6.6.1 to 6.6.4.

It has to be noted that the variables cybernetic effects and cross-consistency results are systemic property but the divergence of the critical variables shown in figure 42 is unpredictable, which will define the uncertainty and the system behavior in future. There can be many such uncertainties among other variables divergence and they generate unlimited possibilities of scenario fields. However, those conditions are integrated during the system analysis phase and the critical variables are the most important for scenario development. The four quadrants formed by the critical variable Mobility service (7) and Economic development (11) are critical future scenarios, which were earlier clustered by goal definition in section 6.5.1 to 6.5.3. The defined goals tend to align according to how the critical variable diverges in the future. These will define how the system is made to behave and how does it look like in future, which will justify 'is' and 'ought to be' consideration. The four quadrants have their own value proposition, which is normative option for the decision support.

6.6.1 Scenario 1: Ideal case

Scenario 1 is an ideal case for sustainable development vision, which one may call an ideological belief but that is the actually desired option. Scenario 1 is an image of future, where peace, prosperity and values consideration are well coordinated between the actors for enabling the quality of life and human environment interaction. The mutual understanding between system controller and system user is properly established, which enables the system's self-regulatory dynamics. The optimistic assumption made so far for vision definition, clustering goal and the influencing characteristics are oriented as desired by system controller and system user. The system controller and user seem to behave as system actor and play active role to shape the self-regulatory growth and de-growth dynamic. Based on this system defining story line, the scenario field is defined as *decentralized public mobility service where value proposition determine the success potential* as shown in figure 42. Decentralized democracy plays a critical role for any change that is desired to be made in the system. All contextual need is well addressed and the disparity gap especially the power flow structure is well capitalized. Adopting all the 9 goals defined in section 6.5.1 to 6.5.3, which depend on behavior correction of actors, is adjustable without distorting the system image and easily integral to address the defined vision to *improve human-well-being by providing safe, equitable and environment friendly mobility services*. The feelings, wishes and dreams of the actors seem to balance with the natural capital available to the actors, which is critical for Human wellbeing (22) and Environment pollution (12) control.

The system's functional value plays a critical role for the scenario 1 image, whose growth can be balanced through active stakeholder participation for any change process. Thus, all the variables defined in Analysis and clustering phase can be aligned on a contextual basis and are based on the cybernetic deduction involving the actors of the system. Therefore, the user, policy maker, technology developer and logistic service provider will have the common objective to increase the functional value of the system to enable the vision to *improve human wellbeing by providing safe, equitable and environment friendly mobility services*. Therefore, the Mobility service (7) tends to provide optimal system efficacy by increasing the automobile usage and quality for user. Thus, it is expected that the product quality is improved and is durable, which will fulfill user expectation. The product responsibility is born by system controller for example the government, user and automobile industry in a well coordinated condition. This will require massive changes in behavior of all actors involved in the system. The behavior change requirement is on taking ownership of product responsibility to fulfill the functional value of the system that will improve the system efficacy. Thus, behavior such as non-motorization, ride sharing, reducing travel requirement, shared mobility options and public service preferences are main condition for such development. On the other hand, the market growth and profitability are controlled and regulated by public authority transparently. Therefore, the freedom, control and choices are part of continuous growth option for the functioning of the system. The entire 9 goals defined in section 6.5.1 to 6.5.3 and new possibilities are easily manageable. Thus, the scenario is preferable option, which depends on behavior change.

6.6.2 Scenario 2: Market force

Scenario 2 is a transformation influenced by market force, where the competition plays a critical role to shape the sustainable development. Consumerism is key growth enabler, which will determine the system transformation and success potential. Service values are part of business motivation and change lever. The option and alternatives are unlimited, where the services keep changing from one value proposition to the other value proposition, which demands extensive innovation requirement. Free market and unlimited choice are the change drivers. However potential market monopoly tends to influence growth control. For example, the well-established automobile industry will have new business opportunities, which tend to claim the sustainable development vision as part of industrial business model. The quality of service is heavily influenced by luxury requirement. The disparity gap between haves and have nots will potentially increase, which will face the challenge of aspirant consumerism. Market manipulation, industrial control of services, increased dependency on market influence, and the cost benefit based value proposition will dominate the service development. Therefore, scenario 2 is defined as *franchise private operated mobility services, where cost benefits determine the success potential* in figure 42. Scenario 2 seems to be pragmatic ideological belief for business but in reality it pushes uncontrolled growth of service development.

Economic dogmatism defines the functional value of service, which is based on open market competition. Therefore, the psychology behind system efficacy is heavily influenced by market growth for Mobility service (7). The motorization and urbanization with the support of mobility system automation is an expected development for that purpose. The ICT service is therefore core business innovator. The differentiated roles and responsibilities of system user, service provider, and system controller cannot be easily controlled in free market competition. Therefore, differentiated goals face the challenge of achieving the common objective of desired vision to *improve human wellbeing by providing safe, equitable and environment friendly mobility services*. In this case the defined goals in section 6.5.1 to 6.5.3 will require further adjustment, which has to be aligned to influencing market force as driver of change. Therefore, multiple system actors behave differently with the profit-oriented motivation to enable Human wellbeing (22) and Environment pollution (12) control. It has to be noted here that although it appears the service development has increased the system efficacy, the consumerism behavior will enforce the re-bound effect on the system. The purpose of mobility service has the potential for shift from main functional purpose to leisure time travel options. The public transport service, rental scheme, ride sharing option and status symbol of luxury will drive the re-bound effect, where quality requirement is unlimited. The best example can be seen in recent development of aviation industry, where the cheap flight services are the result of market competition. Tourism for example is an expected new area of development, where mass travelling is expected rebound effect for business growth. Thus, the scenario 2 is pragmatic case for initial service growth, which will require strong control condition. The market influences the user behavior in open market competition.

6.6.3 Scenario 3: Uncontrolled situation

Scenario 3 is a business as usual case mobility system transformation, which is fully influenced by the consumerism trend and unlimited growth projection. The problematic mobility system development that is identified so far can be reasonably reflected from this scenario field. The success potential for scenario 3 is product branding and unlimited luxury requirement by the consumer. Thus, the ownership culture is expected aspiration of the system actors. The system's success values can be observed from the product brand, which is heavily competitive. Similarly, the consumer behavior is influenced by competitiveness that encourages status symbol of product brand for ownership. New product model has the potential to influence the psychology of consumer, which will increase market demand for new model. Growth is therefore the ultimate development trend. Freedom, choices, luxury, and new brand will continue to enable Human wellbeing (22). Therefore scenario 3 can be witnessed in the developed economies, where the control of growth is not so easy due to rigid consumer behavior requiring freedom and luxury. Material possession is an aspiration built in the system, where unlimited product brand influences the consumer psychology. The role played by the actor is controlled by the market force and therefore the growth control requires market control, which is not so easy due to the competition built in the system. The economic theories of demand and supply define the quality of life even if the product sustainability label is aligned to Environment pollution (12) control. The 9 goals defined in section 6.5.1 to 6.5.3 will deviate from de-growth to growth motivation to fulfill the economic theories, which is not the desired vision for sustainable mobility system development.

Luxury value of the product determines the system's functional value. The product's functional values are diversified into leisure time activities for that purpose, which tend to shift the actual movement function to pleasure function. The vision to *improve human wellbeing by providing safe, equitable and environment friendly mobility services* is a competitive individual goal, which defines status as quality of life. Based on this fundamental goal scenario 3 is defined as *competitive market growth for mobility product development in open market competition where profit determines the success potential* in figure 42. Product centric economic growth will enable the Mobility service (7) requirement. Even if the idea of eco-labeling is integrated in product development, the core value of de-growth requirement will be undermined. Therefore, sustainable development assumes the new business brand for market competition. The control of market growth is market growth itself, which will be based on competition for de-growth. Therefore, the system transformation depends on market transformation, which is accompanied with life style change. The valuation of independency from consumerism is therefore the tool to influence the life style of actors. This might require greater enlightenment for the change. For example, the time with family, time with community, time for human nature interaction, non-motorization for de-growth, and above all the massive behavior correction of all actors at different levels of decision-making process to change the ideological perception of the actors. Collective responsibility for growth control is an ultimate option, which will depend on behavior change.

6.6.4 Scenario 4: Regulated system

Scenario 4 is a transformation influenced by alternative product development in addressing sustainable development vision. Product selectivity is a key to system success potential, which tends to integrate new product that are labeled to be sustainable. It has to be noted that the product label is a business substitute rather than system transformation. The fundamental system problem continues to pressurize the system for growth requirement. We may reference the system pressure for new product rollout in the market from the currently labeled automobile products such as electric vehicles, hydrogen vehicles, cable cars, and alternative fuel, which is expected to address sustainable development vision. Although business substitute with alternative product increases the sustainability values of product in the system, they do not fully represent the system's functional value, which strongly depends on the behavior of actors in the system. The consumerism trend and the luxury requirement will continue to create new market growth that enables the market transformation but not system efficacy. Therefore scenario 4 is defined as *preferential market for mobility product development in a regulated economy where measure of value determines the success potential* in figure 42. The basic enabler for preferential market growth for mobility system can be witnessed through financial mechanism influencing reforms on tax and incentives. The success potential for scenario 4 strongly depends on new product quality and eco-label, which will normally replace the market growth.

The product functional value will define the system's functional value, which will influence the comparative product value scaling in addressing the system vision to *improve human wellbeing by providing safe, equitable and environment friendly mobility services.* The 9 goals defined in section 6.5.1 to 6.5.3 may not fulfill the requirement for the product design, which is influenced by the product value rather than system efficacy. The ownership trend continues to serve for the Mobility service (7) requirement. Therefore, it will not be a surprise for economic growth requirement and unintended rebound effect resulting from new market for movement function fulfillment. The mobility system will even face the financial burden due to high investment requirement for substituting the built environment to enable new product integration for new market force. The system actor will be forced to switch to new market transformation, which has the potential for disparity gap development between haves and have nots. The differentiated role of actors in the system is heavily controlled by product regulation that might influence the hierarchical order of power flow structure in the system. However, the system will indicate, the control can be easily manageable. Policy reform enforces the industrial competitiveness for alternative product development and market value proposition of new product rollout in the market. Product label therefore is in the hand of decision-maker and is not the choice of the consumer. Such system transformation can be witnessed in a conservative economy, where regulation plays a central role for growth and de-growth requirement. In scenario 4, although consumers are heavily controlled, there is potential for value creation and potential adoption of alternative options. The mobility system reforms can be leapfrogged but Human wellbeing (22) might face the challenge of freedom of choice.

6.7 Historical scenario of Bhutan: Scenario 4 projection

From the historical data and current status quo, the mobility system image of Bhutan can be positioned in scenario 4, which states the preferential market for mobility product development in a regulated economy where measure of value determines the success potential that is seen in lower right hand quadrant in figure 42 in section 6.6. The current plan according to historical national data in chapter 4 also indicates Bhutan has good opportunity for mobility fuel switch, which can be optional depending on the choice of government and feasibility of the choices. The government preference in the current situation is to switch conventional fossil fuel to hydro electricity [171]. The rational for this choice according to literature sources influence the variable Fuel energy security (3) and Environment pollution (12) [72]–[74], [79], [171]. Based on this baseline condition future mobility system can be further projected as an internal scenario of scenario 4 represented by mobility system image in figure 42 and potential opportunities can be explored from there.

Table 35: Summery of scenario 4 in context to Bhutan

Scenario	Aspect	Projection	Remarks
Scenario 4_1	Energy potential	2030 onward	strategy for clean fuel source
Scenario 4_2	Efficiency improvement	Immediately	Optimize existing situation
Scenario 4_3	Electric two wheeler	Initial start	Without charging infrastructure
	Electric light vehicle	Initial start	With quick charging infrastructure
	Electric medium vehicle	2030 onward	Improved road and electric infrastructure
	Electric heavy vehicle	2030 onward	Improved road and electric infrastructure

The scenarios summarized in table 35 such as energy potential estimation, efficiency improvement alternatives, fuel switch for two wheeler, fuel switch for light vehicle, fuel switch for medium vehicle, and fuel switch for heavy vehicles that are potential future. Since lack of infrastructure is a barrier for electric vehicle in current situation, the scenarios are projected for the future to optimize hydro electricity as fuel substitute for mobility. There are two alternatives for fuel switch from the fossil fuel source to renewable source such as electric vehicle [72]–[74], [79] and power to X(gas/liquid) technology [196]. However, the power to x technology is still under research phase, which might take longer time for commercial maturity. Since the scenario projection is future oriented, the current availability of technologies cannot be ignored. However, for both options, renewable energy potential will be critical condition for sustainable mobility system development and it seems to be abundant in Bhutan due to presence of hydro electricity. It has to be noted here that the technology is not the final solution to mobility challenges although they cannot be ignored as identified in mobility system image in section 6.6, which indicated behaviour and life style change requirement is primary condition for system transformation. Therefore, low cost option and low tech solution are desirable alternative for the future of mobility system transition to sustainable mobility system development.

6.7.1 Scenario 4_1: Energy potential estimation, strategy for clean fuel source

The calculation of infrastructure density in section 4.5.1 shows, 0.472 km/km^2 of all type of road is currently available, where 14.96% growth has occurred in last 10 years (refer to chapter 4). The changes are mostly seen in new road construction and up gradation of existing road, where 15.81% of growth is noticed in new construction and 8.39% of growth is noticed for up gradation. The current infrastructure is approximately 50% unpaved road, which will continue to be upgraded in addition to new construction in future. If all automobile are on road together, the road density calculation in section 4.5.2 shows, vehicle density of expressway is 14,800 automobile/km, vehicle density of primary national highway is 52 automobiles/km, vehicle density of secondary national high way is 92 automobiles/km, vehicle density of district road is 45 automobiles/km, vehicle density of urban road is 220 automobiles/km, vehicle density of farm road is 8 automobiles/km and vehicle density of access road is 53 automobiles/km respectively(refer to chapter 4). Similarly the automobile per inhabitant calculation shows, heavy vehicle share of 15 heavy vehicles / 1000 inhabitants, medium share of 3 medium vehicles / 1000 inhabitants, light share of 86 light vehicles / 1000 inhabitants, two wheeler share of 14 two wheelers / 1000 inhabitants, power tiller share of 4 power tellers / 1000 inhabitants, tractor share of 1 tractor / 1000 inhabitants, earth mover share of 4 earth movers / 1000 inhabitants and electric vehicle share of 1 electric vehicle /10,000 inhabitants respectively. In a business as usual case the vehicle growth projection is expected to be 328,835 automobile counts in 2030 as shown in table 36. Highest number of automobile can be expected in light vehicle category with the average annual growth of 13.39%. Growth trend is a calculated value derived from historical data for last 10 years since 2008 until 2018(refer table 19 & 20 section 4.5 chapter 4).

Table 36: Vehicle growth projection

Vehicle categories	Weight	Growth trend	2020	2030
HV	> 10 ton	9.13	12,236	29,304
MV	3 -10 ton	12.02	1,927	5,996
LV	< 3 ton	13.39	70,457	247,622
TW	>100 kg	5.39	11,431	19,316
Other	> 1 ton	13.50	6,883	24,419
EV	< 3 ton	2.08	120	147

The projected automobile growth and change in infrastructure development is expected to influence both mobility behaviour and fuel demand. For example, the growth of light vehicle indicates high dependency on personal car ownership and less development of public transport service alternative for mobility function. On the other hand, the freight mobility will remain unchanged irrespective of passenger kilometre travelled (PKT) but will be strongly influenced by the consumption destination and source of consumable's origin, which is fully influenced by economic development trend and settlement pattern. The fuel demand for automobile that are stationary is another mobility category used as farm machinery, which will not be influenced by travel distance but based on operating hours. Table 37 shows in the current situation, automobile fuel consumption expressed in fuel consumed for every 100 km distance travelled, passenger capacity of different mobility mode, average annual fuel consumption, average annual travel distance and average range of passenger kilometre travelled by different mobility mode. This approximation is made based on the transport energy efficiency audit report of Bhutan [166]. Since fuel consumption data for different vehicle categories are not readily available, the transport energy efficiency audit report can only be used for approximation. The passenger kilometre travelled indicates there is a potential for transport efficiency improvement by improving public transport service and optimizing the vehicle usage, which will be further elaborated in section 6.7.2. In the current situation the heavy and medium vehicle shows high passenger kilometre travelled. However, their functional use is different and often used for goods mobility. On the other hand, the passenger kilometre travelled by light vehicle and two-wheeler is relatively low compared to heavy and medium vehicle for passenger mobility and they are mostly personal cars. Table 37 shows the comprehensive fuel consumption efficiency of different automobile categories, which will be used for efficiency projection in section 6.7.2.

Table 37: Fuel consumption and passenger km travel (PKT)[166]

Vehicle categories	Function	Fuel(L/100 km)		passenger	consumption year (l)	Annual travel(km)	Max PKT(km)
		Diesel	Petrol				
HV	Passenger	10 to 17	-	> 25	5,000-6,000	30,000 -45,000	750,000-1,125,000
	Freight	10 to 17	-	3	5,000-6,000	30,000 -45,000	90,000-120,000
MV	Passenger	8 to 12	-	13 - 24	4,500 -5,000	36,000-40,000	864,000-960,000
	Freight	8 to 12	-	2	4,500 -5,000	36,000-40,000	72,000 -80,000
LV	Passenger	5 to 7	5 to 6	4 to 12	630 -670	10,000 -20,000	40,000 - 80,000
TW	Passenger	-	3 to 4	2	100 -200	3,500-5,000	7000-10,000
Other	Stationary	10 to 34	-	1	500-1,000	Stationary	-

Since national fuel consumption cannot be based on the approximate value for hydro energy potential estimation, the fuel import statistics of NSB is used for projection [139], [169], [170]. Based on the automobile growth trend and functional use of different automobile categories, fuel consumption is projected for 2030 as shown in table 38. The average annual consumption growth trend is calculated based on the historical data (refer to section 4.3 for more detail). The standard energy content in fuel is used from the IPCC default values as net calorific value per ton of fuel as shown in table 38 [181], [182], [184], [185]. In addition to surface mobility, the fuel consumption in aviation sector is also shown in table 38 for estimation purpose for the future fuel demand and supply scenario. The projection shows 18,415,048.65 GJ of energy demand for diesel fuel, 6,745,442.14 GJ of petrol fuel and 1,025,842.17 GJ of kerosene fuel based on an average annual fuel consumption growth of 8.50%, 10.21% and 13.80% respectively. The highest fuel demand in a business as usual case is seen for diesel fuel consumption. However the scenario will change if an intervention is made for example the efficiency improvement, which can be realised from table 37 PKT considerations. Efficiency improvement will be further elaborated in section 6.7.2. Note that the calculated value in table 37 is an indication that there is room for efficiency improvement before fuel alternatives are explored. In this section focus is made on how the fuel switch addresses fuel efficiency in which business as usual growth trend is assumed.

Table 38: Fuel consumption in business as usual growth projection

			Fuel quantity(T)		Energetic value(GJ)	
Fuel type	Growth	NCV(GJ/t)	2018	2030	2018	2030
Diesel	8.50	43.33	159,722.50	424,995.35	6,920,775.93	18,415,048.65
Petrol	10.21	44.80	46,912.34	150,567.90	2,101,672.83	6,745,442.14
Kerosene	13.80	44.59	4,878.00	23,006.10	217,510.02	1,025,842.17

The projected fuel demand is further compared with alternative fuel in table 39. In the current situation the net energy balance shown in figure 27 in section 4.6 indicates, the fuel diversion of Bhutan from fossil fuel to mobility as energy storage option is logical as energy source is 100% hydro and the domestic demand exceed generation (refer to chapter 4). Additionally, the seasonality and demand load variation can be optimised by strategic energy storage option as mobile energy storage. Currently available fuel alternatives for fuel diversion from fossil to renewable can be potentially achieved through electrical energy storage in battery for use in vehicle [72]–[74], [79] and electrical energy storage as gas or liquid fuel in fuel cell or power to gas technology for longer time period [196]. Both the technical options offer advantages and disadvantages. For example, although the energy storage in battery as electric mobility is very efficient alternative, they suffer long term energy storage in mobile system. On the other hand, the electricity conversion to gas or liquid fuel has the potential for long-term storage and potentially vehicle weight reduction can be realised. However, energy efficiency is comparatively very low compared to other fuel alternatives. The fuel demand projection based on this comparative study is used to calculate the future mobility fuel energy demand for Bhutan as shown in table 39. The projected energy demand in table 39 shows, 42,560,887.46 GJ of CH_4, 21,382,230.24 GJ of fuel cell, 18,816,939.52 GJ of electric hybrid, and 8,605,018.27 GJ when used as pure electric for fuel diversion, which may be used as comparative baseline decision support for fuel choice.

Table 39: Potential fuel alternatives

Fuel type	2030	Multiplier factor			
	Projection(GJ)	CH4	Fuel cell	Hybrid	Electric
Diesel	18,415,048.65	1.75	0.86	0.75	0.32
Petrol	6,745,442.135	1.38	0.67	0.59	0.25
Kerosene	1,025,842.167	1	1	1	1
Energy demand(GJ)	26,186,332.96	42,560,887.46	21,382,230.24	18,816,939.52	8,605,018.27

The multiplier factors are used in table 39 is from the literature source [72]. Note that for the kerosene fuel the multiplier factor is 1 and it is assumed that efficiency will remain the same as well to wheel energy efficiency data is not available although fuel alternative are identified for aviation fuel [86].

Owing to technical maturity and efficiency consideration, electric mobility seems to be an attractive alternative for Bhutan. From the fuel demand projection, it is clear that the demand for fuel import will increase in business as usual case, which is accompanied with toxic emission due to fuel combustion. To address this challenges, 100% shift from fossil fuel to electric source will require national energy generation potential and domestic demand projection for electricity diversion to mobility. Table 40 shows the energy generation and domestic demand projection in 2030 considering 2020 as base year, which does not consider electricity use as mobility fuel. This is performed to understand the domestic electrical load. By 2030 it is expected that the generation capacity of hydro will increase from 2,518 MW to 4,114 MW with the average plant factor of 50% [192], [194], [197]. On the other hand the domestic demand is expected to increase proportionally from 387 MW to 880 MW with average operating hours of 6 hr per day [197]–[201]. The calculated value shows that the generation capacity increases by 38% and the domestic consumption increases by 56%. On the other hand the overall national electricity consumption is 7.68% in 2020 and 10.70% in 2030 of the total generation. This would mean the energy available for export and use as mobility fuel is more than 80%.

Table 40: National energy potential

Electricity scenario projection	2020	2030	Remarks/sources
Installed capacity (MW)	2,518.00	4,114.00	From DGPC & NTGMP 2018
Plant factor	50%	50%	From DGPC, 2020
Energy generation (MWh)	11,028,840.00	18,019,320.00	Calculated value
Domestic peak power demand(MW)	387.00	880.00	BPC 2019 and NTGMP 2018
Operating hours/day (hours)	6.00	6.00	Calculated from NTGMP 2018
Energy consumption (MWh)	847,530.00	1,927,200.00	Calculated value
Energy generation (GJ)	39,703,824.00	64,869,552.00	Energy Conversion
Energy consumption (GJ)	3,051,108.00	6,937,920.00	Energy Conversion

Although at a first glance the energy generation and fuel demand scenario shows very optimistic result for fuel switch to alternative availability even with low energy efficiency fuel (CH_4), where national generation from hydro is 64,869,552 GJ and it exceed the highest projected mobility fuel demand of 42,560,887.46 GJ, there are other factors that influence future energy scenario development. As seen in figure 27 in section 4.6, the national economy is dependent on export of hydro electricity and import of transport fuel, careful consideration on energy import and export and net energy balance show, storage requirement is critical in lean season (refer to chapter 4). For that purpose the seasonality of generation and demand variation has to be known for successful transition to 100% electric mobility. In the current situation Bhutan is still importing electricity in lean season to meet domestic electricity demand, which will not change much even with the addition of national generation capacity in 2030 because the hydropower plant factor of 50% will more or less remain constant unless the alternative storage is planned [192], [194], [197]. 50% plant factor has cascading effect on domestic electricity demand and seasonal generation variation as in lean season the plant factor fall to as low as 15% making the generation potential very low against the projected demand [198]–[201].

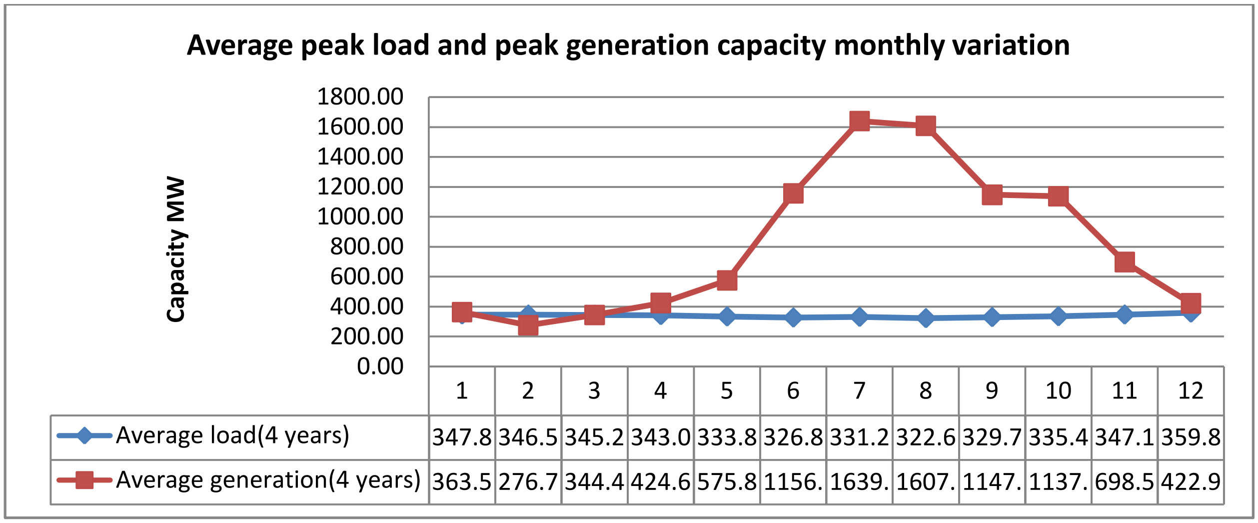


Figure 43: Generation and demand variation, average of 4 years

Seasonality and generation variation can be observed from figure 43. Average of 4 year data is analysed to see the demand variation and generation variation based on the current data source from Bhutan Power Corporation (BPC) and Druk Green Power Corporation (DGPC) since 2016 [192], [194], [198]–[201]. The hydropower plant factor ranges from 15% to 108% for different power plant and in different months, which depends on monsoon and plant operating conditions [198]–[201]. On an average the generalised annual plant factor for hydropower is between 40-50%, where lean seasons can last from November to May (7 months). This will have a major impact for the fuel switch from fossil to electrical if storage is not properly planned. Therefore, even if fuel efficiency of power to gas technology is very low, they can still be looked for long term mobile energy storage alternatively. However due to lack of commercial maturity, this can only be used as initial stage research trial in Bhutan as alternative mobility fuel source.

The electricity as fuel substitute for mobility use is limited to short term energy storage as automobile need to be recharged on a weekly/daily basis depending on travel requirement. Considering the average firm power capacity of 21-108%, the expected peak generation can go up to 4,443 MW and the lowest generation can fall to 863 MW in 2030, which will face the same challenge of lean season electricity import [197]–[201]. The addition of projected energy demand of 8,605,018.27 GJ (398,380.48 MWh) for fossil fuel substitute (all fuel type) by hydro electricity additionally stresses the domestic consumption by increasing the base load by approximately 1,091.45 MW peak. Even if the load shift is managed, the challenge will continue because the average electricity load profile of Bhutan shows more or less the flat load profile curve (see figure 44). It has to be noted here that the fuel demand projection is for all categories of fuel including that of aviation fuel. However aviation fuel represents only about 2% of total fuel demand. Therefore, strategy for 100% electric mobility is next to impossible due to various reasons; such as lean season challenges, electrification difficulty for all automobile type and categories and different mobility mode. Therefore, in the following efficiency improvement alternatives are explored.

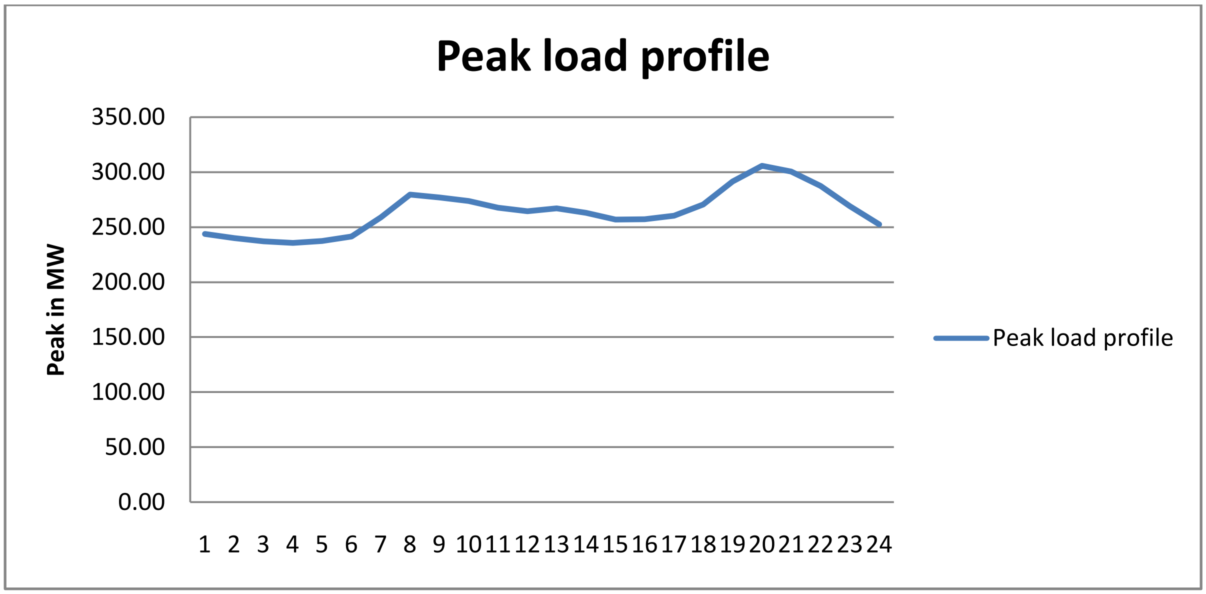


Figure 44: Electrical energy peak load profile

A statement can be made from this projection that for the current development of electric vehicle it will require major reforms in energy demand and supply and grid load consideration. When the fuel demand in transport sector increases drastically, the electric load profile and demand variation will be major challenges that need to be addressed.

6.7.2 Scenario 4_2: Efficiency improvement, without fuel switch

Efficiency improvement in mobility system is fully or partially influenced by human behaviour even if technology choice and infrastructure offer alternatives. On the other hand, the behaviour is fully influenced by economy and supply chain market orientation. The basic condition for behaviour change requirement is to reduce motorized travel behaviour for both passenger and freight mobility. The de-motorization is therefore possible only if decentralized economy is in place, where mass production and consumption is reduced to regional or community level local economy rather than globalized supply chain market, which seem to be practically unrealistic in the globalised society. Therefore, in the current mobility system development trend, there are two possible alternatives such as optimizing automobile and infrastructure capacity. For example; enabling optimum automobile speed on road called as green speed level through infrastructure quality improvement and optimizing the use time of the automobile and optimizing their capacity are possible alternative(Nasir et al 2014). Optimized usages of automobile are often found in public transport service and ride sharing alternatives [25], [44], [49], [91]. For that purpose, it is important to know the passenger kilometre travelled by all automobile categories and potential optimization options for all kinds of mobility mode and type, which roughly provides an estimate on efficiency improvement possibility.

Table 41: Passenger kilometre travelled by automobiles[166]

Vehicle categories	% share	Function	passenger capacity	Average annual travel (km)	PKT(km)	
					Min	Max
HV	0.49	Passenger	> 25	30,000	300,000	750,000
	10.37	Freight	3	20,000	20,000	60,000
MV	0.34	Passenger	13 - 24	30,000	150,000	600,000
	1.41	Freight	2	20,000	20,000	40,000
LV	0.10	EV passenger	4	-	-	-
	4.86	Taxi passenger	4 to 12	33,000	66,000	396,000
	64.76	SUV & passenger	4 to 12	11,000	11,000	44,000
TW	10.74	Passenger	2	5000	5,000	10,000
Other	6.36	Stationary	1	-	-	-

In the case of Bhutan ride sharing alternatives is possible only in surface transport, where passenger and freight mobility is mixed. Although heavy duty vehicle is used for movement of goods, they are also used for informal travel alternatives by people especially in rural area. The transport energy efficiency audit was conducted in Bhutan inclusively for all type of vehicles and mode by department of renewable energy in 2015 [166]. Based on the primary survey data of transport energy efficiency audit report, passenger kilometre travel by different automobile in Bhutan is derived in table 41. Note that the aviation sector is not included here as they are considered to be service oriented already, which can be considered as a well organized public service compared to surface transport mode. Also, aviation sector represents negligible share for domestic travel option in Bhutan. Aviation is therefore only considered for future fuel energy security as shown in scenario 4_1 in section 6.7.1. In table 41 highest automobile share is seen in light vehicle categories (>69%) and lowest in the heavy and medium passenger vehicle (<1%) indicating weak public transport service. On the other hand, the average annual distance travelled by heavy and medium passenger vehicle is higher than that of light vehicle categories represented by SUV and passenger, indicating that its service is not utilized fully, whereas taxis travelled more annual distance than that of heavy and medium passenger vehicle category. The freight mobility is mostly used for commercial purposes for goods mobility and does not provide optimization option for passenger mobility efficiency improvement although it has significant value addition for mobility as a system. On the other hand two-wheeler is mostly used for local travel and for leisure time use for tourism such as mountain biking and personal ride by an individual. The maximum and minimum passenger capacity is assumed for estimation purpose. The assumption is minimum10 and maximum 25 passenger for heavy passenger bus, minimum 1 and maximum 3 passenger for other heavy vehicle, minimum 5 and maximum 24 passenger for medium passenger bus, minimum 1 and maximum 2 passenger for other medium vehicle, minimum 1 and maximum 4 passenger for all light vehicle, minimum 3 and maximum 12 passenger for taxi and minimum 1 and maximum 2 passenger for two wheeler respectively. The automobile category represented by others includes power tiller, tractors, earth mover and other agriculture farm machinery and are therefore not suitable for passenger mobility. Therefore the first efficiency improvement alternative can be analysed based on passenger kilometre travelled (PKT) and the energy consumption per PKT of passenger automobiles.

Table 42: Fuel efficiency in terms of PKT and optimization potential

Vehicle categories	% share	Function	Average fuel efficiency			difference	Optimization potential (%)
			l/100 Km	PKT/L (max)	PKT/L (min)		
HV	0.49	Passenger	13.00	576.92	230.77	346.15	60
	10.37	Freight	20.00	30.00	10.00	20.00	67
MV	0.34	Passenger	13.00	461.54	115.38	346.15	75
	1.41	Freight	20.00	20.00	10.00	10.00	50
LV	0.10	EV	-	-	-	-	-
	4.86	Taxi	7.00	565.71	94.29	471.43	83
	64.76	SUV & passenger	7.00	62.86	15.71	47.14	75
TW	10.74	Passenger	3.00	33.33	16.67	16.67	50
Other	6.36	Stationary(l/hr)	-	-	-	-	-

Based on the data set of table 41, which is derived from the transport energy efficiency report [166], average fuel consumption by different automobile categories expressed in passenger kilometre travelled per litre of fuel is calculated. While the annual passenger kilometre travelled by the heavy and medium vehicle is high, they are also subject to low fuel efficiency and therefore offer lower passenger kilometre travelled when it is expressed in PKT per litre of fuel, which indicates the optimization of light vehicle use may result to more or less the similar result. For example, the heavy bus and taxi has very close PKT, indicating that the ride sharing alternative is equally significant like in public transport service alternative although space efficiency may differ drastically. Furthermore, an optimization potential in the range of 50-80% (refer to table 42) is releasable if all options are considered and user behaviour is aligned to sharing culture. Note that the freight mobility may not be suitable for future of passenger travel although in the current situation mixed passenger and freight mobility can be seen. However, the current estimate provides the possible efficiency improvement magnitude for optimization.

Table 43: Passenger km travel projected efficiency

Vehicle categories	Growth trend	Count in 2030	% share	Function	PKT/L (max)	PKT/L (min)	Total Km(max)	Total Km(min)
HV	9.13	29,304	0.49	Passenger	576.92	230.77	762,807.4	305,122.9
			10.37	Freight	30.00	10.00	839,461.7	279,820.6
MV	12.02	5,996	0.34	Passenger	461.54	115.38	537,693.2	134,423.3
			1.41	Freight	20.00	10.00	96,626.6	48,313.3
LV	13.39	247,770	0.10	EV	-	-	-	-
			4.86	Taxi	565.71	94.29	9,773,652.6	1,628,942.1
			64.76	SUV & passenger	62.86	15.71	14,465,792.4	3,616,448.1
TW	5.39	19,316	10.74	Passenger	33.33	16.67	643,851.1	321,925.6
Other	13.50	24,419	6.36	Stationary(l/hr)	-	-	-	-
Total passenger km travelled by all vehicle (max and min)							27,119,885.1	6,334,995.9
Maximum possible efficiency using all possible optimization options (%)								76.64

The growth projection and optimization potential can be roughly visualized from the current representation of mobility share and their future development. Table 43 shows the projected mobility growth trend and automobiles in 2030 in a business as usual scenario represented by % share of automobile category. In the business as usual scenario the growth of light vehicle is highest (>69%) compared to other automobile category. This indicates that the vehicle ownership will continue to grow in Bhutan unless drastic modification of public transport service is prioritized. On the other hand, if all the optimization potential is fully capitalized the overall PKT per litre of fuel will be drastically increased, which is however highly dependent on to commuter behaviour. In the business as usual scenario if vehicle run on full passenger capacity a maximum of 77% travel efficiency can be visualised from the projected PKT in table 43. The efficiency improvement of up to 77% may be achieved through increased public transport services, car sharing alternatives and using two-wheeler for local travel requirement. However, the major challenge for the service oriented growth is fully influenced by quality of service and availability of user centric service options. Therefore, the passenger mobility can be re-oriented to service optimization of light vehicle rather than ownership culture, which will require systemic changes in mobility service business. For example the mobility as service can be seen as any other utility company functioning that provides diversified car rental options [45]. In such scenario the automobiles are not owned by the user but it is owned by Service Company providing the rental services combined with the public transport services. Since the freight mobility function is different, they cannot provide much alternative as the loading capacity of automobile is already well established which is at the moment mostly optimized. Therefore, the major challenges can be seen in passenger mobility, which is fully dependent on user behaviour.

Apart from the optimized use of automobile, the infrastructure optimization can also be explored. Higher fuel efficiency of automobiles is seen in the speed range of 50 to 80 km/hr called as green speed limit, which can change the PKT per litre of fuel for different mobility category(Nasir et al 2014). As seen in section 4.5.1, the overall infrastructure change is 14%, where the paved road has increased by 8.39% and simultaneously the unpaved road infrastructure has increased by 15.81% annually. In the current situation, road density of Bhutan is 0.47 km/km^2, where highest vehicle density is seen in express way and urban road and lowest in farm road, which is mostly unpaved (refer to chapter 4). The overall road infrastructure design consideration is summarized in table 44 that shows the potential for efficiency improvement if the green speed limit can be enabled through infrastructure quality improvement and green speed consideration [157], [202].

Table 44:Infrastructure design condition consideration (MoWHS 2002; Nasir et al 2014)

Road type	Designed speed (Km/hr) for different slope gradient and road type in Bhutan				Green speed(km/hr)	
	Level terrain(0 -10%)	Rolling terrain (10-25%)	Mountainous terrain (10-25%)	Steep terrain (>60%)	Min	Max
PNHW	60	50	40	30	50	80
SNHW	50	40	30	20	50	80
DR	40	30	20	15	50	80
FR	30	25	15	10	50	80

The infrastructure design of Bhutan shown in table 44 shows that the current speed limit is not up to the green speed limit of 50 to 80 km/hr except for primary national high way, where the speed limit range between 30 to 60 km/hr. Therefore, optimization of infrastructure has the potential to increase the fuel efficiency, where the automobile can be driven at higher gear which offers much higher fuel efficiency. The change in speed limit between 10 to 50 km/hr has the potential to improve the fuel efficiency by up to 40% (Nasir et al 2014). Therefore, infrastructure quality improvement offers fuel efficiency improvement of up to 40%, which is also influenced by the driving behaviour. In general, it can be safely assumed that the combined mobility system efficiency can range between 40- 70% if infrastructure quality is improved.

6.7.3 Scenario 4_3: Fuel alternative, strategy for e-mobility

The rational for e-mobility consideration has two fold impacts and that are to reduce energy demand and environment pollution due to high efficiency and low emission [72]–[74], [79]. However it can be decisive for the choice if full life cycle comparison is not done, which is missing even in IPCC reports especially for the full system impact categories for mobility [72]–[74], [79]. Therefore, more detail data is necessary to clearly estimate such scenario. In the current situation e-mobility seems to be advantageous if electricity source is renewable [72]–[74], [79] and Bhutan seem to have the luxury of 100% hydro as energy source. Based on the reasoning from the LCA result concerning environment impact due to mobility [72]–[74], [79] and Bhutan's transport energy efficiency report [166], approximate real world mileage of automobiles used in Bhutan considering internal combustion engine and electric engine is compared in table 45. The real world energy consumption of electric vehicle increases by approximately 40% when vehicle weight is doubled whereas it only increases by 5% with change in motor power according to Weiss, Cloos&Helmers (2020) [79]. Therefore, the categorical variables weight and associated fuel consumption can be visualized for e-mobility strategy for Bhutan. The automobile category others is not considered for electric conversion, which is about 6% of the total automobile count and are mostly stationary machine used for farm machinery. Their electric conversion is not yet fully known and operational. Similarly, the aviation sector comprise of about 2% of total fuel consumption, which makes e-mobility strategy to remain to only 92% for overall mobility.

Table 45: Average automobile mileage and fuel efficiency

Vehicle categories	weight	% share	Function	l/100 Km	Average energetic fuel efficiency		
					Diesel(kWh/ 100 km)	Petrol(kWh/ 100 km)	Electric(kWh/ 100 km)
HV	> 10 ton	0.49	Passenger	13.00	156.47	-	44.00
		10.37	Freight	20.00	240.72	-	44.00
MV	3 -10 ton	0.34	Passenger	13.00	156.47	-	38.00
		1.41	Freight	20.00	240.72	-	38.00
LV	< 3 ton	4.86	Taxi	7.00	84.25	87.11	33.00
		64.76	SUV & passenger	7.00	84.25	87.11	33.00
TW	>100 kg	10.74	Passenger	3.00	-	37.33	9.00

The efficiency of the electric engine is high compared to the mileage offered by internal combustion engine [79]. For example the heavy electric vehicle consumes 44 kWh for every 100 km as against 156.47 kWh for every 100 km compared to internal combustion engine vehicles (refer to table 45). Heavy electric vehicles especially used for passenger is very useful for Bhutan as energy source is 100% hydro electricity and its emission is relatively low compared to fossil fuel. The heavy electric vehicles and two-wheeler are not yet explored in Bhutan, which seems to be future alternative for energy security question.

While the energy efficiency of e-mobility is higher than that of fossil fuel, the systemic orientation and operational context is critical, which will determine the innovation potential of system sustainability. In the business as usual case as a baseline, the optimization potentials are explored in section 6.7.2, which roughly showed between 40-70% of efficiency improvement, is possible (refer to scenario4_2). This improvement is highly dependent on user behaviour that will require systemic transformation in terms of operational context. For example, the service orientation of current mobility that allows mobility to be viewed as utility service and that can be easily regulated to address the fuel switch from fossil to electric as control, which can be incentivised for the service provider rather than the user. The same optimization potential can be seen in table 41 (up to 70%) when system is oriented to service centric development. However, with the electric conversion the per capita energy consumption can be drastically improved. For example, the passenger km travelled by heavy buses can be compared with diesel and electric, which shows additional 70% efficiency improvement possibility (refer to table 46). On the other hand, the use of two wheeler offers much higher automobile to passenger weight ratio, which is often time underestimated. Therefore, combined implication of public transport, mobility as a service development and two wheel cultures has double fold positive impact for Bhutan in terms of systemic optimization and electric conversion. However, the fuel switch of passenger car and two-wheeler to e-mobility is faced with two critical challenges. They are high initial cost and the national dress code that is not suitable for two wheeler [166]. Public buses and heavy truck are not yet considered for 100% e-mobility strategy as of now, which is critical aspect for energy security question.

Table 46: Mileage in terms of passenger km travelled

Vehicle category	% share	Function	PKT/L (max)	PKT/L (min)	Fuel efficiency PKT/kWh						Optimization potential (%)
					Diesel		Petrol		Electric		
					max	min	max	min	max	min	
HV	0.5	Passenger	576.9	230.7	3.69	1.47	-	-	13.11	5.24	60.00
	10.4	Freight	30.00	10.00	0.12	0.04	-	-	0.68	0.23	66.67
MV	0.3	Passenger	461.5	115.3	2.95	0.74	-	-	12.15	3.04	75.00
	1.4	Freight	20.00	10.00	0.08	0.04	-	-	0.53	0.26	50.00
LV	4.9	Taxi	565.7	94.29	6.71	1.12	6.49	1.08	17.14	2.86	83.33
	64.8	SUV & passenger	62.86	15.71	0.75	0.19	0.72	0.18	1.90	0.48	75.00
TW	10.7	Passenger	33.33	16.67	-	-	0.89	0.45	3.58	1.79	50.00

Vehicle mileage and fuel efficiency can be further projected in future, which shows the electric conversion in a business as usual case has the potential to increase the overall mobility system efficiency by 69% (refer to table 47) even if systemic efficiency improvement is not considered. Therefore, it makes logical for e-mobility as an option to address the energy security question. However major challenges for fuel switch to e-mobility can drastically impact the national electric grid network and charging infrastructure development, as reflected in scenario 4_1, where the lean season energy import and peak power balance is necessary condition that needs to be looked into more detail. The grid load capacity and seasonal energy generation variation is practical situation, which might require alternative storage for clean fuel source.

Table 47: Projected fuel efficiency, real world scenario Bhutan 2030

Vehicle categories	Automobile count in 2030	Automobiles usage by type	Annual Km traveled by automobile	Annual total km travelled (million)	Energy demand (GWh)		
					Diesel	Petrol	Electric
HV	1,322	Passenger	30,000	39.67	62.07	-	17.45
	27,982	Freight	20,000	559.64	1347.18	-	246.24
MV	1,165	Passenger	30,000	34.95	54.69	-	13.28
	4,831	Freight	20,000	96.63	232.60	-	36.72
LV	17,277	Taxi	33,000	570.13	480.35	496.65	188.14
	230,138	SUV & passenger	11,000	2531.51	2132.87	2205.23	835.40
TW	19,316	Passenger	5,000	96.58	-	36.06	8.98
Total energy demand and for LV 100% diesel or 100% petrol					4345.81	4434.47	1346.22
Efficiency improvement due to electric conversion (%)					**69.02%**	**69.64%**	

The second important aspect of e-mobility is its positive impact on environment, which is decisive if life cycle study is not performed [72]–[74], [79]. For example, if source of electricity is not renewable it has the potential to shift the emission from automobile to energy generation, which is in fact higher than that of fossil fuel due to energy conversion loses. However it appears that the urban air pollution can be reduced by electric vehicle as electricity generation is outside of the urban centre [73]. This might be the case of new electric vehicle policy in the SAARC region, where EV gets preferential treatment, which is based on the reasoning that urban air pollution can be lowered [128], [203]. However the life cycle impact of automobile break even mileage and emission on the basis of passenger km travelled seem to show insignificant difference for electric vehicle and combustion engine vehicle if electricity source is not clean [74]. Therefore it is only in the condition that if energy source for battery production and use phase electricity is renewable, the electric vehicles are more advantageous [74]. In the case of Bhutan since energy source is 100% hydro, both battery production and use phase energy consumption can have positive impact on environment although the grid emission factor is not yet clearly reflected in any literature sources specific to Bhutan(refer to section 4.6 chapter 4 for data gap). Further the lean season energy import from India significantly impacts the emission, which is not considered in this study. The default grid emission factor for hydro can range between 0.0005t to 0.152t CO_{2e}/MWh [178]. Similarly, the emission factor of diesel, petrol and kerosene is shown in table 13 in sections 4.4, where environment impact due to different fuel consumption is calculated in section 4.4.1 to 4.4.3 (refer to chapter 4). The more detail and real world emission for different vehicle categories can be computed for which the converted value (g/kWh) of the emission factor shown in table 13 and default hydro emission factor is further analysed in table 48. All the default values are converted to g/kWh for the comparison purpose and their original values are obtained from different literature sources [178], [181]–[185]. In the case of hydro default value the higher value is used as Bhutan hydro power is mostly large scale ranging between 300 to 1000 MW installed capacity [192], [194].

Table 48: Default emission factor converted to g/kWh

Fuel type	Emission factor (g/kWh)								Sources
	CO2	CO	SO2	NOx	N2O	CH4	NMVOC	PM2.5	
Diesel	266.760	3.600	0.684	2.880	0.002	0.014	0.720	0.017	IPCC & IMPRO-car
Petrol	249.480	28.800	0.504	2.160	0.002	0.090	5.400	0.014	IPCC & IMPRO-car
Electric	152.000	-	-	-	-	-	-	-	Default value hydro

Based on the default emission and the approximate automobile mileage for different automobile categories [166], vehicle emission in terms of g/km is compared in table 49. The e-mobility as an alternative shows low CO_2 emission compared to combustion engine vehicle and is free from other emission species.

Table 49: Emission from different automobile in g/km

Vehicle categories			kWh/100 km	Emission(g/km)							
				CO_2	CO	SO_2	NO_x	N_2O	CH_4	NMVOC	$PM_{2.5}$
HV	**Diesel**	**Passenger**	156.47	417.398	5.633	1.070	4.506	0.003	0.022	1.127	0.027
		Freight	240.72	642.151	8.666	1.647	6.933	0.005	0.034	1.733	0.042
		Electric	44.00	66.880	-	-	-	-	-	-	-
MV	**Diesel**	**Passenger**	156.47	417.398	5.633	1.070	4.506	0.003	0.022	1.127	0.027
		Freight	240.72	642.151	8.666	1.647	6.933	0.005	0.034	1.733	0.042
		Electric	44.00	66.880	-	-	-	-	-	-	-
LV	**Diesel**		84.25	224.753	3.033	0.576	2.426	0.002	0.012	0.607	0.015
	Petrol		84.25	210.194	24.265	0.425	1.820	0.002	0.076	4.550	0.012
	Electric		33.00	50.160	-	-	-	-	-	-	-
TW	**Petrol**		37.33	93.139	10.752	0.188	0.806	0.001	0.034	2.016	0.005
	Electric		9.30	14.136	-	-	-	-	-	-	-

The emission calculation summery of table 49 has direct impact on human health especially in terms of urban air quality and therefore human wellbeing can be an added value as an argument for the e-mobility as an alternative in context to Bhutan mobility system development, which is very unique situation.

From the estimation and the future projection, the e-mobility seems to be very attractive option for Bhutan. However lack of infrastructure and electric grid stability still remain questionable [127]. The infrastructure development especially the quick charging infrastructure can only be followed based on electric transmission network stability and load distribution. Lean season energy demand is already seen as a major challenge in scenario 4_1. Therefore it can be recommended that for the initial development of e-mobility two wheeler and buses rather than car and heavy freight vehicle seems to be more appropriate. This can also lead to de-motorization and service orientation as most of the urban centres are within the radius of 20 km, which can be covered by two wheeler and public buses [127]. Mobility as a service industry seems to be future for e-mobility where all automobile categories can be integrated into utility businesses like electricity supply.

6.8 Synthesis: Recommended strategy

Strategy is a potential system influence factor consideration for meaningful deployment of the decision. There can be any one of the following: planning-oriented, responsive, and proactive strategy, which determine the probabilities, opportunities, and desirable future as shown in figure 45 [30]. Based on figure 45, mobility system scenario can be further positioned in the strategy field.

	Planning-oriented Strategy	Responsive Strategy Opportunity-seeking / risk-avoiding	Proactive Strategy
Focussed strategy (strategy based on one reference scenario)	***Strategy based on the scenario with the greatest probability*** *Conventional one-dimensio-nal planning is easy to communicate – but: traditional prognoses and most probable scenarios come true less often then planners think.*	***Strategy based on the scenario with the greatest opportunities*** *Powerful but risky strategy to achieve the best possible results.* ***Strategy based on the scenario with the greatest threats*** *Risk-avoiding strategy to use in Crisis-Management.*	***Strategy based on the desirable scenario*** *Enterprises create »their own future« – difficult to handle with external scenarios.*
Future-robust strategy (strategy based on several scenarios)	***Safeguarded strategy based on the scenario with the greatest probability*** *Conventional strategy which is safeguarded by alternative scenarios.*	***Strategy concentrating on the maximization of flexibility*** *Effective strategy to cope with uncertainties – but often not powerful enough.* ***Strategy concentrating on the minimization of threats*** *One-sided concentration on risk-minimization.*	***Safeguarded strategy based on the desireable scenario*** *Enterprises create »their own future« and safeguard their strategy by putting the strategy in different environments.*

Figure 45: strategy field[30]

The mobility system vision defined in section 6.3 is the result of system analysis, which is mainly focused on critical target variable identification in chapter 5 [8].The critical target variable identification process is cybernetic in nature, where the desired mobility system transformation to sustainable mobility system is fundamental consideration. For that purpose, conception of goals in section 6.4 based on three system leveraging variables is positioned for objective definition for the defined vision. The goal conception is dependent on more detailed normative values of the variables, where cross-consistency analysis in section 6.5 is performed, which is a cybernetic deduction of vision into optional future. Definition of system's goals in section 6.5.1 to 6.5.3 further elaborates possible goals for optional future, which is again context dependent. The final stage of mobility system image is a narrative, which defines the scenario field in section 6.6 and the story lines for narrative scenarios in sections 6.6.1 to 6.6.4 are a final description of the system image. Therefore the system image visualization is iterative and cybernetic, which does not follow fit for all strategy for success potential in future [7], [8], [51], [10], [11], [17], [18], [28], [29], [32], [33]. They require consideration of strategic options for the future. It has to be noted that even the strategy is cybernetically oriented, which can only be truly known if desire, wishes and feelings of the actors are known. Therefore, the decision making process is complex and requires a meaningful strategy for further adjustment keeping in mind the original system image is not distorted. The strategy can be developed based on one single reference scenario and / or several scenarios [30]. The system vision is broad but focused on a single future scenario, which represents the mobility system image. The multiple scenarios are possible developments of that roughly complete system vision represented by Quattro Stagioni logic. They are potential futures taking into account the uncertainty of that roughly complete system image. Table 50 represents the transfer of the so far deduced scenarios for strategy formulation from the complete variable list of mobility system. .

Table 50: Scenario transfer

	Planning oriented strategy	Responsive strategy	Proactive strategy
Focused strategy (Strategy based on one referenced scenario)	Business as usual case	Digitized mobility system	Mobility as a service
future robust strategy (strategy based on several scenario)	Scenario 2 Scenario 3	Scenario 4	Scenario 1

The strategy field that represents single focused strategy and future robust strategy decision approach according to Gausemeier et al [30] has three possibilities such as planning oriented strategy, responsive strategy and proactive strategy as shown in table 50. These two strategies are elaborated in section 6.9 to 6.10 in the following. It has to be noted that the strategy is planning guide and does not fully address the actual development of the plan. The surprises and unintended side effects are always accompanied when they are deployed. Therefore, alteration of decision field based on those unintended side effects cannot be ignored for the success of the defined vision to be operational.

6.9 Focused strategy

Focused strategy is a one-dimensional strategy addressing the defined vision or the target goals. In such strategy development the stakeholder communication is limited to decision makers, which seem to appear easy for implementation. This is exactly the case with the prediction of the system's future based on the one vision with different benchmarking baseline. They have appeared in section 6.5.1 to 6.5.3 as three possibilities, such as business as usual case, digitized mobility system and mobility as a service industry. The meaningful valuation of any possible development depends on the choice of enabling policy support, which requires step by step process to overcome them. It has to be noted that the defined system vision in such strategy formulation is fixed and uncertainty considerations are rare. Therefore, unintended surprises are more or less the expected end result even if fine tune planning is implemented. The three possible ranges of the vision defined in section 6.5.1 to 6.5.3 as system goals are further elaborated in the following.

The *business as usual case* is a situation, where policy reforms intend to change the transaction of product and service flow in the system. The strategy represents the planning-oriented strategy in table 50. For example the deployment of strict regulation on driving a personal car in urban environment, such as congestion charge, parking fee, and automobile tax based on size and space utilization, fuel tax and infrastructure usage fee. Similarly, the use of other modes of transport such as flight, trains, buses and shared mobility option with reduced financial burden fall under these categories. However, the intention of transforming the system in such situation is more likely that the actors of the system (here the user) immediately get used to the financial regulation and the normal conventional mobility trend tends to dominate alternatives to the desired option. The mobility system tends to generate more revenue resulting from the financial imposition imposed on the system actors. The *business as usual strategy* is the result of decision maker's choice to regulate the conventional mobility system to transform them to alternative availability.

The strategy to *digitized mobility system* for transformation is an alternative that tends to achieve the system efficiency through various means. However, the unintended side effect development from the virtual platform needs to be taken into account. System digitization and automation is potential change lever for efficiency improvement but does not actually replace the feelings and dreams of the user. The strategy represents the responsive strategy in table 50. For example, the online booking, home office scheme, online meeting, and home shopping trends tend to shift the actors´ behavior from mechanical operation of the system to automated operation of the mobility system, which will influence the growth of ICT industry. However, it has to be noted in such situation that the system operation can be transformed but not the actual mobility requirement. The side effect or the unintended rebound effects are potential future development. For example, the higher share of job market for home office and higher income from ICT technology choice is clear focused future. However, the shift of mobility need from functional purpose to recreational purpose will increase sooner or later. Therefore, the strategy has the potential to control the material and energy efficiency of mobility system, which is valuable response strategy for system management. However, their future development is accompanied with opportunities as well as threats. Rebound effects are more or less the clear future surprises.

Mobility as a service industry is a transformation of the mobility system from product dominated service value to service dominated product value. The strategy is desirable but also has many unintended side effects as they progress. For example, the availability of job opportunities and operational service of production industry will face the economic challenge. The strategy is a proactive strategy as shown in table 50. The services such as car rental, flexible housing for mobile workers, industrial business shift from product sale to sale of services and the re-orientation of supply chain market are some example for service centric development. Even if *mobility as a service industry* is a desirable future option, their functioning is strongly influenced by economic system. Hence the strategy needs to consider the financial institution as part of the mobility system, which is not so easy when singularity focused strategy is adopted. It has to be noted that the public transport service is an already existing example of mobility as a service industry, which is not enough for the current mobility demand. However, the user reaction to avail those services still faces the challenge of stigma of ownership as status symbol, which will potentially encourage mobility user to opt for ownership culture.

Thus, it can be concluded that the focused mobility services are easy implementation option, which is one dimensional decision consideration and represents one single scenario. Mostly the one vision without uncertainties consideration represents the system scenario field. The range of possible development can be predicted but surprises are unavoidable for actual functioning of the system. Often time focused strategy does not fulfill the desired vision, which will require deeper stakeholder negotiation for the change. The mission, goal and objective are influenced by the single scenario field. The uncertainties are often over or under estimated in the planning and decision-making process. Such strategy is strong influence factor for mobility system policy development, which is often time addressing sustainability aspect but actual operation faces ground reality. The ground reality is heavily influenced by the system actor reaction to the availability and its associated uncertainties in future, which is linked to range of other associated factors for example, the human psychological aspect. Thus, we can conclude from this single scenario field, the strategy is good tool for vision definition but does not actualize the mobility system's operational context. Therefore, more flexible and expected surprises can be integrated in the mobility system scenario with multiple scenario fields. Deduction of Quattro Stagioni logic in figure 42 indicates the possible development of the critical variables, which shows the normative value proposition of the defined goals in sections 6.5.1 to 6.5.3. This multiple scenario field will be elaborated in section 6.10 to address further the resilient system strategy.

6.10 Future robust strategy

Future robust strategy is a strategy that addresses the uncertainty and expected future surprises, which will enable the system's flexibility, avoid potential threats, optimize potential opportunities and manage the desirable future based on those possible future considerations [30]. For that purpose, the potential future scenarios are required to be visualized in the present moment. The Quattro Stagioni logic in section 6.6 is useful for visualization of possible futures formed by the critical variables in four quadrants in figure 42 [10], [11], [20], [134]. The scenario formulation process is part of Analysis-Projection-Synthesis (APS) approach [11], which indicates potential future uncertainties of the mobility system (see sections 6.6.1 to 6.6.4 for detail scenario narratives). As soon as these scenario fields are introduced, the 9 goals defined in section 6.5.1 to 6.5.3 can be integrated, which actually represent one single broad future vision. It has to be noted here that the deduction of single vision into scenario field is to introduce the potential uncertainties, which is cybernetically oriented. The critical variables are therefore the explanatory variables for the normative description of the cybernetic effect. The transfer of the goals to the scenario field can represent the potential future robust strategy, which is adjustable keeping in mind the original cybernetic in correct order. This endeavor will require variable influence factor consideration to formulate the strategy.

The critical variables Mobility service (7), Economic development (11) and Enabling condition (14) are potential system leveraging variables, which influence the target variables Human wellbeing (22) and Environment pollution (12). However, both system leveraging and target variables are fully or partially influenced by other system variables in the system. The four possible scenarios are the result of possible development of leveraging variables Mobility service (7) and Economic development (11) defined by Quattro Stagioni logic in section 6.6. The critical variable Enabling condition (14) is a system control variable, which depends on Mobility service (7) and Economic development (11) for system control condition. Therefore, the potential scenario in them influences the actual future scenario, which will determine the kind of strategy for system transformation. The variability of Mobility service (7) and Economic development (11) can potentially influence the behavior of mobility system and therefore future uncertainties can be observed from these critical variables, which will show robust future strategy. Therefore, defining future robust strategy is an iterative process resulting from system vision, goals, and scenarios deduction for future success. It has to be noted that the vision, goal and scenarios are ideological and strongly depend on actor's behavior. Therefore, the mobility system strategy must address the behavior correction of the actors. It can also be concluded from figure 42 that the mobility system transformation is dependent on the actor's behavior, which will require a shift from consideration of system's functional value and not the automobile product functional values. Mobility system functional value depends on service centric development, which is critical for mobility system transformation to sustainable system as shown in figure 42 in section 6.6.

In section 6.6 the variables Mobility service (7) and Economic development (11) are considered as potential system leveraging variables, which is context dependent and the possible development are uncertain in future. Since these critical variables influence all the mobility system variables, their possible extension of normative values also represents the potential transition of all the mobility system variables, which is defined by mobility system vision and 9 goals in section 6.5.1 and 6.5.3. Furthermore, vision and goal development are based on cybernetic effect system of chapter 5, which indicates roughly but inclusively all mobility system variables and therefore their uncertainties in the future. The strategy that addresses all the future uncertainties can now be re-looked for possible implementation plan. We can also conclude from this iterative process that defining mobility system strategy is a cybernetic deduction of complex network of influencing effect, which can now be synthesised considering the defined system vision, goals and scenarios.

The four quadrants defined in figure 42 showed potential future scenarios for mobility system development, where the system vision and goals can be assigned in a cybernetic orientation for their development. Based on this logic, the four quadrants are defined in figure 42 as;

1. Scenario 1: Decentralized public mobility service where value proposition determines the success potential
2. Scenario 2: Franchise private operated mobility services, where cost benefit determines the success potential
3. Scenario 3: Competitive market growth for mobility product development in open market competition where profit determine the success potential
4. Scenario 4: Preferential market for mobility product development in a regulated economy where measure of value determines the success potential

The mobility system vision and goals defined so far fall in the range of possibilities within this scenario field and can be influenced by cybernetic effect of the variable orientation in the system. The quadrants formed by the crossing of the two important critical uncertainties defined by the critical variable, Mobility service (7) and Economic development (11)gives the first hint for strategic decision support formed in four scenario quadrants. Transfer of the intended vision and goal in the scenario field determines the robust future strategy for system synthesis, which can influence system control policy and therefore strategic mobility system plan recommendation. The goals for the defined vision to '*Improve human well-being by providing safe, equitable and environment friendly mobility services*' are as follows, which is formulated in section 6.4 with the help of critical variable and their feedback effect in chapter 5. This can be compared to the clustering technique introduced by Gausemeier et al [30] in much more simplified form.

1. Goal 1: Enhance mobility growth by adoption of existing best practice to achieve better quality of life
2. Goal2: Increase service demand by imposing consumer behaviour shift to achieve better quality of life

3. Goal 3: Increase service demand by technology innovation to achieve better quality of life
4. Goal 4: Enhance economic growth by adoption of alternative mobility to achieve better quality of life
5. Goal5: Enable service economy development in mobility industry to achieve better quality of life
6. Goal 6: Increase industrial competitiveness through system automation to achieve better quality of life
7. Goal 7: Enable economic growth through improved mobility services for better quality of life
8. Goal8: Enable mobility service growth through industrial competitiveness to achieve better quality of life
9. Goal 9: Enable technology innovation to improve mobility service for better quality of life

The defined goals, which are based on cybernetic effect system and feedback effect will exhibit unique future image when they are positioned in the quadrant formed by the critical variables Mobility service (7) and Economic development (11) as shown in table 51.

Table 51: strategy definition

	Scenario 1 (strategy 1)	**Scenario 2 (strategy 2)**	**Scenario 3 (strategy 3)**	**Scenario 4 (strategy 4)**
Goal 1	Probable	Probable	Possible	Possible
Goal 2	Desirable	Desirable	Threats	Opportunity
Goal 3	Opportunity	Threats	Opportunity	Opportunity
Goal 4	Probable	Probable	Possible	Possible
Goal 5	Desirable	Desirable	Threats	Opportunity
Goal 6	Opportunity	Threats	Opportunity	Opportunity
Goal 7	Probable	Probable	Possible	Possible
Goal 8	Desirable	Desirable	Threats	Opportunity
Goal 9	Opportunity	Threats	Opportunity	Opportunity

The 9 defined goals are value free assumptions, which can take any uncertainty value of figure 45, such as threats, probable, possible, opportunity and desirable, that will define planning, proactive and responsive strategy. The strategy can now be developed based on this condition depending on the context. In table 51 the normative values attributes are assigned to all the 9 goals defined in section 6.5.1 to 6.5.3, which can be used to define robust strategy depending on the context. It has to be noted that the normative values (threats, probable, possible, opportunity and desirable) are future uncertainty consideration, which enable cybernetic oriented stakeholder debate for common agreement. The desirable values for example are the system vision itself, which is ideal future but is also accompanied with many constraints for its development in the future. Furthermore, the scenario bundle in table 51 indicates the potential scenario field for strategy formulation. For example, scenarios2 &3 are planning oriented strategies, scenario 4 is a responsive strategy and scenario 1 is a proactive strategy. In planning oriented strategies, where scenarios 2 &3 are positioned, mostly the market influence determines the planning process. Responsive strategy where scenario 4 is positioned is the imposition of regulatory norms for change requirement. The proactive strategy (scenario 1) is an ideal desirable situation resulting from the combined values of planning and responsive strategy. Thus the 5 potential values (threats, probable, possible, opportunity and desirable) define the strategy for the 9 defined goals in table 51.

The value free scenario field of figure 42 in section 6.6 and the scenario narratives of section 6.6.1 to 6.6.4 can now be re-oriented for strategy definition as shown in figure 46. It has to be noted that the scenario values are normative, which cannot be reduced to numeric values based on the numerical data. Therefore, very important conclusion can be drawn from here that the design of system image is normative descriptive, which can only be realised through robust negotiation keeping in mind the original cybernetic in proper order.

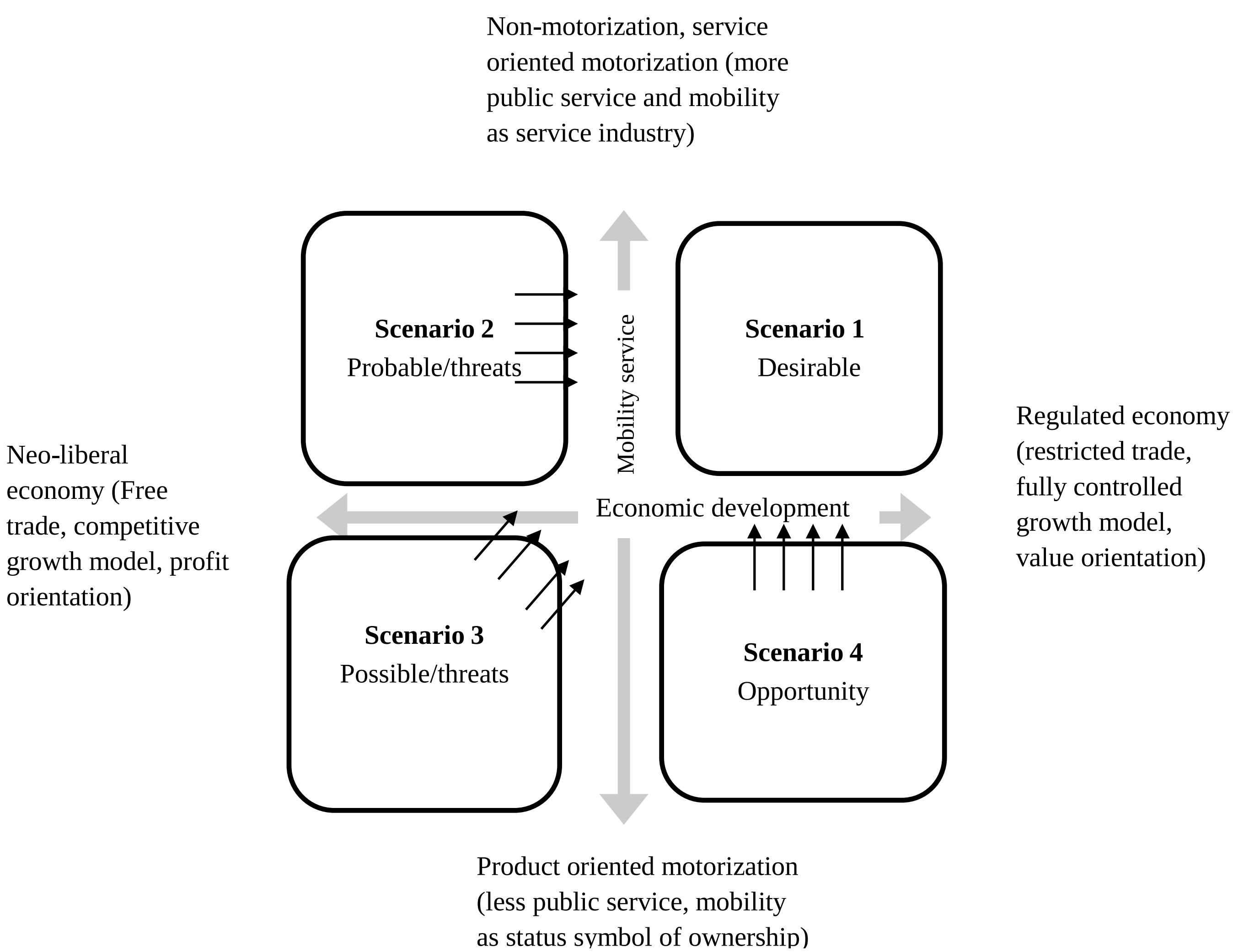


Figure 46: Goals transfer to system Scenario

Based on this normative scenario containing attributes of figure 46 and the 9 goals defining their future uncertainties in table 51, strategy formulation becomes possible. The four scenario fields with normative values assigned to the goals show 4 possible strategies that can be foreseen in the future of mobility system transformation process. The strategy can be used for test model in real world condition. Success and failure factor can then be decided for actual implementation. At this stage the strategies can be recommended for system transformation to a desired one. These strategies will be further elaborated in section 6.10.1 to 6.10.4.

6.10.1 Strategy 1: Regulation imposed behaviour correction

Strategy 1 is defined by scenario 1 and the potential uncertainties resulting from normative values attributes assigned to the 9 defined goals. Scenario 1 is a desirable and ideal future that the mobility system can be transformed to sustainable mobility system. Scenario 1 is service oriented de-growth projection, which requires extensive system actors´ behaviour correction. The nine goals can take any one of the future paths, which requires strategic control. For example, the demand side management of mobility system defined by goal 1, 2&3 are possible value free projections. Goal 1 which is a business as usual case development is probable even if the intention of system planner aims for desirable future. Goal 2 which is system re-orientation to service centric development is desirable for which the goal 3 can enable the development of goal 2. Therefore, the system digitization and service orientation require behaviour correction of system actors, whose dreams and wishes are dependent on the type of mobility service available to them. Similarly, the supply side management requires similar business behaviour to fulfil the needs of the mobility users. For that purpose, goal 5 is desirable and can be enabled through availing the digitization opportunities resulting from goal 6. The ideal scenario tends to fail if the synergies between demand and supply are lacking. Therefore, to address demand and supply management, the strategy for synergies optimization includes, for example, the role of financial institutions to facilitate the business growth and reduced financial burden to the system user.

The strategy can be realised from the defined goals 7, 8 &9. For example, the regulatory norms for service-oriented mobility system development, which integrates the users contextual needs. The first strategy for service development depends on industrial co-operation with service providers that will facilitate the business transaction as desired. The second step for their development depends on regulatory norms imposition to system users to shift to new business model. For example, the automobile purchase ban for owning but to encourage the purchase for contract rent. The public office can easily manage the contract scheme for automobile usage to its employee. The critical condition in such situation demands product responsibility by the user, which requires conditional damage regulation. Therefore, the automobile insurances and automobile industry will find strong synergies. On the other hand, the operation of such services can be further optimized by service digitalization, where users find it easy to adapt to new supply chains. Thus, user centric services are critical for system transformation to sustainable system. Similar approach can also be adopted in other modes of mobility services like public transport, aviation sector, where co-operation between the service providers is critical for smooth transition. The big question on how will the existing business values is preserved, such as business that is depending on sales of product and automobile, whose livelihood is dependent on the values of their services, requires critical consideration in such situation. Therefore, in such condition, the optimal synergies between service providers and automobile manufacturers require shifting the business value from automobile service value and quality of service function that the conventional service provider's livelihood is part of the new business opportunities.

6.10.2 Strategy 2: Cost imposed behaviour correction

Strategy 2 is a strategy for scenario 2, which is a potential and contextual case involving threats, possibilities and opportunities. The potential threats and possibilities result from the freedom of choice for the system actors. Although freedom is fundamental value for Human wellbeing (22), the freedom without societal norms and values is as good as captivity. The desirable development faces the threat of lack of user acceptability due to freedom of expression as main condition for change. However, the threats are also accompanied with opportunities. For example, the demand side management defined by goal 1, 2 &3 has three possible normative values (probable, desirable and threat) as shown in table 51. The business as usual development is probable if the system actor's contextual needs are not prioritized. On the other hand, the digitization trend has the potential to virtually rule out the system behaviour, where users are captivated by the digitalized environment. In either case the desirable service orientation will face the challenge of un-controlled growth. Similarly, the goals 4, 5& 6 tend to influence the mobility demand, which will focus on business growth influenced by profit oriented service growth. In such a situation the robust strategy that will enable the desirable system transformation will require control condition that will define the type of strategy to be adopted. The main control factor will rest on enabling condition, where system's functional value should be main driving force and not the profit as ultimate system growth consideration.

The strategy for desirable service centric development can be realised from goals 7, 8&9, which tend to enable the potential risk minimization for the service development. Product responsibility cost rather than product ownership cost define the service centric development. The costs will determine the actor's psychology, which is dependent on the control of demand side management and supply side management of service transaction. Here the cost of service value is critical, where the potential threats of lack of product responsibility by the user needs cost burden imposition as main control condition. The strategy such as shift of tax policy from industrial control to user product responsibilities control is an option. Similarly, the service function can be enabled through system digitization, which is extremely risky business monopoly development. Therefore, operational norms and values for digitalization needs co-operation between automobile industry and ICT services. Furthermore, the tax management requires strong regulation on control of financial flow in a transparent manner, where mobility service functional value should define the control strategy. For example, the value sharing option for the user is an excellent strategy for service development. They can be in any form such as sharing unused auto ride vouchers, shift of unused vouchers to another mobility mode, the use of same voucher for grocery shopping and so forth. Similar strategy can also be adopted in other mobility modes such as aviation sector, goods supply chain, and any form of public transport services. This strategy depends on transparency of information flow and mutual co-operation between the actors, which also require behaviour change. Therefore, the fundamental functional value of the system should influence the life style change and living in an open business environment, which is built environment for liberal society already.

6.10.3 Strategy 3: Luxury and ownership cost imposition

Strategy 3 is for the context of scenario 3, which is actually undesired mobility system growth. In scenario 3 the automobile product dominates the freedom of choice and is the prevailing system's functional value identification. New product brand, luxury demand, ownership as status symbol, and industrial product sale projection are major threat to the mobility system development. Market manipulation and competition are major opportunities that enable the growth margin of the business. Ridership, quality service, differentiated service values, industrial product quality improvement and alternative supply chain management are potential opportunities for the desirable system development. Service cost and quality cost are some key psychological aspects that tend to influence the mobility user. Even in the product-oriented system development, three potential developments exist such as business as usual case, service centric development, and digital mobility. In such a situation if intervention is not done the business as usual case is possible, which will determine the mobility service needs and it is a threat because automobile ownership tends to dominate the mobility service. On the other hand, digitalization is an alternative actor psychology playing field, which is potential opportunity for intervention. In such scenario the freedom of choice is unlimited and cannot be easily controlled. For that purpose, a psychology playing field is necessary requirement for control condition. For that reason goals 1, 2&3 can take potential normative values (possible, threats, opportunity) assigned in table 51. Demand side management psychology playing field can be optimized by system digitalization, where the automobile product brand no more becomes the status symbol for ownership but everyone's choice depending on mobility purpose. Similarly, the goals 4, 5 & 6 determine the supply side management, where the potential market manipulation can be transparently communicated to the user. Therefore, the control strategy depends on co-operation between users, service providers and industrial business.

The control strategy can be realised from goals 7, 8 & 9, where the possible development and their threats and opportunities can be optimized. In such situation status symbol of ownership is a physiological stigma, which needs to be transformed. For that purpose, the user behavioural values can be positioned as status symbol through various measures. For example, shifting the status values to space usage, where automobile size determines the status symbol. Levying no parking in main economic hubs for luxury cars is an excellent control measure, which will face the opposition from the users. On the other hand, the shared rented car with the same size will have freedom to use the space can potentially help marginalize the user behaviour. Similar strategies can also be adopted for the usage of other mobility modes such as train and aeroplane, goods supply chain and industrial location and preferential options for non-motorization. Such strategies strongly depend on actor common understanding justified by majority count. Therefore, industrial co-operation and business functioning is critical condition, which is dependent on the behaviour change. Behaviour change of the users also depends on the market behaviour and therefore the life style transformation is the main focus of strategy 3, where system digitalization is a potential control measure for system growth control and efficiency improvement.

6.10.4 Strategy 4: Public owned mobility service

Strategy 4 represents the context addressing scenario 4, which is product dominated and fully regulated system growth projection. Due to the regulatory norms and values controlling the system development, the control is very easy in scenario 4 and therefore the strategies 1, 2 &3 can be easily adopted. The basic factor that will enable the development of desirable mobility system depends on education and clear value proposition possessed by the decision maker. In such situation decision maker ultimately makes major change compared to the user behaviour. User behaviour is developed based on the regulatory norms and values. Therefore, robust mobility system policy and their implementation influence the system growth. Even in regulated system the three potential ranges (business as usual case, service centric, digital system) exist, which is dependent on the quality of decision makers plan. Therefore goal 1, 2 &3 shows potential normative values assigned to them. For example, if the system plan is made based on business vision, it is possible for business as usual case to facilitate the mobility system, which is mostly based on product ownership and unlimited luxury requirement. However, if the mobility system's functional values are prioritized, goals 2&3 are an opportunity for demand side optimization. Similarly, the goals 4, 5&6 are dependent on the robust planning, where goals 5&6 can be capitalised as an opportunity. Therefore, robust strategy can be easily developed in a regulated system.

The strategy development can be realised from goals 7, 8&9, which enable the desirable condition of demand and supply side scenario management. In such a situation, service centric mobility can be thought of as any co-operate government, which facilitates the mobility services. The cooperate government integrates the basic business transactions, where automobile sale, maintenance service, service control, automobile quality and their operational condition are regulated similar to any utility services. For example, the electricity supply, water supply, ICT services and so forth, which will become core business value of an independent government holding. The public transport services and other modes of mobility can be integrated in such business model. Pay and drive a car for ridership rather than buy and own a vehicle is core business values, which will determine the mobility system's functional value. In such business orientation, co-operation between financial institution, automobile industry, automobile service provider, ICT industry and other form of mobility service is fundamental requirement. Additionally, the livelihood of people depending on mobility as core business needs to be integrated to the cooperate office for smooth transition. For example, the taxi services, private bus services, tourism travel services and so forth, those are potential franchise market development in the future. The strategy intends to address the mobility as service industry development, which is currently seen as common consumer goods. The deployment of such strategy in regulated system is much more convenient compared to the liberal system, where the freedom is major barrier. However, for Human wellbeing (22) condition, the regulation requires lifestyle transformation, which can only be achieved by user contextual need fulfilment. Such strategies are already seen in decentralization of co-operate administration, where communities are made to run the service on a contextual basis.

6.11 Summery result of mobility system image the context of Bhutan

Considering the feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ as a status quo of the mobility system in the current state from the effect system in chapter 5, it indicates growth requirement for the mobility system development to fulfil better quality of life in Bhutan. From this feedback effect the system control variable for system's self-regulation are Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21). It is also important to note that the critical variables Mobility service (7), Economic development (11) and Enabling conditions (14) represent the system leverage potential as a global variable. These variables define normative future scenario in figure 47, which is explored as mobility system scenarios in section 6.6 and the system image did not change although the context is different.

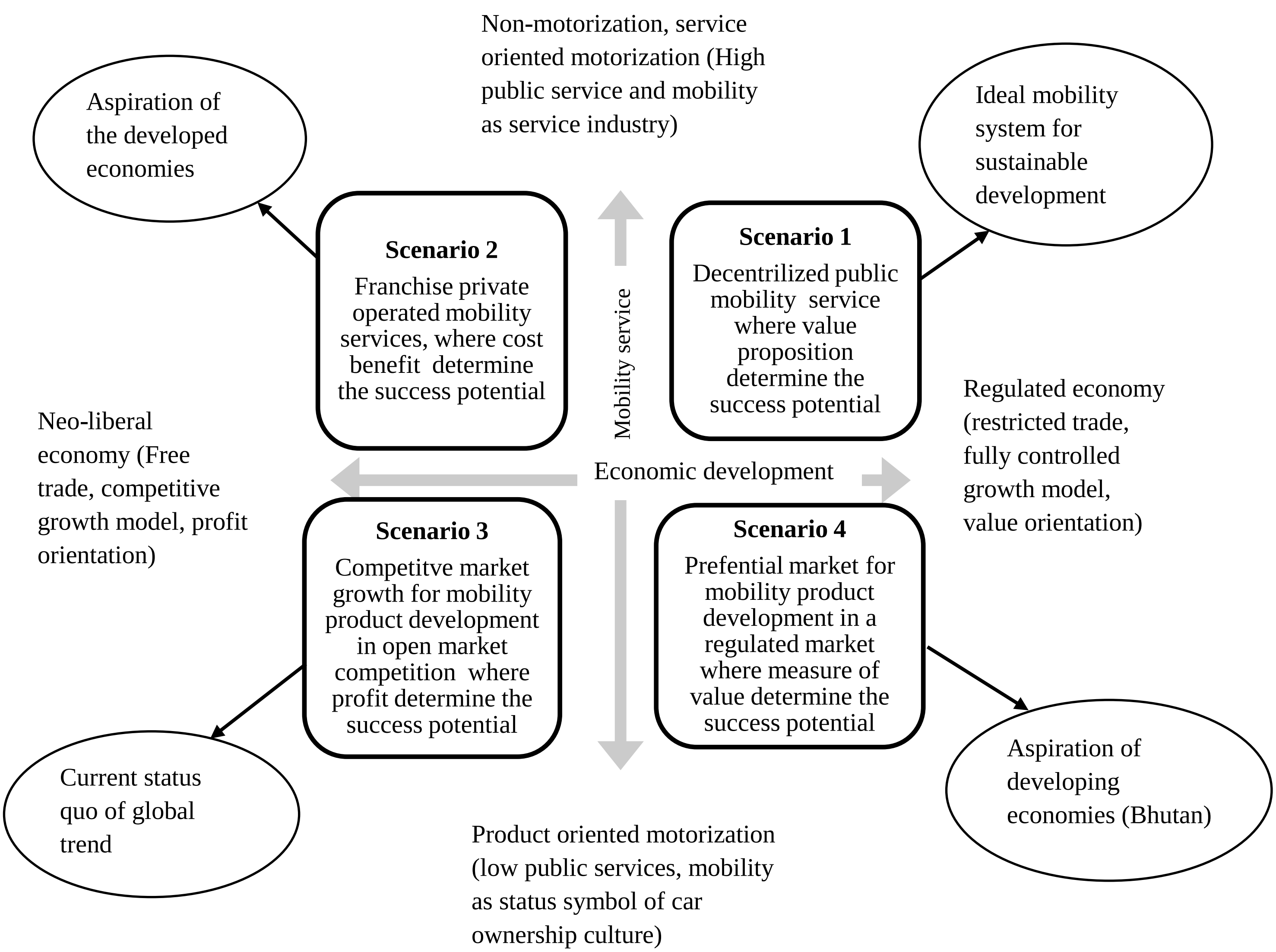


Figure 47: Mobility system image

Figure 47 shows the mobility system development that tends to influence the normative behaviour trend of the system's future. Two critical system variable Mobility service (7) and Economic development (11) define the mobility system scenarios, which can be strategically leveraged thorough the variable Enabling condition (14) for their development. The system's behaviour is conceptualized based on the mobility system vision, goals, scenarios and strategies, which is based on the cybernetic effect of 22 different mobility system variable identified in chapter 3, 4 & 5. The ideal and desirable mobility system vision, which is positioned in the upper right hand quadrant in figure 47 is where sustainable mobility system can be fully achieved. The desirable vision is defined by scenario 1, which depends on behaviour correction. These generalized scenario field is contextual and uncertain for their development in future. The context of Bhutan seems to appear unique from the statistical data record and development philosophy. Value based development, where the priority is given to sustainable development target in a regulated environment seem to enable the system development. However Bhutan assumes scenario 4 considering current development trends, which is still product centric development. The major focus for the system optimization scope is based on electrical energy as mobility fuel source. It appears that the mobility system variable Fuel energy security (3) is considered as major system change lever, which acts as neutral feedback variable and not necessarily transform the system from scenario 4 to scenario 1 addressing sustainable mobility system development.

Although the fuel switch remains the major system change lever, the system transformation will require behaviour correction of user to achieve the desirable scenario1. The current status quo as seen in the statistical data in section 4.2 until up to 4.4.1 show for sustainable trajectory, alternative development path is necessary (refer chapter 4). For example, in the current mobility system development, urban centric mobility development trend has strongly influenced the centralized economic development, leaving non-resilient virtual economic growth in urban area. The situation of Bhutan is relatively different considering the landlocked geography and limited space availability for human settlement. More and more rural area is increasingly becoming less populated and mostly the senior citizen represents the rural population size. Therefore, mobility system should increasingly address the rural infrastructure development and increase the job market in rural area. Mobility in this context can be view as trade-off between job location and settlement cost, where economic decentralization accompanied with service centric development is critical. In the case of Bhutan, the desirable scenario 1 can have major opportunities, where lifestyle transformation can be witnessed by making intervention in mobility system. The strategy to system digitalization and service orientation supported by clean fuel is an opportunity in regulated system, where behaviour correction can be easily managed through regulatory norms. Mobility system is a complex network of influence factor, where Rural-urban dynamics (21) and Spatial dynamic (5) are critical economic bottleneck situation in context to Bhutan mobility system development. Even if electric fuel is fully deployed without the service centric development it will continue to face the spatial challenges. The growth of infrastructure has been very quick as against the automobile growth trend especially the rural farm road, which needed much more mobility service for rural populace. However current statistic shows lack of public mobility service in urban area and almost no service in rural area. Therefore, improving the living standard of rural people, which is influenced by access to mobility service will need mobility system growth requirement alternatively. The current mobility system development and spatial challenge is influenced by rural-urban migration, which is also influenced by the urban centric economic growth. Therefore, future mobility system development path is linked to invisible and optional system trajectory that results from 22 variable lists and their cybernetic effect system. The current status quo and future aspiration of mobility system image is shown in figure 48, which is deduced from the general scenarios resulting from Quattro Stagioni logic in figure 42 in section 6.6 to indicate the context of Bhutan.

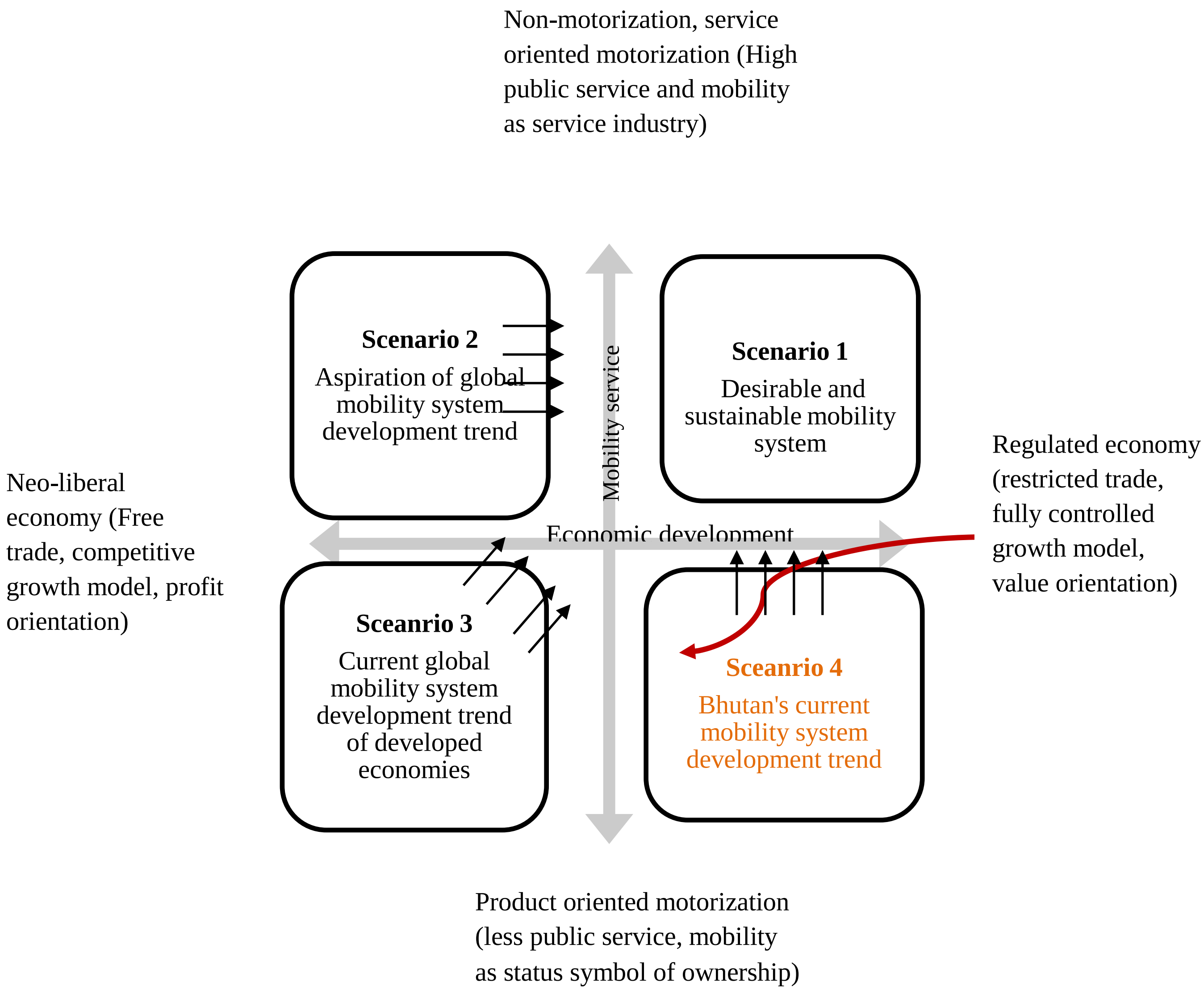


Figure 48: Current mobility system status quo

The current statistic indicates that the mobility system of Bhutan is roughly positioned in scenario 4 defined by Quattro Stagioni logic in figure 48. The current scenario however seems to be an opportunity to leap-frog to desirable scenario 1 by enabling strategy 4 as discussed in section 6.10.4. The opportunity can be optimized through system transformation from product orientation to service orientation, which is dependent on behaviour correction of both market growth and user reaction. In the case of Bhutan both the behaviour correction (user and market) can be regulated to optimize the desirable scenario 1.

The economic development model of Bhutan is value oriented as per the 5 year development plan laid under the Gross National Happiness (GNH) philosophy. Considering the four scenario projections of mobility system in Bhutan, which is mostly addressing energy security challenges, will have to be oriented to service centric and that will require economic decentralization rather than mobility transformation. For example, the electrical energy value addition and increasing the energy demand for industrial growth in rural area is critical to address Human wellbeing (22), which is directly linked to mobility system. Even though Bhutan envisions sifting fuel supply from fossil fuel to electricity, the current development trend indicates encouragement of technology supported ownership shift from internal combustion engine to electric vehicle. Unless the technology shift is also accompanied with service centric development such as electric buses, two wheel electric drives and non-motorization, the path to sustainable development will continuously remain the same as shown in figure 48. On the other hand the heavy duty vehicle, which is mostly used for freight movement requires alternative approach in addressing energy security question. Therefore, it is envisioned that mobility system development path will also be influenced by the shift from carbon intensive economy to low carbon economy as projected in Bhutan's mobility future scenario section 6.7.1 to 6.7.3, which has to be accompanied by major reforms requirement influenced by behaviour shift of the consumer and infrastructure development for e-mobility addressing economic decentralization as central theme for the development trajectory.

Therefore conclusion can be drawn from the scenario logic that service centric development of both Economic development (11) and Mobility service (7) is a desired future path to sustainable development and is a sustainable mobility system. The policies that tend to influence their growth need better Enabling condition (14), which can be enabled through strategy 4 as defined in section 6.10.4 in case of Bhutan. The context of Bhutan can be further refined for service development and policy recommendation for sustainable system design. The main pillar for service orientation should result from functional value of the system that enable the service function and not the product brand value that influence human psychology for consumerism, which is critical for the sustainable development and transformed lifestyle adoption.

7 Summary result of analysis, projection and synthesis

Based on the literature review to enquire mobility as a potential system in chapters 1&2, it is identified that mobility as a system is a complex system and for that purpose research questions have been hypothesised for mobility system inquiry, which is however adjustable in cybernetic order rather than strictly defining research problem situation in the beginning because of the complex characteristics of its orientation and the system property defining the problem situation. Therefore, system inquiry can only be an iterative process based on initial guiding research questions to reconfirm the problem situation. The research questions initially defined are;

1. Which variables sufficiently define the mobility system in the present situation?
2. What are the possible leverage points for the mobility system transition to sustainable mobility system in the future?
3. To what magnitude can it be sustainable?
4. And what are the challenges and opportunities for such transition in terms of socio-ecological change?

Initial inquiry of the system analysis indicated, the ontology (how it is?) and epistemology (how do you know how it is?) as necessary condition to observe the system as a whole, where observer shifts the position to view the system from inside and outside of the system, which is based on Vester Sensitivity software supported analysis [8], [24], [26]. The major drawback recognized from the literature review on system study concerning how is the system (ontology), shows that most of the research identified system as a linear object. This can be already first conclusion, where mobility system cannot be broken in simple linear object. The most commonly the earlier research result shows mobility system as linear projection of single predictable future, which is often based on specific objectives pre-defined. If we observe closely in this study, it is as much as possible avoided the conventional approach of future prediction but explore how the system would behave keeping in mind the cybernetic orientation of its constituent agents. This approach is adopted considering the limited availability of scientific literature sources addressing the complex systemic problem issues. For example the few available literature sources revel that the future is unpredictable and irreducible complexity that can only be negotiated with the actors (users and decision makers) of the system keeping in mind that the original system is at-least roughly known [8], [10], [11], [17], [18], [29], [30], [51]. Then we arrive to a point that how we can make the system behave considering the epistemological aspect after understanding the ontology. Therefore, the major research problem situation emerge enabling the system characteristics itself concerning how to integrate ontological and epistemological world views and that became the major research goal for this study thereafter even if the four guiding research questions above are the central theme. For that reason Analysis-Projection-Synthesis (APS) has been adopted to integrate ontological and epistemological aspect, which is robust and holistic [11]. APS approach integrates three formalistic methods such as system analysis which define the system based on variable identification and cybernetic effect consideration, scenario development and projection to identify and sort critical uncertainty of critical variables, and scenario transfer and synthesis to arrive to a workable and logical strategy for execution, which is however iterative and often heuristically positioned as new research paradigm [8], [10], [11], [18], [20], [29], [30], [51], [133], [134]. Therefore, there is no rigid structure and formal process to understand the system's property but to integrate different tools and techniques that enable the inquiry process holistically. Even if the APS has been used to make mobility system inquiry, some adjustment is additionally made to define mobility system especially concerning the scenario and goals formulation, which is fully iterative and normative endeavour. Therefore, whatever result has been deduced so far is cybernetically oriented and the specific case is context dependent for the projection of future scenario resulting from those contextual and normative descriptions of the mobility system. Mobility system transformation to sustainable system was main consideration, which attributes lifestyle transformation for mobility need to initialize sustainability goal. For that purpose, mobility system defined by global variable list is agglomerated in cybernetic order and the first cybernetic verification performed. Therefore, first step was to identify global variable list with their indicator values that reveals the key system defining parameters, which can then be explored in detail using APS approach. The comprehensive summary result is as follows.

1. Which variables sufficiently define the mobility system in the present situation?

The analysis phase of mobility system enquiry is mainly focused on how is the mobility system in current situation, which needed variable list to define the ontology (how is it). The system is analysed with the help of Vester Sensitivity Model software tool. There are 22 variables identified from literature survey and based on online stakeholder consultation involving students, experts and general public in general to understand the ontology of the mobility system. The identified variable that define mobility system are: Infrastructure development (1), Technology development (2), Fuel energy security (3), Institutional capacity (4), Spatial dynamic (5), Accessibility (6), Mobility service (7), Resilience to accident (8), Capital investment (9), Operational capital (10), Economic development (11), Environment pollution (12), Safety and security (13), Enabling condition (14), Cultural values (15), Attractiveness and aesthetics (16) Awareness on new mobility (17), Participatory planning culture (18), Justice and fairness (19), Political power (20), Rural-urban dynamic (21) and Human wellbeing (22). This answers the first research question on which variables sufficiently define the mobility system, which is however cybernetically interconnected and cannot be treated in isolation. The list of variables is holistic and covers the mobility as a rough system image, which can be used for initial test model design for the actual operational context of mobility system. These 22 variables have been analysed using Vester complex system analysing criteria, where impact matrix and cybernetic effect system were extensively analysed in chapters 3, 4&5.

2. What are the possible leverage points for the mobility system transition to sustainable mobility system in the future?

From the first analysis which is based on variable consideration, the mobility system image is further processed using the cross impact matrix based analysis of the variables effect. The process has been extensively carried out by involving students, expert and independent evaluation. Cross impact assessment enable variable causality and detail matrix based influence factor consideration. This process showed, Mobility service (7), Economic development (11) and Enabling condition (14) as critical system leveraging variables, which answers the second question on what is the leverage point for the system. The leverage potential is however cybernetically oriented and context dependent, which requires more detailed decomposition owing to many uncertainties involved in it. System leveraging variables are highly influential and are risky intervention for any changes, which can be seen as normative value-based scenarios, defined by system cybernetics property. Therefore, their cybernetic effect was further analysed considering the feedback effect for system vision definition. The cybernetic property of the system is used for vision definition as future image projection from the system's indicator variables and they are stated from the indicator variable Human wellbeing (22) and Environment pollution (12). The indicator variables assume the mobility system vision: *improve human-well-being by providing safe, equitable and environment friendly mobility services.* The qualification of this vision is defined by the system defining variables feedback effects from the cybernetic effect system. The positive feedback effect is chosen to analyse the potential influence factors requirement $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$. Based on the influence factors and cross-consistency assessment, the mobility system is reduced to potential futures such as business as usual, service centric mobility and digitized mobility, which are contextual normative descriptions defining the range of possibilities. These potential normative descriptions are projected further with value free nine mobility system goals in section 6.5.1 to 6.5.3, which define the system vision. Thus, by projecting the mobility system on account of normative descriptions, the challenges, opportunities, and potential threats can be reduced into a scenario field. For that purpose, Quattro Stagioni logic is used to define mobility system scenario field, which indicates the future uncertainties of the defined mobility system vision in sections 6.6.1 to 6.6.4.

3. To what magnitude can it be sustainable?

The sustainability of mobility system development assumes normative value proposition, which is decomposed as a descriptive scenario field using Quattro Stagioni logic and strategy for it to be sustainable. The specific case study was considered for this endeavor and system analysis of Bhutan is projected. The projection of critical variable shows, Bhutan assumes Scenario 4, which is defined by preferential market for mobility product development in a regulated economy where measure of value determines the success potential. The strategy for this specific scenario can be addressed through strategy 4, which is defined by public owned mobility service.

The strategy can have two potential chances for it to develop in the future and those are Desirable and Opportunity alternatively depending on how strategic decision is taken. The entire 9 goal defined from demand side management, supply side management and control through policy are at the moment an opportunity for Bhutan taking into account the overall cybernetic orientation of the variable in the system. The more detail mobility situation of Bhutan is elaborated in chapter 4. Chapter 4 also give an insight about variable influence factors and empirical evidence concerning how mobility system image has different influencing effect on the overall system image identification.

4. What are the challenges and opportunities for such transition in terms of socio-ecological change?

The major challenges appear to be perceived human psychology and behavior for how normal daily life is supported by mobility. The analysis indicate, the mobility as a status symbol will continue to support market growth if early interventions are not made where the growth of undesired ownership-based motorization trend tend to continue even with the new and alternative mobility options. This might even come as sustainability washing for business growth. On the contrary, the mobility system can be transformed into service centric system to achieve sustainability goal. This can only happen if the user behavior is oriented to service choice, which depends on how effectively the system is made to function as service centric development. Therefore, making mobility system's functional service be transformed to measurable system growth and de-growth projection rather than automobile product brand value as a key criterion for system optimization, which we can call it as sustainable system. Therefore, mobility system transformation demands life style transformation and sustainable mobility as a system seems to be an initial step for that purpose. It has to be noted here that it is meaningless to transform automobile product unless system is made to function as service orientated system to enable Human wellbeing (22).The valuation of product transformation is meaningful in a system that do not provide human psychology playing field, where service development is core principle. Therefore, the new mobility such as e-mobility, clean fuel alternatives, non-motorization and autonomous driving alternatives can only be sustainable if system is re-oriented to service rather than product ownership. It is true for all mobility modes such as aviation sector, train system, public services and water transport for both passenger and goods mobility requirement.

The life style transformation addressing sustainable mobility development depends on what kind of strategy is adopted in different contextual scenarios, where the behavior correction of the system actors (both users and decision makers concerning demand and supply side business transaction) is the key driver. For that purpose, strategy has to be formulated, which is elaborated in sections 6.10.1 to 6.10.4. The core value for the implementable strategy depends on cooperation, integration and decentralization, which is context dependent. Therefore, strategies that enable business re-orientation to desirable service centric mobility system development are fundamental condition for transforming current mobility system to sustainable mobility system.

The question to what magnitude mobility system can be sustainable can only be explored through a contextual case. For that purpose, chapter 4 explores additionally the case study of Bhutan, which shows unique contextual scenario 4 from the Quattro Stagioni logic from the scenario projection in figure 42.

Thus we can conclude that the mobility system analysis, projection and synthesis is unpredictable and irreducible even if the future is made to appear as a reduced system, which is relatively complex and requires complete system variable re-orientation in cybernetic pattern. Conclusion can also be drawn from this study that the mobility system is negotiable keeping in mind the original cybernetic rather than predicting single future, which is mostly enabled through new technologies and fuel alternatives. The major transformation requirement is dependent on the actor's behavior, which seems to be a difficult endeavor but critical aspect. However, the transformation is not impossible if mobility system value proposition is transformed, such as mobility as a service industry rather than product dominated automobile business growth, which will require business and lifestyle change. Therefore, mobility system transformation can be viewed as initialization for sustainable livelihood as many variables are influenced by the functioning of routine daily mobility activities on a regular basis. The following conclusions can be a generalized mobility system property.

i. Variables defining mobility system are highly contextual and they require cybernetic analysis for successful transition to sustainable system.
ii. The critical variables that are identified describe potential future leverage situation, which is however risky and disposes with many uncertainties if cybernetic effect is not taken into account.
iii. The reorganization of uncertainties depends on desired system future, which cannot be imposed by decision maker or system observer. It has to be negotiated keeping in mind the original cybernetic effect is made to behave as self-regulating system.
iv. The potential threats, challenges and opportunities can be bundled from projected scenarios, which will make a meaningful strategy for system policy choice.
v. Mobility system cannot be reduced simply depending on the observer´s need and inquiry based on predefined problem situation, which seem to have dominated the current and future mobility system assessment both scientifically and in operational context.
vi. The potential side effects are unintentional but will continue to grow into bigger problems if they are not recognized early during the system design and planning process, which will require contextual scenario identification.

Thus, mobility system obeys all the above conditions and therefore requires negotiated value proposition for its transformation to sustainable system. Therefore, this study contributes to science concerning how mobility system is interconnected and what are potential areas to transform the system. Further research can be continued from the list of feedback effects as new hypothesis and research questions from the cybernetic effect system of chapter 5, which is still open ended question to be evaluated.

Limitation: The study could not conduct on site stakeholder consultation for specific case of Bhutan, which is still pending. The statistical data has been used to define the context of Bhutan in chapter 4, which is shown here only to understand the potential magnitude for system transformation from current mobility system to future sustainable system. However, negotiation is critical for successful transformation of the system and to avoid potential future surprises.

7.1 Conclusion

Based on the normative projection of mobility system, it can be concluded that mobility as a system is complex and it cannot be reduced to one isolated system but is interconnected with many other systems. Therefore, mobility as a main system is influenced by its subsystems, which are referred in this study as global variables that form the building block for the design of mobility system. The 22 different variables that are introduced in the main text, which influence the rough image formation of mobility as a system is critical to roughly visualize the system as it is, rather than reducing the complex interdependency of actuating variables into deficient linear cause and effect relationship, which is often seen in most of the research finding. Furthermore, the tendency of the cause and effect relations is contextual and is subject to cybernetic assessment with the involved stakeholders. For that purpose, the only possible conclusion that can be drawn is a normative scenario field and potential uncertainties that might arise in future. Therefore, the statistical data record can be useful only when the system's interdependency is sufficiently visualized. The mobility system with its variable is made to behave sustainably in cybernetic order, which is based on the variables interactions and the cybernetic effect system construction for successful transition to optional alternatives. Among the 22 different variables, it was found that three critical variables influence the system transition the most. They are Mobility service (7), Economic development (11), and Enabling condition (14). All three critical variables are somehow linked to the other variables and their transformation influences the mobility system image formation in future. For the design of sustainable mobility system, mobility as a service development is critical and is heavily dependent on the behaviour of user and the market re-orientation for mobility business. The push and pull factors can be noticed while opening a dialogue with the involved stakeholders, which can only be resolved by analysing the chains of feedback effects observed from the semantic of effect system for meaningful conclusion and realistic decision support. The feedback effects can be used for uncertainty sorting during the process of scenario projection. Even the feedback effects and scenarios are subject to iterative adjustment keeping in mind the intended vision. Therefore, Quattro Stagioni logic is used to define scenario field for potential future image formation of mobility system from the critical variable. The four scenarios that can be visualized from the quadrant formed by the critical variable reduce the complexity and open the margin that the system is partitioned for comparative choice, which is however cybernetic oriented. After understanding the scenario field and cybernetic effect, it can be recommended that the service-oriented mobility system development is more appropriate as against automobile ownership, which is however strongly influenced by the global automobile market and strategy to enable their service development. Irrespective of new and conventional mobility technology, service centric mobility system development is critical for the success of sustainable future vision. This would mean the life style change is necessary condition, where mobility as a service seems to be an excellent change lever for better quality of life and to reduce the disparity gap among the user and to optimize system efficacy and efficiency for successful transition.

The detail analysis indicates there is huge potential if market is re-oriented and system transformation is re-looked from the perspective of decentralization. The regional value addition is key criteria for sustainable livelihood development, which is influenced by economic progress. Mobility requirement and economic progression strongly influence the human wellbeing, which cannot be looked only from the mobility as a single system. The mobility of people and goods is determined by livelihood requirement and is mostly based on the current trend of centralized and mass production and consumption. Centralized growth tendency has many uncontrollable growth cycles leading to systemic failure. For example, the limited urban space and lack of job opportunity in rural area is some key issue that need to be resolved for successful transition for mobility system transition to sustainable system development in future. Economic decentralization has the potential to shift the growth ideology to value addition, which seem to be an alternative for the success of sustainable system development. The decentralization approach optimizes the space limit and increases distributed pattern of economic growth, where mobility as a service industry can make value addition to human activities integrated for economic growth. Improving efficiency by increasing the service centric development cannot fully address the growing challenges of space limitation in urban area and market need for mobility industry. Furthermore, technology as an enabler to efficiency improvement and pollution control cannot fully address the space limitation. This is exactly what is seen in the case study of Bhutan. Although there is strong focus on sustainable urban mobility by increasing e-mobility in urban area, the vehicle congestion issues still continue in urban center. On the other hand, the growth requirement in rural area is faced with the challenge of rural-urban migration. From the case study of Bhutan, mobility as a service industry has the potential to increase the efficiency by approximately 70% and reduce the fuel demand by 70% if ownership free e-mobility is encouraged. However, the rural area continues to face the challenge of accessibility and rural-urban migration continues, which is influenced by the economic situation in rural areas. Therefore, there is always a push and pull factor for sustainable development vision and mobility is one major indicator for sustainability measure in terms of energy and material demand and air pollution. In the case of Bhutan e-mobility seems to be an excellent choice but it additionally requires more detail study on electrical load and transmission infrastructure requirement for the transition to e-mobility.

Since description of mobility as a system is very limited, this study explored mobility as a system, which is complex and is influenced by many different global variables. The qualification and quantification of influencing variablesthat define the mobility system image can contribute substantialfuture research as the boundary system can now be roughly visualized. Furthermore, the variable choice and their influenceis contextual, which is cybernetically oriented that can only be negotiated keeping in mind the system is made to regulate by itself. Therefore, further discussion based on the effect system construction can be used as a baseline mobility system test model for decision making process. Mobility as a service is still the core value that cannot be omitted for sustainable mobility system design.

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Annex

The effect system of Infrastructure development

The variable Infrastructure development (1) is positioned in the active region in the variable's systemic role in the system as shown in figure 6 in section 3.1.3. The variable Infrastructure development (1) is therefore a strong lever of change variable in the system.

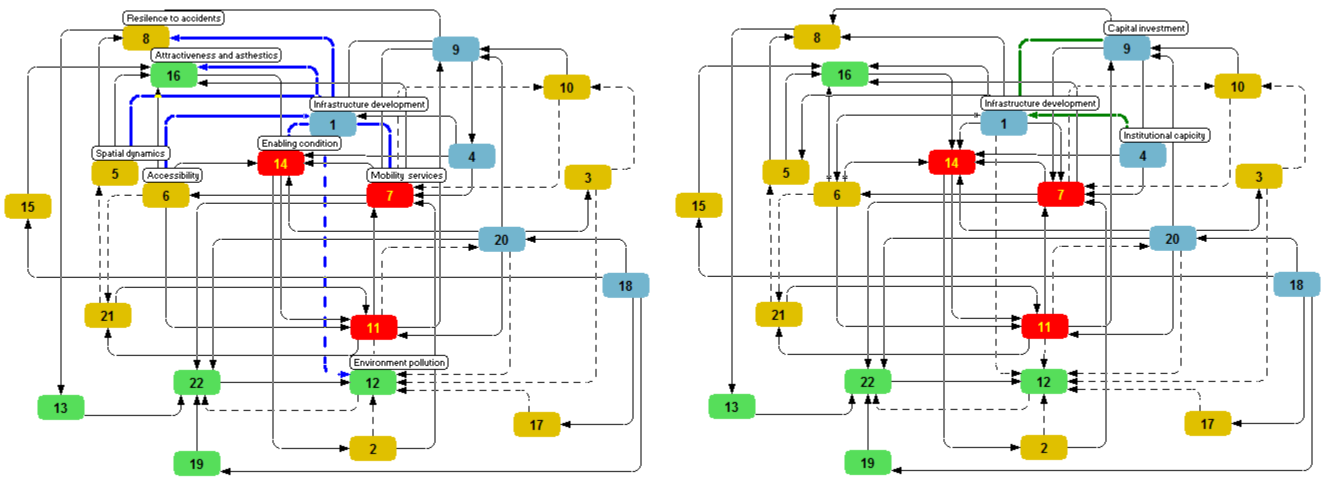

Figure 49: Effect system of Infrastructure development

The effect system of the variable Infrastructure development (1) is shown in figure 49. The variable Infrastructure development (1) influences the variables Spatial dynamic (5), Mobility service (7), Resilience to accidents (8), Environment pollution (12), Enabling condition (14), and Attractiveness and aesthetic (16) whereas the variable gets influenced by the other system variable Institutional capacity(4) and Capital investment(9) as shown in figure 8.The left hand side of figure 49 shows the variable Infrastructure development (1) influences the other system variable, whereas the right hand side of figure 49 show the other system variable that will influence the Infrastructure development(1). The following set of influence can be noticed from the effect system of Infrastructure-development (1) from figure 49;

- $1 \rightarrow 5$ The increase in infrastructure development (1) has the potentials to make more space available for mobility function. It can also be argued that the increasing infrastructure will decrease the land space availability. However, for the mobility system functions the direct effect is that more built up space will enable de-congestion for the mobility need there-by facilitate more flexible movement. Therefore, increase in infrastructure increases the Spatial dynamic (5) which is an equal effect.
- $1 \rightarrow 7$ The increase in Infrastructure development (1) has the potential to improve the quality of mobility service for both transport need of people and goods delivery. The better infrastructure can

potentially help enhance the multimodality options for mobility need. Therefore, increase in mobility Infrastructure development (1) increases the Mobility services (7), which is an equal effect.

- $1 \rightarrow 8$ The increase in infrastructure has the potentials to improve the resiliency of mobility for unforeseen situations. Better infrastructure provides alternative transport options thereby increasing the mobility mode for both people and goods during difficult situations. Furthermore, better infrastructure addresses the need for daily monitoring of the mobility of goods and people. Therefore, increase in mobility infrastructure increases the Resilience to accidents (8), which is an equal effect.
- $1 \rightarrow 6$ The availability of more infrastructures has the potential to connect to multiple places by distance and type, such as rural areas and isolated community to facilitate the mobility need for movement of both people and goods. Therefore, increase in Infrastructure development (1) increases the Accessibility (1), which is an equal effect.
- $1 \rightarrow 12$ The good quality infrastructure has the potentials for decreasing the environment pollution by integrating alternative transport options for both people and goods. The integration of alternative mobility can only be enhanced if relevant infrastructure is in place to address that need. Therefore, improving the infrastructure will potentially decrease the Environmental pollution. Hence the increase in Infrastructure development (1) will decrease the Environmental pollution (12), which is an opposing effect of the equal effect.
- $1 \rightarrow 14$ The increase in Infrastructure has the potential to enhance the quality of mobility service. Alternative option integration for the contextual need of different population category strongly depends on the enabling conditions that support good infrastructure development. Therefore, increasing the infrastructure in first place will increase the Enabling condition (14) which is an equal effect.
- $1 \rightarrow 16$ The good quality infrastructure has the potentials for better quality service which can potentially increase the comfort, frequency and alternative options for users for both transports of people and goods. Therefore, increase in infrastructure increases the Attractiveness and aesthetics (16) which is an equal effect.
- $4 \rightarrow 1$ The Infrastructure development (1) is strongly dependent on the availability of human resources and skill sets to develop them. Furthermore, the responsible institutions that take responsibility for the development of human resources and technical knowhow strongly depend on good institution and their capacity to develop good quality infrastructure. Therefore, good Institutional capacity (4) will further enable the Infrastructure development (1) which is an equal effect.
- $9 \rightarrow 1$ Although the infrastructure becomes critical for better transport and logistics demand, their development is heavily dependent on to the availability of financial resources and human resources to develop them. Increase in availability of financial resources and human resources determine the availability of Capital investment (9) that has the potential to increase the Infrastructure development

(1). Therefore, the increase or decrease on Investment capital (9) will proportionally increase or decrease the Infrastructure development (1), which is an equal effect.

Effect system of technology development

The variable Technology development (2) occupy a neutral zone in the variable's systemic role of in figure 6 in section 3.1.3, which is a potential feedback control variable to stabilize the system. The technology development influences the variable Mobility service (7) and Environment pollution (12), whereas the variable Enabling condition (14) influence Technology development (2) as shown in figure 50.

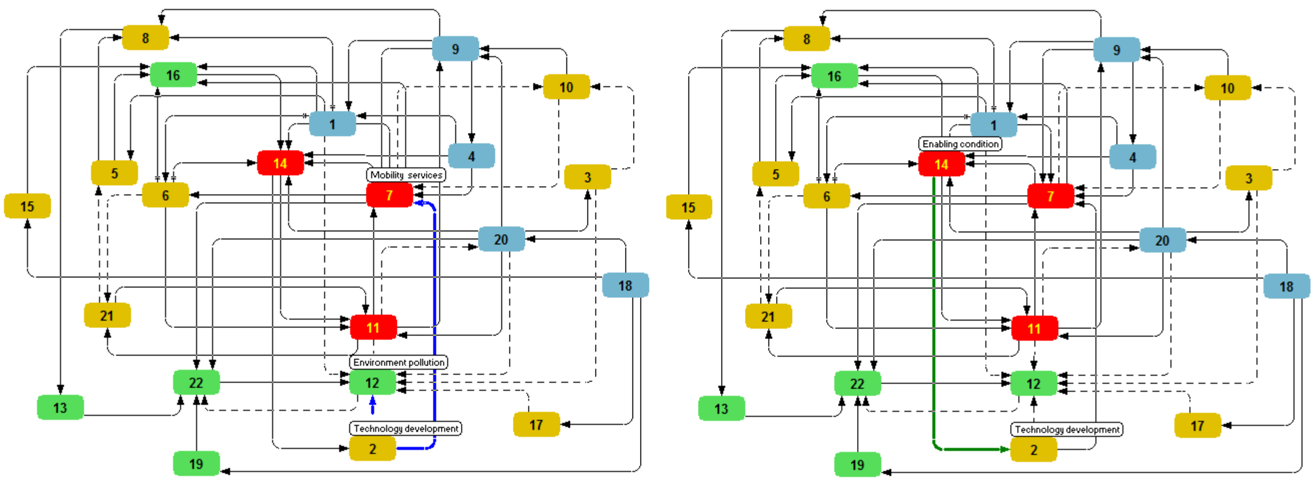

Figure 50: effect system of technology development

The left-hand side of figure 50 shows the influence of Technology development(2) on rest of the variable and the right hand side of figure 50 shows the Technology development(2) influenced by other system variable. The following can be seen from the influencing variable and the variable that gets influenced by the influencing variable from the effect system of figure 50.

- $2 \rightarrow 7$ The availability or access to better technology has the potential to increase alternative options for movement function for the transport of both people and goods. However, it has to be noted that technological solution is tool that makes the movement function easy and not necessarily fully transform the system although they are critical for motorization and long-distance transport of people and goods. Therefore, increase in technological solution increases the Mobility service (7) which is an equal effect.
- $2 \rightarrow 12$ The availability and access to alternative technical solution has the potentials for reducing the negative impact on environment. The increased efficiency in material and energy demand for motorization is critical condition for technical solution for enabling the environment pollution control. Both the aspect of material and energy efficiency requires technology innovation which is inevitably

linked to technology development. Therefore, increase in alternative technical solution has potentials to reduce Environment pollution (12), which is an equal effect.

- $14 \rightarrow 2$ The Technology development (2) is however strongly influenced by the Enabling-condition. The development of innovative technical solution requires both skilled human resources and strong support for development of research and development centres which however requires enabling environment in terms of new technology rollout, piloting alternative solutions, acceptance of new technology development. Therefore, better Enabling condition (14) further promotes the Technology development (2), which is an equal effect.

The effect system of fuel energy security

The variable Fuel energy security (3) occupies a neutral zone in the variable's systemic role in the system in figure 6 in section 3.1.3, which is a potential feedback control variable.

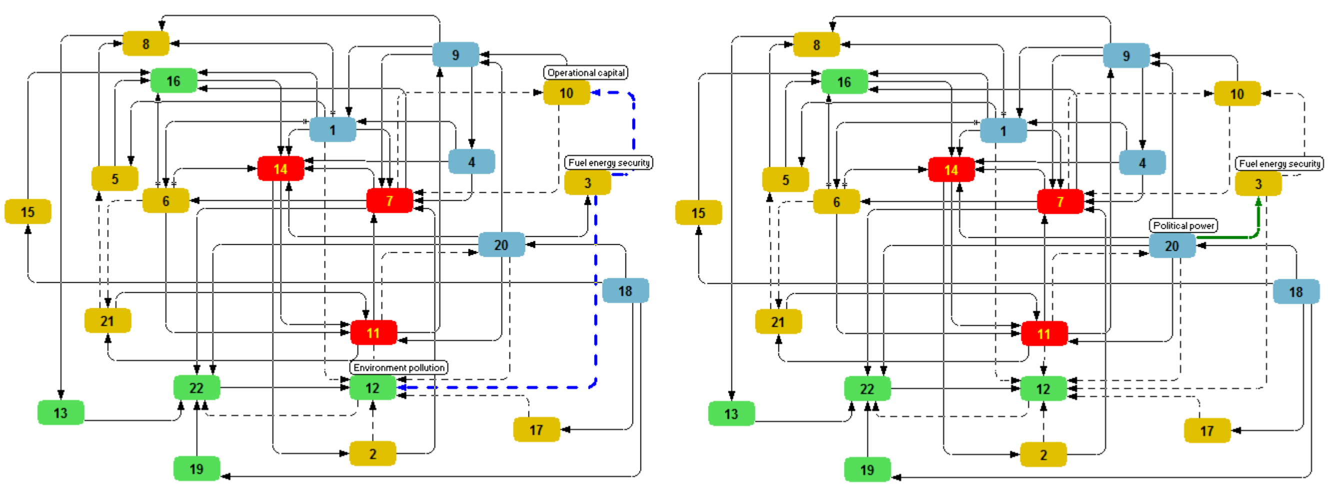

Figure 51: effect system of fuel energy security

The variable Fuel energy security (3) influences the Operation capital (10) and the variable Environment pollution (12), whereas the variable Political-power (20) influence the Fuel energy security (3) as shown in the figure 51. The neutral variable has strong potentials for stabilizing the critical variables in the system. The dependency of the variable to the external influence factor indicate, although they are neutral is a strong system stabilizing variable. Following can be seen from the variable's effect system in figure 51.

- $3 \rightarrow 10$ The availability and quality of fuel is fundamental need for the mobility function which affects the daily running cost for transport activities for both people and goods movement. The fossil based fuel supply has always been recognized as daily cost for normal life activities which can lead to high cost for transport function for both people and goods movement. Decreasing the dependency on fossil resources increases the security of supply and potentially the quality of fuel source. Decreasing dependency on fossil resources has the potential to economic value addition for mobility function thereby leading to lower cost of operation of transport system. It can be argued that the fossil fuel offers much cheaper alternative for transport, which is however directly link to economy leakage considering the import dependency unless the fossil fuel are national resources. Therefore increasing the Fuel-energy-security (3) decreases the Operational cost (10) which is an opposite effect.

- $3 \rightarrow 12$ The shift from conventional fossil based fuel supply to fuel the transport system to an alternative renewable source has potential for emission reduction although externalized environmental cost is seen in the current situation. The maturity of renewable energy sources for mobility use to address the mobility function has indicated the next generation motorization trend will increasingly depends on renewable resources. Therefore increasing the Fuel energy security (3) has the potential to reduce Environment-pollution, which is an opposite effect.
- $20 \rightarrow 3$ De-coupling the mobility fuel demand from fossil resources is strongly dependent on to the strong political commitment. Strong and stable Political power (20) of any geo-political boundary can potentially enable the transition from fossil fuel based mobility to alternative renewable resources. Therefore increasing the Political power (20) by increasing people's participation to accept the transition from fossil fuel for mobility function to renewable fuel for mobility function increases the security of fuel supply. Therefore increasing the Political power (20) increases the Fuel energy security (3) and is an equal effect.

Effect system of institutional capacity

The variable Institutional capacity (4) is positioned in the variable's systemic role in the mobility system model in figure 6 in section 3.1.3 as potential lever of change. Institutional capacity (4) influences the variables Infrastructure development (1), Mobility service (7) and Enabling condition (14), whereas it gets influenced by Capital investment (9) as shown in figure 52. The variable Institutional capacity (4) is responsible for managing, monitoring, training, research and development for mobility need. The Instructional capacity (4) is different from that of mobility industries and company dealing with the mobility product development and sales.

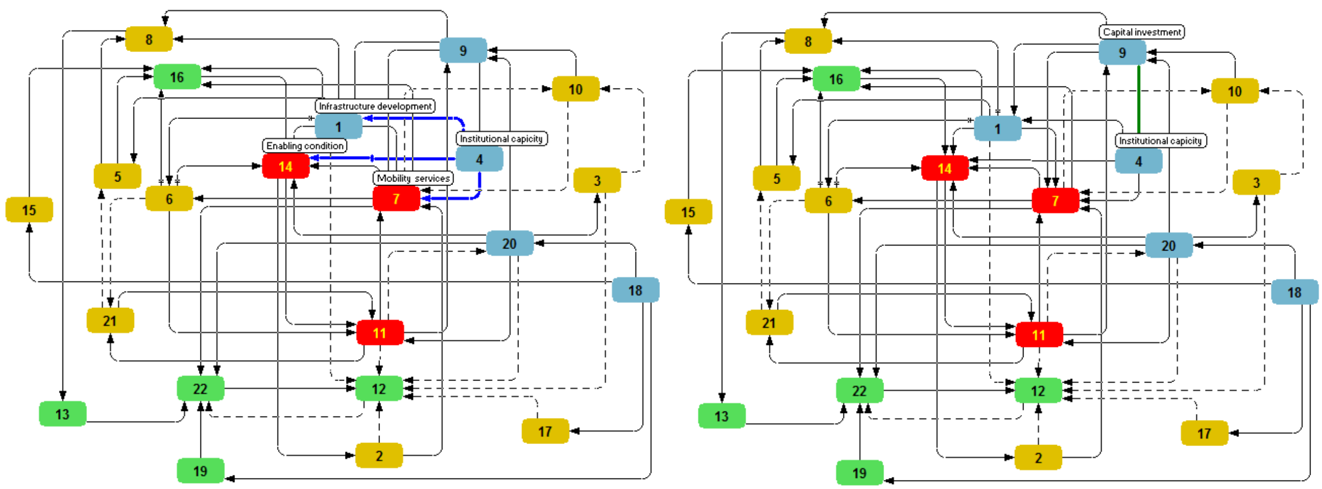

Figure 52: Effect system of institutional capacity

Although the mobility product development has potential influence on institutional capacity, they are weak link which can be seen as external influence from the industrial sectors and therefore not considered in this effect system owing to long chain of indirect influence, which is taken care in technology development as a separate variable. The following can be seen from the figure 52.

- $4 \rightarrow 1$ Availability of capable institution that can train, educate and transfer the skill set requirement for performing a mobility functions is critical. The availability of skilled human resources is fully dependent on to the good quality institution. Mobility Infrastructure development (1) is a fundamental need to enable the mobility function for the movement of both people and goods which is dependent on to availability of adequate human resource capacity. Therefore increase in the Institutional capacity (4), which is responsible for mobility system development, has the potential to enhance the Infrastructure-development (1) and the effect is positive.
- $4 \rightarrow 7$ The coordination between capable institution and the mobility service provider is a basic condition for measuring and improving the quality of mobility services. Service performance auditing, price monitoring and user requirement analysis for both people and goods movement is fully dependent

on to the availability of unbiased mobility institutions. Therefore the increase in Institutional capacity (4) for intuitional coordination between service providers has the strong influence on the improvement of mobility service (7), which is an equal effect.

- $4 \rightarrow 14$ The availability of dynamic institution, which is open to new development and willing to change with the changes, where the need of the user for both people and goods movement is necessary to address the uncertainties condition of anticipated predefined specific objective. Also the change monitoring and analysis requirement, depend on the strong Institutional capacity (4). Therefore increase in Institutional capacity (4) has the potentials to create better enabling environment for positive changes to be made. Therefore increase in Institutional capacity (4) will increase the Enabling condition (14) which is an equal effect.
- $9 \rightarrow 4$ Although capable institution is a primary condition for performing mobility function in its optimal operational conditions, they strongly depend on the availability of financial resources to develop them. Capacity development is therefore inevitably linked to the availability of financial resources for education, training, research and development, and managing the institution. Therefore the Institutional capacity (4) development is strongly influenced by availability of financial resources. More availability of financial resources has the potentials to increase the capacity of Institutions. Therefore increase in Investment capital (9) increases the Intuitional capacity (4) which is an equal effect.

The effect system of spatial dynamic

The variable Spatial dynamic (5) is a neutral variable positioned in the neutral zone in the variable's systemic role in figure 6 in section 3.1.3. The variable is a basic limit factor which cannot be increased or decreased but can be re-organized according to the contextual need. The variable Spatial dynamic (5) influences the system variable Attractiveness and aesthetics (16) and Resilience to accidents (8) whereas it gets influenced by the other system variables Infrastructure development (1) and Rural urban dynamic (21) as shown in figure 53.

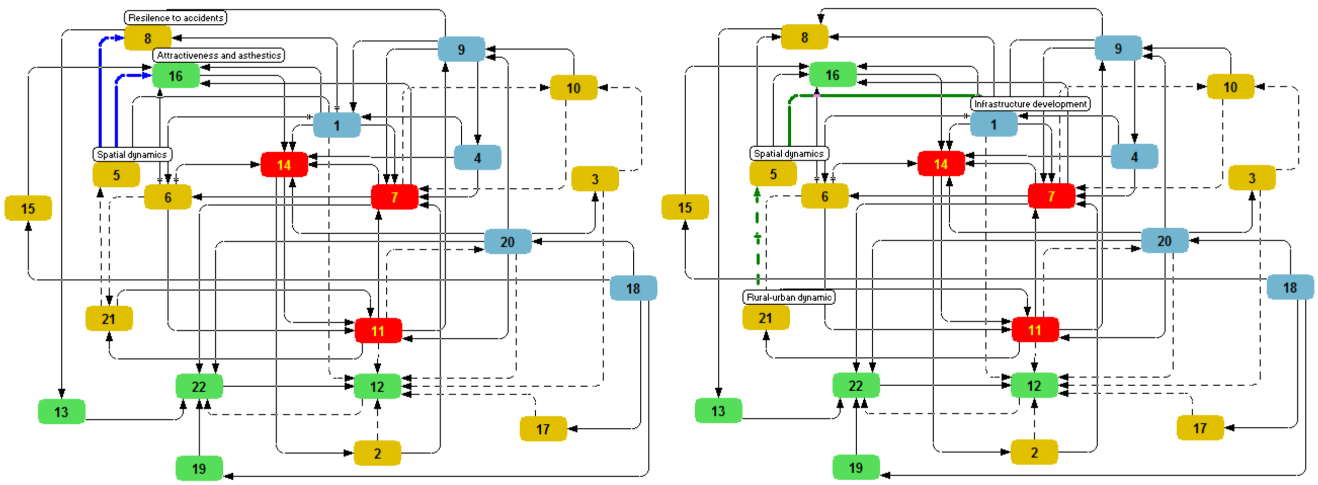

Figure 53: Effect system of spatial dynamic

The variable Spatial dynamic (5) is a potential corrective measure that can be used to stabilize the leveraging variables. The following can be seen from the effect system of the neutral variable Spatial dynamic (5) from figure 53.

- $5 \rightarrow 8$ The resilient mobility system is a movement function that decongests the free flow of people, goods and services. The availability of more free space for movement function has the potential to increase the mobility to response to localized accidents and natural disaster, which is basic requirement for rescue operation. Therefore making more space availability for movement function has the potential to increase the resiliency of mobility system. Thus increasing or decreasing the Spatial dynamic (5) proportionally increase or decrease the Resilient to accident (8), which is an equal effect.
- $5 \rightarrow 16$ Proper land use management and utilization of space for non-motorized mobility options and land use planning for recreational services increases the attractiveness and aesthetic outlook, which has the potential to de-motorize mobility system. The increase in recreational space and increasing the non-motorization has the potential for behaviour change of the user for both people and goods movement. Therefore optimizing the Spatial dynamic (5) for movement function proportionally increases or decreases the Attractiveness and aesthetics (16), which is an equal effect.

- $1 \rightarrow 5$ Although de-congested and attractive space is desirable, they are highly influence by the need for motorized and non-motorized Infrastructure development (1). Therefore creating optimized and user centric movement function demands an optimized infrastructure to fulfil the mobility requirement for both motorized and non-motorized options. Normally short distance mobility requirement can be facilitated by non-motorized infrastructure, whereas the long distance mobility require motorized infrastructure. It can be argued that increasing the infrastructure decreases the naturally available space but for the need of mobility function optimized infrastructure increases the availability of space. Therefore optimizing the infrastructure increases the Spatial dynamic (5) which is an equal effect.
- $21 \rightarrow 5$ The land use change is influenced by rural urban migration, which is currently seen to be problematic. Increasing urban infrastructure without the consideration of its capacity limit will encourage the rural urban migration uncontrollably. Similar effect can be seen in reverse trend, where urbanization trend has the potential to use the available agricultural land, which will have huge impact on the land use change and the consequence is irreversible. The need for mobility function increases with the migration trend which will potentially decrease the available space for free movement of people, goods and service. The same is also true if increased urbanization trend continue, the available space for cultivation will decrease in rural areas. Therefore increasing the Rural-urban-dynamic (21) in one central location will decrease the Spatial dynamic (5), which is an opposite effect.

Effect system of accessibility

The variable Accessibility (6) is positioned in slightly critical zone whose modification can only be done from outside of the system. The variable Accessibility (6) influences the other system variable Economic development (11), Enabling condition (14), Attractiveness and aesthetics (16) and Rural urban dynamic (21), whereas the variable Infrastructure development (1) and Mobility service (7) influences the Accessibility (6) as shown in figure 54. Accessibility for mobility ranges from different aspect such as access to new technology options and alternative fuel options in addition to mobility service access, which has the potentials to facilitate the mobility need alternatively than those that are already available.

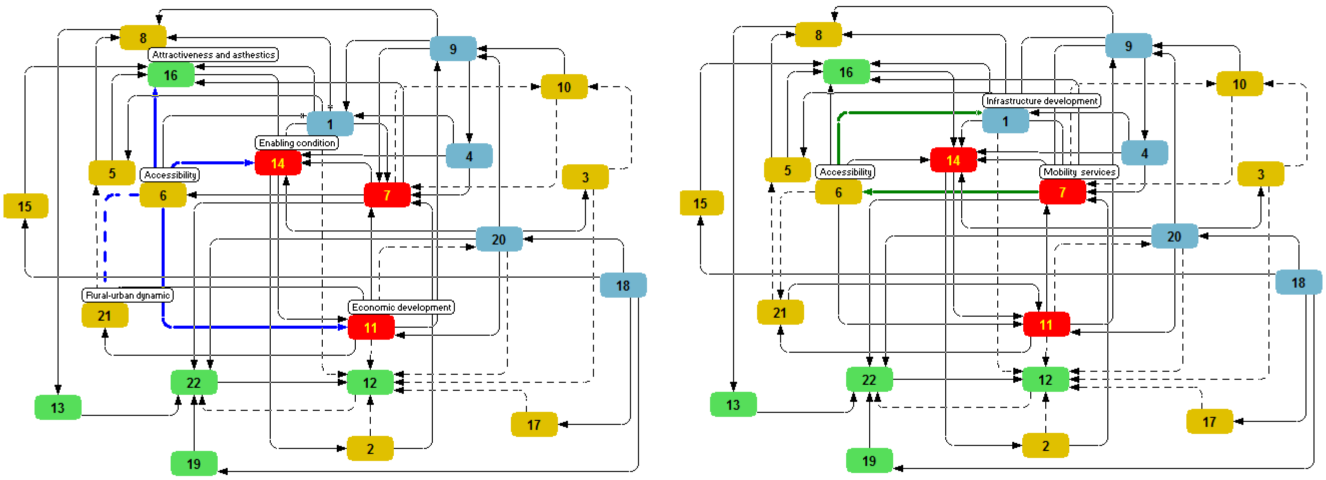

Figure 54: Effect system of accessibility

Although the effect system of Accessibility (6) has many indirect links, which has potential influences on the other system variable, only the direct influences are considered in the current effect system as the indirect effect will be seen in the feedback effect. The following can be seen from the effect system of figure 54.

- $6 \rightarrow 11$ Better access to mobility facilities has the potentials for higher degree of transaction for daily service activities thereby increasing the market as well as access for different services. Access also increases the potentials for job availability for different population category. Therefore increasing the Accessibility (6) has the potentials for better economic transaction and many different alternatives for consumers. Hence increasing or decreasing the Accessibility (6) proportionally increases or decrease the Economic development (11), which is an equal effect.
- $6 \rightarrow 14$ The access to alternative mobility options has the potential to shift the user behaviour for the same mobility need to move people, goods, and services in alternative way. The multimodality and user choice strongly depend on the availability of good mobility network connection for movement of both

people and goods. Therefore increasing or decreasing the Accessibility (6) proportionally increases or decreases the Enabling condition (14), which is an equal effect.

- $6 \rightarrow 16$ The access to alternative mobility options increases the competiveness for service provider where the desired mobility need of user depend on the quality of services. Therefore increasing the access to more options for movement of both people and goods has the potentials to increase the service quality. Hence increasing or decreasing the Accessibility (6) proportionally increases or decreases the Attractiveness and aesthetics (16), which is an equal effect.
- $6 \rightarrow 21$ The access play critical role in connecting isolated communities to more possibilities, which have the potentials to shift migration of rural community to urban region for the search of more possibilities. The reverse trend is also true for the easy access to agricultural supply in urban region. Therefore increasing the access potentially decreases the migration of people which is inverse proportionality. Hence increase in Accessibility (6) potentially decreases the Rural urban dynamic (21), which is an opposite effect.
- $1 \rightarrow 6$ Although the accessibility (6) is a critical condition for user decision support and multiple alternative choices for the user for both movement of people and goods, they strongly depend on the availability of relevant infrastructure. Better and multimodal infrastructure development potentially increases the access to more alternatives. Thus increase or decrease in Infrastructure development (1) proportionally increases or decreases the Accessibility (6), which is an equal effect.
- $7 \rightarrow 6$ Availability of quality services determine the competiveness and more alternative options, which is inevitably linked to the availability of Mobility service (7). Increasing the Mobility service (7) has the potential to increase the frequency and multi-modality for the movement of both people and goods. Therefore increasing or decreasing the service proportionally increases or decreases the Accessibility (6) which is an equal effect.

The effect system of mobility service

The variable Mobility service (7) is positioned in the critical zone in the variable's systemic image in the system as shown in figure 6 in section 3.1.3. The variable Mobility service (7) has the potential to leverage the system, which is however very risky intervention if not controlled with the feedback measures from the other system variables.

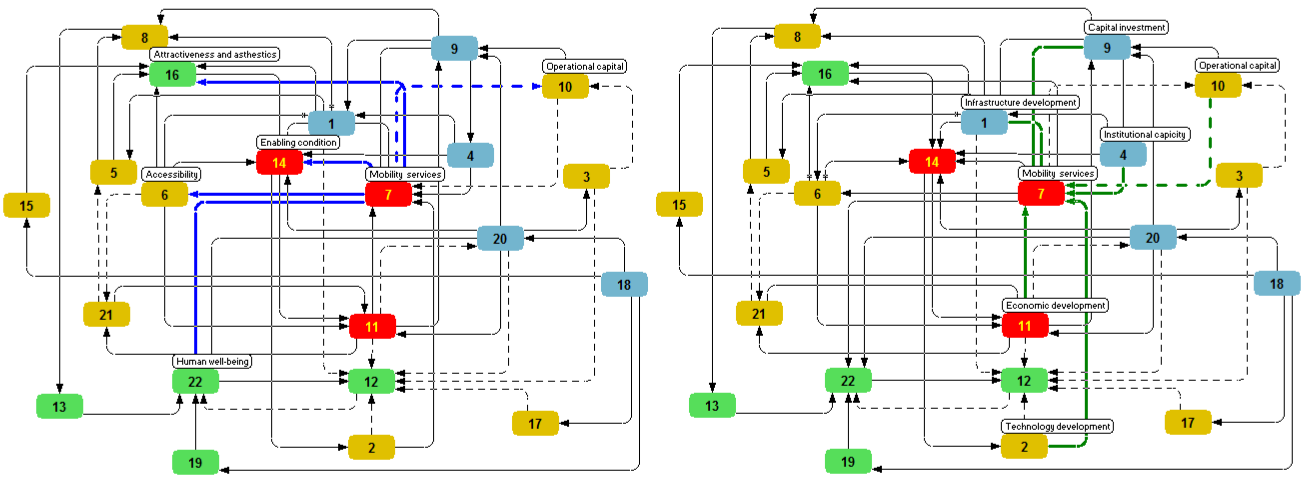

Figure 55: Effect system of mobility service

The leveraging variable Mobility service (7) influence the variables Human well being (22), Accessibility (6), Enabling condition (14), Operational capital (10) and Attractiveness and aesthetics (16), whereas the mobility service is influenced by Infrastructure development (1), Technology development (2), Institutional capacity (4), Capital investment (9), Operational capital (10) and Economic development (11) as shown in figure 55. The following can be seen from the effect system of the leveraging variable Mobility service (7) from figure 55.

- $7 \rightarrow 6$ The alternative options for mobility function, which is based on the service development rather than that of product has the potential to value add Accessibility (6) need for movement of people and goods alternatively. The increase in service decreases the need for ownership but increases the functional value of mobility products for motorization, which has the potential to increase the Accessibility (6). Thus increasing or decreasing the movement function from product consumption to service consumption proportionally increase or decrease the Accessibility (6), which is an equal effect.
- $7 \rightarrow 10$ Increasing the functional value of a mobility product by increasing the usage frequency and by more consumers has the potential to increase economy of scale for a single product distributed to different function and consumer categories. Therefore increase in Mobility service (7) has the potential to decrease the daily mobility cost of people and goods. Hence increasing Mobility service (7) decreases the Operation capital (10) which is an opposite effect.

- $7 \rightarrow 14$ Availability of multiple services from a single mobility product or technology has the potential to enable diversity and flexibility, which makes the movement function a normal daily service. The increased service of single product increases the enabling environment for user decision support, where availability of diversity and variety play a critical role. Therefore increasing or decreasing the Mobility service (7) proportionally increase or decrease the Enabling condition (14), which is an equal effect.
- $7 \rightarrow 16$ Availability of variety and diversity has the potential for increasing the quality, which is dependent on to the service sector development for mobility need for both people and goods movement. The diversity and variety increases competitiveness, which has the potential for decreasing the cost. The availability of reliable service is also a key to consumer behaviour change. Therefore increasing or decreasing the Mobility service (7) proportionally increase or decrease the Attractiveness-and-aesthetics (16), which is an equal effect.
- $7 \rightarrow 22$ Availability of multiple options, easy and comfortable mobility is one way to improve the living condition. The easy and comfortable mobility has the potentials to enable the access to healthcare for sick people and education for children. Similarly better Mobility service (7) has the potentials to increase easy access to the daily consumables. Furthermore easy and convenient mobility service opens a greater degree of social interaction, where visit to friend and family increases. Therefore diversifying the motorization by use of minimum resources has the potentials to increase the leaving conditions. Hence increase or decrease in Mobility service (7) proportionally increase or decrease the Human wellbeing (22), which is an equal effect.
- $1 \rightarrow 7$ Although it is desirable to increase quality mobility service consumption instead of product to fulfil the mobility need for the movement of people and goods, their development strongly depend on the availability of relevant infrastructure. Therefore the infrastructure that enables the shift from product consumption to service consumption is critical. Hence increasing service centric Infrastructure development (1) has the potential to increase the development of more Mobility service (7), which is an equal effect.
- $2 \rightarrow 7$ Availability of quality Mobility service (7) depends on the relevant technical support to ease the service development. New and alternative mobility technologies that are developed to fulfil the consumer desire to consume the service instead of technology product have the potential to leverage the transition of mobility technology industry from delivery of service instead of product to the consumer. Thus innovation in Technology development (2) has the potential to change the consumer behaviour. Therefore increasing or decreasing the Technology development (2) proportionally increase or decrease the Mobility service (7) availability, which is an equal effect.
- $4 \rightarrow 7$ Availability of quality Mobility service (7) and the management of the services strongly depend on the role played by the relevant institution to monitor the performance of the service rendered to the

consumer by the service provider independently. The performance monitoring require both technical and management capabilities of the institution responsible for it. Therefore development of Intuitional capacity (4) further enhances the Mobility service (7). Thus increase or decrease in Institutional capacity (4) proportionally increase or decrease Mobility service (7), which is an equal effect.

- $9 \rightarrow 7$ The development of mobility as service industry is strongly influenced by the initial Capital investment (9)for service procurement, advertisement, and human resource development for the service function management and initial know how skill sets development. Therefore it is an investment decision which will impact on the development of Mobility service (7) industry to fulfil the mobility need of both people and goods. Therefore increasing the shift in investment decision for service development rather than promoting the mobility product consumption proportionally increases or decreases the Mobility service (7) development, which is an equal effect.
- $10 \rightarrow 7$ The development of Mobility service (7) industry is strongly influence by the existing mobility product oriented ownership culture whose transformation depends on competiveness. Better quality of service depends on higher cost of operation which has the potentials to weaken the competiveness. Therefore increase in Operation capital (10) decreases the consumer preference to opt for the Mobility service (7). Hence increase in Operation capital (10) decreases the Mobility service (7) development, which is an opposite effect.
- $11 \rightarrow 7$ The development of Mobility service (7) industry is influenced by the market availability and consumer preference, which is strongly dependent onto the external factor Economic development (11). Mobility function remains inevitable for the Economic development (11). Strong economy demands more mobility need for daily transaction and logistics flows where mobility functional cost for both people and goods is important aspect to be considered, which is one of the operational cost for economic performance indicator and will have critical role to playfor the cost optimization. Therefore better and growing economy opens the new market for Mobility service (7) industry development. Hence increase or decrease in Economic development (11) proportionally increase or decrease the Mobility service (7) industry development, which is an equal effect.

The effect system of resilience to accidents

The variable Resilience to accidents(8) is positioned in a neutral zone in the variable's systemic role in the system as seen in figure 6 in section 3.1.3, which is a good feedback control variable for stabilizing the critical variables. The variable influences the Safety-and security (13),whereas the variable Resilience to accident (8) is influenced by Infrastructure development (1), Spatial dynamic (5) and Capital investment (9) as shown in figure 56.

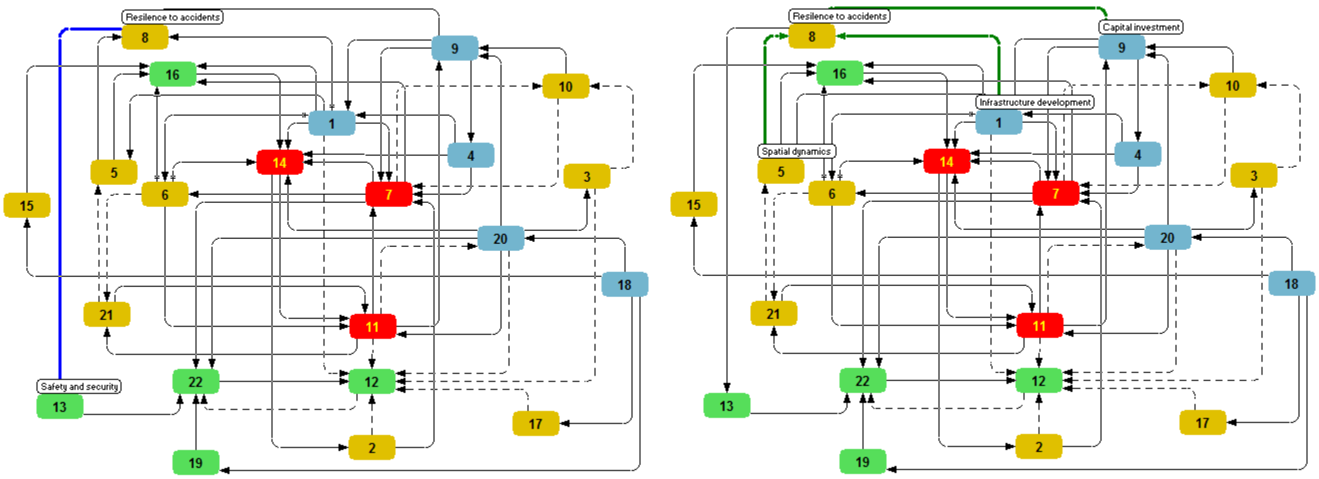

Figure 56: effect system of resilience to accidents

The variable Resilience to accident (8) is a special case of mobility system that has the potential to withstand and response to unexpected situations which has direct impact on livelihood conditions. The following can be seen from the effect system of the variable Resilience to accidents (8) in figure 56.

- $8 \rightarrow 13$ The movement of people and goods are subject to changes in daily weather condition and also to the technical failure, potentially leading to localized accidents. Further the movement function is critical during the time of disaster. For both daily commutation and in the event of disaster the availability of alternative and multimodal options equipped with good communication system has the potential to enable safe and secure movement of both people and goods. Therefore increasing the mobility resiliency potentially increases the Safety and security (13). Hence improving the Resilience to accident (8) increases the Safety and security (13) which is an equal effect.
- $1 \rightarrow 8$ Although movement of people and goods that is Resilient to accidents (8) are desirable, they strongly depend on the availability of relevant and resilient infrastructure that supports motorization and non-motorization. The resilient infrastructure are those aspect that enable monitoring of movement function in the real time mode, which enables fast and direct communication system. Therefore

increasing resilient infrastructure increases the mobility resiliency. Hence increase in resilient Infrastructure development (1) increases the Resilience to accidents (8), which is an equal effect.

- $5 \rightarrow 8$ The desirable movement of both people and goods, which is Resilient to accident (8), is strongly dependent on to the availability of de-congested mobility system. The availability of free space is also critical during the time of disaster that will influence the rescue and after effect control. Increasing the Spatial dynamic (5) by better land use management and settlement planning increases the Resilience to accident (8) improvement. Thus increasing or decreasing the Spatial dynamic (5) proportionally increase or decrease Resilience to accident (8), which is an equal effect.
- $9 \rightarrow 8$ The mobility need that enables the movement of both people and good in safe and secure conditions require additional investment apart from that of normal mobility need. The increase in mobility investment has the potential for development of resilient mobility system equipped with communication technology that additionally supports the mobility need. Thus increase in Capital investment (9) has the potential to increase the Resilience to accident (8) mobility system development, which is an equal effect.

The effect system of capital investment

The variable Capital investment (9) indicates as a lever of change variable of the system from the systemic image of figure 6 in section 3.1.3, which has the potential for mobility system transformation.

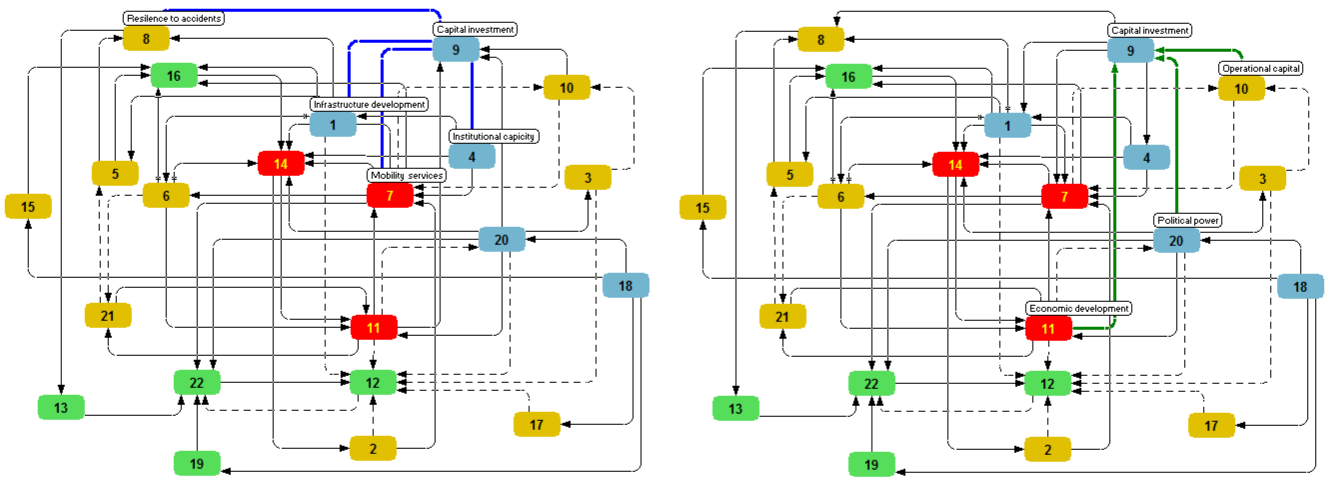

Figure 57: effect system of capital investment

The variable Capital investment (9) influences the system variable Infrastructure development (1), Institutional capacity (4), Mobility service (7) and Resilience to accident (8) whereas the variable Operational capital (10), Economic development (11) and Political power(20) influence the variable Capital investment (9). The Capital investment (9) is a variable that informs on the ability to finance the new mobility system development. The following can be seen from the effect system of Capital investment (9) from the figure 57.

- $9 \rightarrow 1$ The availability of financial resources is critical for any infrastructure development and the same applies to the development of mobility infrastructure. However they depend on the power of financial institution. On the other hand the availability of good infrastructure is by itself a physical assert which can be qualified as available capital assert. Therefore higher investment decision by the financial institution has the potentials for the development of new assert, which can have strong value addition to supplement the financial resources. Thus increase of Capital investment (9) increases the Infrastructure development (1), which is an equal effect.
- $9 \rightarrow 4$ The human resource and skills development is critical for the transition to alternative mobility system, which is an important condition for the change and their sustainability. Human resource development depends on the availability of training or education institution. The development of such institution is subject to availability of financial resources for initial development and their running cost. They strongly depend on the investment decision on development of intangible assert such as skills and

future human resource. Therefore increase in Capital investment (9) has the potential to increase the Institutional capacity (4), which is an equal effect.

- $9 \rightarrow 7$ Sourcing and channelling the financial resources for Mobility service (7) is an important condition for the change. Therefore investment decision on service development rather than the product development depends on the capital financial resource allocation that will determine the sustainability of mobility for the movement of both people and goods. Lower cost of capital borrowing is critical for the development of Mobility service (9) industry. Thus increasing the Capital investment (9) for service promotion has the potential to increase the Mobility service (9), which is an equal effect.
- $9 \rightarrow 8$ The design of resilient mobility system depends on the initial plan which considers all aspect of mobility function. The integration of for example digital and real time communication system is resource intensive and depend on initial capital availability. Thus allocating adequate capital has the potential to develop resilient mobility system. Therefore increasing the Capital investment (9) has the potentials to increase the resiliency and therefore the Resilience to accident (8) mobility system development, which is an equal effect.
- $10 \rightarrow 9$ The physical capital asserts are resource intensive and their sustainability will depend on the return of the initial investment. The return of the initial investment is only possible if physical assert generate further operating capital for its sustainability. The minimum user fee is liable for consumer for the use of the available physical capital assert. Therefore the Capital investment (9) depend on the ability of the physical assert to payback the investment that will have to be included in the Operation capital (10). Hence increase in Operation capital (9) has the potential for early return on investment that potentially increases the Capital investment (9) decision, which is an equal effect.
- $11 \rightarrow 9$ Although the Capital investment (9) is fundamental for system change, they are strongly influenced by the external factors, the Economic development (11). Strong economy has the power to invest more for new development. Therefore better the economic growth; there is higher chance for sourcing the financial resources for new and alternative mobility system development. Therefore increase in Economic development (11) proportionally increases the availability of Capital investment (9), which is an equal effect.
- $20 \rightarrow 9$ Although investment on new mobility is critical, financing them is strongly influenced by external factors the political support. The political commitment for sustainable and low emission mobility development also has the potential for sourcing the initial capital as grant from external donor. Additionally strong Political power (20) determines the government influence on new development and changes. Further the powerful political decision influence the national Capital investment (9) priorities that will have strong impact on the financial intuitions for new mobility financing. Therefore increase in

Political power (20) proportionally increases the availability of Capital investment (9), which is an equal effect.

Effect system of operational capital

The variable Operational capital (10) is positioned slightly in the critical zone in variable's systemic role in the system in figure 6 in section 3.1.3 whose modification is subject to feedback control. The variable Operation capital (10) influences the variable Capital investment (9) and Mobility service (7), whereas the variable Fuel energy security (3) and Mobility service (9) influences the variable Operational capital (10).

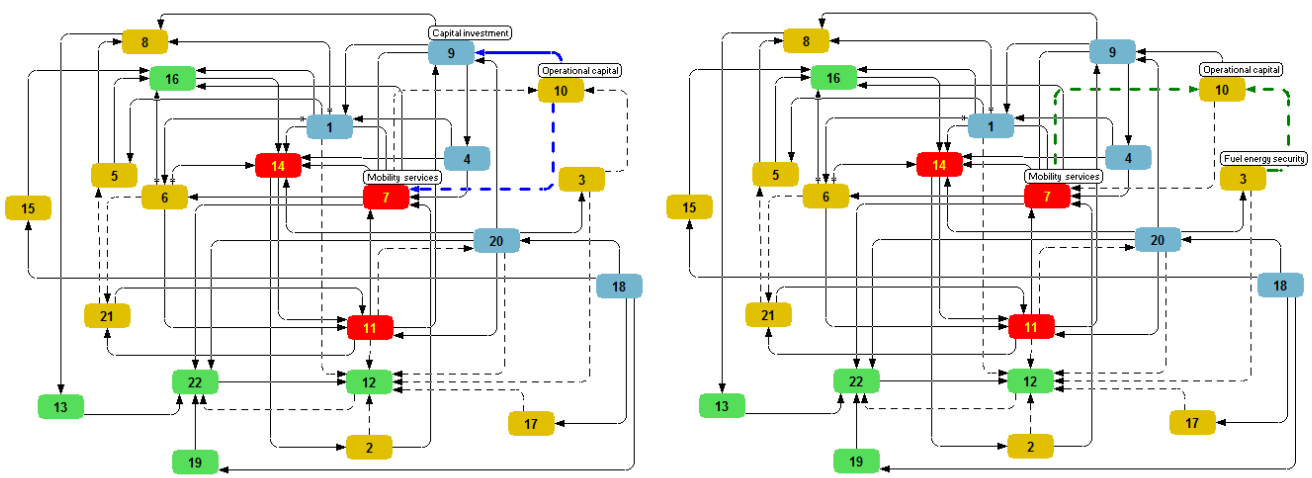

Figure 58: effect system of operational capital

The variable Operational capital (10) is subject to feedback control and has the tendency of pendulum movement in the system. The following can be seen from the effect system of figure 58.

- $10 \rightarrow 7$ Higher the quality of service desired, the cost of operation tends to increase whereas the higher cost of service will potentially face the weak consumer preference thereby losing the economy of scale. The consequence is increase in Operational capital (10) potentially decreases the development of Mobility service (7). On the other hand, the cost of product consumption as an ownership culture, which also provide the same Mobility service (7) face the similar problem of high cost of owning the product rather than using the service, which has the tendency to shift the user behaviour from ownership culture to ridership culture for movement function for the mobility of both people and goods. Hence increase in Operational capital (10) decreases the Mobility service (7), which is an opposite effect.
- $10 \rightarrow 9$ The operational capital (10) has the potential to increase the national revenue from the available capital assert that facilitate the mobility functions. Therefore increasing the Operational capital (10) has the potential to increase the revenue, which can potentially supplement the Capital investment (9).Hence

increase or decrease in Operational capital (10) proportionally increase or decrease the available revenue from the capital assert and the Investment capital (9), which is an equal effect.

- $3 \rightarrow 10$ Although lower mobility cost increases the competiveness, mostly the operating fuels is import dependent and are mostly based on tax subsidized fossil fuel. Reducing the import dependency by subsidy shift to alternative fuel substitute to enable alternative mobility fuel for movement function has high impact on mobility operation cost and gross economic value addition. Therefore increasing the Fuel energy security (3) has the potential to increase national economic value addition that translates to lower Operational capital (10) for movement function, which is an opposite effect.
- $7 \rightarrow 10$ While low operation cost has the potential for more consumer preference, availability of more service diversity has the potential to supplement the operation cost minimization. Therefore increasing the Mobility service (7) has the potential to increase competiveness. Competiveness also potentially increases the quality and reliability of service. Hence increase in Mobility service (7) decreases the Operational capital (10), which is an opposite effect.

The effect system of economic development

The variable Economic development (11) is an external influence for the mobility system. The variable Economic development (11) is positioned as critical variable in the variable's systemic role in the mobility system in figure 6 in section 3.1.3. Therefore Economic development (11) although influences the mobility system from outside is a critical system variable that has strong system leveraging potentials. The inclusion of Economic development (11) in mobility system planning unfolds many unknown problem space which is often time overlooked. The variable Economic development (11) influences the system variables Mobility service (7), Capital investment (9), Environment pollution(12), Political power (20) and Rural urban dynamic(21) whereas it is influenced by the other system variables Accessibility (6), Enabling condition (14), Political power (20) and Rural urban dynamic (21). The leveraging variable Economic development (11) overlaps with the variable that it influences and is influenced by other system variable which will be discussed further in feedback effect. Same applies to all the other system variable effect system. Although it appears the influence factor overlap and seem to repeat, they show unique behaviour if it is observed from different variable's positions.

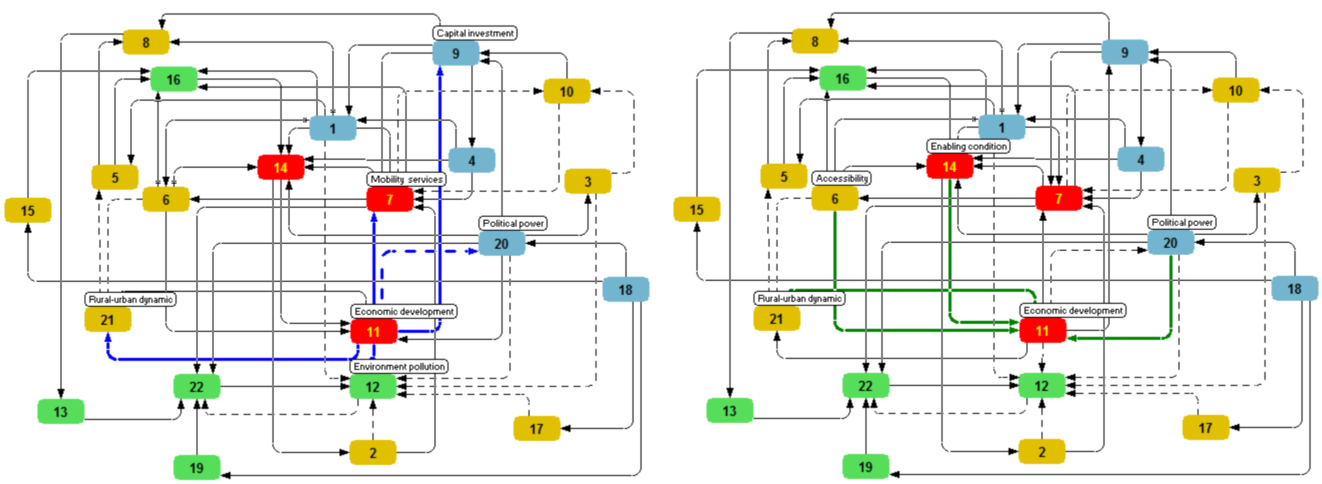

Figure 59: effect system of economic development

The economic system and mobility system are inseparable as both the system has mutual interdependency for the system functioning. The following can be seen from the effect system of Economic development (11) as shown in figure 59.

- $11 \rightarrow 7$ While the choice of economic system determine the type of mobility system, the Mobility services (7) for any economic activities are inevitable. The types of economic system determine the need for mobility of people from different place to carry out the economic activities. The goods and service production centre will influence the mobility need and settlement pattern of people which strongly impact the mobility orientation. Similarly the supply of goods and services to the consumer to different location further determine the mobility need to enable the consumer need. Therefore the source of consumption and origin of consumables will strongly influence the mobility need. The Economic development (11) determines the source and origin of the consumables and the consumer. Optimizing the Economic development (11) trend to reduce the mobility need that will proportionally reduce the need of Mobility service (7), which is therefore an equal effect.

- $11 \rightarrow 9$ The source of both capitals asserts and financial capital is strongly dependent on to the strength of economy. Powerful economy has the greater strength to make the availability of capital resources. For the development of good mobility system, the availability of capital resources both in terms of financial capital and human resource are critical. The development of financial resource and human resource strongly depend on the Economic development (11). Therefore increase in Economic development (11) has the potential to increase the mobility capital financing and human resource development that increases the Investment capital (9) in general, which is an equal effect.
- $11 \rightarrow 12$ The better economic growth also has direct impact on the natural capital such as land, air and water. The growth of economy potentially tends to increase the consumption of natural capital. Additionally the current trend of economic growth is linear where the increased consumerism decreases the ability of natural capital to replenish. On the other hand increased Economic development (11) pushes the increased need of mobility system to support their growth. Therefore Economic development (11) has negative effect on environment unless alternative resilient economy is adopted. Hence Economic development (11) increases the need of mobility system and thus decreases the natural capital to replenish easily leading to more Environment pollution (12). The positive growth of economy has negative impact on Environment pollution (12), which is an opposite effect.
- $11 \rightarrow 20$ Economic growth strongly influences the need for mobility thereby weakening the control condition especially the political decision on de-growth strategy. Furthermore in a strong economy where consumerism is pre-dominant, the political participation is weaken, which has the potentials to push further the economic growth leading to increased need of mobility. The uncontrolled economic growth has the potentials to push the consumerism habit of the people further. Therefore liberal Economic development (11) has the potential to weaken the Political power (20), which is an opposite effect .
- $11 \rightarrow 21$ The choice of people to opt for quality life depends on availability of good jobs and different services for livelihood conditions. The economic growth has the potentials to enable the availability of more jobs and livelihood need. However the current trend of job availability and livelihood need are perceived to have developed in the urban environment. The availability of job is dependent on to the Economic development (11) and in the current situation it is mostly seen in urban area, which is encouraging the rural population to migrate from rural to urban region especially the young generation in search of jobs. The concentration of Economic development (11) in urban areas has the potentials to

increase the migration of rural population further to urban environment. The consequence is increase in Economic development (11) in urban area increases the population migrating from rural area. Therefore the current trend of Rural urban dynamic (21) potentially increases the Economic development (11) unless the control measures are in place to reverse the trend, which is in either direction an equal effect.

- $6 \rightarrow 11$ While the economic growth has the potential to demand more mobility requirement, the access to mobility system determines the growth of economy. The access to mobility system has the potentials for increasing the balanced regional economic growth that has the potentials to gross economic value addition. Therefore the access play critical role in economic decentralization. Hence increasing the Accessibility (6) has the potential for balancing the economic growth and access to consumables from multiple source of origin. The availability of diversity and multiple options for consumable has the potentials to value add on the gross economy. Thus increasing or decreasing the Accessibility (6) proportionally increase or decrease the Economic development (11), which is an equal effect.
- $14 \rightarrow 11$ The alternative options for de-growth development strongly depend on the control conditions. The control conditions influence the behaviour of the consumer. Therefore de-enabling the current economic growth trend and shifting to more resilient economy strongly depend on good enabling environment both economically and politically. Thus better Enabling condition (14) by design of new control policy has the potential to revalorize the current economic growth trend. Revalorized economic growth trend has the potentials to decrease the need of motorized mobility system. Thus creating good Enabling condition (14) has the potentials for de-growth fulfilment of current Economic development (11), which is an equal effect.
- $20 \rightarrow 11$ While the economic growth has strong influence on the control of political decision, the growth by itself depends on the people's participation. The economic growth initially shows the better livelihood condition but has repercussion effect if not controlled, which lead to increase inequalities and disparity in the society. The increased inequalities and disparity push further the status symbol, which is common trend in the current mobility system development. The inequalities and disparities have the potential for increasing the people's participation in the political system. Thus increased participation increases the potentials for alternative and resilient economy development that also has the potential for removing the status symbol for the need of mobility luxury. Thus the control by Political power (20) increases development of alternative economic system. Hence the increase in Political power (20) increases the Economic development (11), which is an equal effect.
- $21 \rightarrow 11$ While economic growth influence the migration of people from rural area to urban area, the reverse trend is equally possible if control measures are applied. The urban growth increases the competiveness, which has the consequence of increased cost of living. Further the uncontrolled urban growth creates the space limitation, which adds to increased living cost and congestion. Although the urban development potentially facilitates economic growth, the cost of economic growth is proportional.

The cost of centralized economic growth is shared by the consumer, which impact the leaving cost thereby the shift in urban-rural migration is potentially possible. Urban-rural migration depends on good access to jobs which depend on the Economic development (11). Therefore reverse trend though not easy is critical for the development of resilient livelihood conditions. The reverse trend of Rural urban dynamic (21) increases with the shift of growth model of decentralized and regional economy which is desirable for de-growth strategy. These external influences strongly influence the mobility system development. Increased reverse trend of Rural urban dynamic (21) is dependent on to increased decentralized and regional Economic development (11), which is an equal effect.

Effect system of environment pollution

The variable Environment pollution (12) is positioned in the region of reactive zone in the variable's systemic role in the system in figure 6 in section 3.1.3. The variable Environment pollution (12) is strong system indicators which depend on the development of other system variable. The variable Environment pollution (12) influences the Human well being (22) whereas Infrastructure development (1), Technology development (2), Fuel energy security (3), Awareness on new mobility (17), Political power (20) and Human well being (22) influences the variable Environment pollution (12) as shown in figure 60.

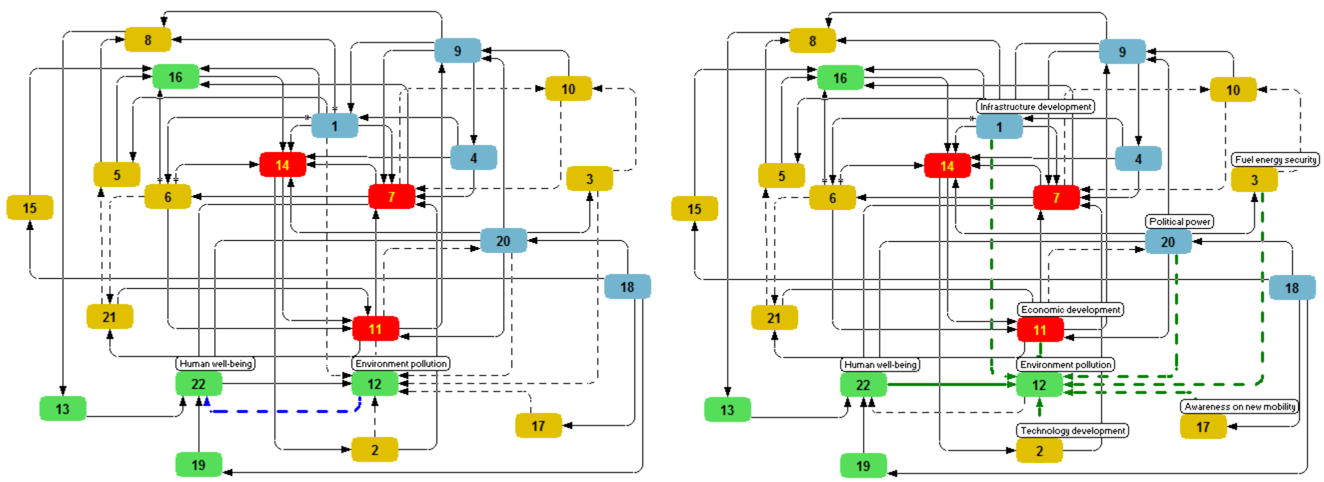

Figure 60: Effect system of environment pollution

The variable Environment pollution (12) is a potential variable for system goal definition or it can be a potential target variable which determines the system performance. The following can be seen from the effect system of Environment pollution (12) from figure 60.

- $12 \rightarrow 22$ The good quality air has direct impact on human health. Mobility system is partially responsible for air pollution in both urban and rural environment. Increased level of air pollution also has direct effect on climate change which is a global problem and threatens the human survival. Therefore the target to reduce air pollution from mobility system potentially increases human health. Health is a strong indicator for the quality and happy life. Therefore decreasing Environmental pollution (12) increases Human well being (22), which is an opposite effect.
- $1 \rightarrow 12$ Defining a goal to reduce Environment pollution (12) potentially influences the design and development of infrastructure that are more resilient to environment. The resilient infrastructure influences the mobility behaviour of people and mobility requirement for the movement of goods and services. Therefore environmental consideration as a priority target will have major impact on the development of resilient mobility infrastructure rather than priority target setting for infrastructure

development that enable only motorization. More non-motorized infrastructure tends to develop when Environment pollution (12) control is a primary goal. Thus increasing resilient mobility Infrastructure development (1) decreases Environment pollution (12), which is an opposite effect.

- $2 \rightarrow 12$ Defining the goal to decouple mobility Technology development (2) from Environment-pollution (12) will have strong impact on current trend of motorization. The first priorities of non-motorization strongly influence the development of mobility system that will potentially remain independent to technical solution for movement function. Even if the needs of technology are inevitable the developments of new and alternative mobility technology tend to dominate the mobility services. Therefore Environment pollution (12) reduction as a target goal has the potential to re-orient the technology innovations that are resilient to environment. Thus increase in alternative Technology development (2) decreases the Environment pollution (12), which is an opposite effect.
- $3 \rightarrow 12$ Setting target to increase Fuel energy security (3) to reduce the Environment pollution (12) will have major reforms on the decision on the fuel pricing and tax system. The availability of quality fuel determines the emission reduction potential and the choice for alternative source influence the security of supply. Therefore increasing Fuel energy security (3) potentially decreases the use of fossil fuel, which is the main source of emission and the Environment pollution (12). Hence increase in Fuel energy security (3) decreases the Environment pollution (12), which is an opposite effect.
- $11 \rightarrow 12$ The influence of external factor Economic development (11) on Environment pollution (12) will have strong influence on mobility system development if goal of economic growth is to decouple Environment pollution (12). Decoupling economic growth from Environment pollution (12) strongly discourages the material and energy intensive mobility need for economic growth. Therefore decoupling economic growth address the de-growth strategy, which has the potential to reduce Environment pollution (12). However economic growth is inevitably linked to development that is material and energy intensive which increases Environment pollution (12). Hence positive Economic development (11) has negative impact on Environment pollution (12), which is an opposite effect.
- $17 \rightarrow 12$ The communication as change enabler is critical for informing consumer for the choice of mobility that is available. Lack of knowledge is often time seen as communication gap, which is strong component for consumer behaviour change. Although many different technical and service oriented mobility options are available these days, they are not fully known by many users. Therefore Awareness on new mobility (17) strongly influences the goal definition and consumer behaviour orientation to new availability. Increase in Awareness on new mobility (17) has the potential to trigger the behaviour change of consumer towards more environment friendly mobility options, which decreases the Environment pollution (12). The increase in Awareness on new mobility (17) decreases the Environment pollution (12), which is an opposite effect.

- $20 \rightarrow 12$ The political commitment strongly influences the environment protection and therefore the mobility system, which is critical considering the uncertain social acceptability for alternative mobility options that are available. Setting environmental target especially the action to climate change mitigation will strongly influence the development of new and alternative mobility option. Further the political decision strongly depends on the power of ruling government to control the reforms in the national policy and target setting. Thus strong and stable Political power (20) has the potential to align mobility system development that is more environment friendly, which potentially decreases the Environmental pollution (12). Therefore increase in Political power (20) decreases the Environment pollution (12), which is an opposite effect.
- $22 \rightarrow 12$ The duality of consumerism and de-growth strategy is strongly dependent on to goal definition, which can be mobilized through middle path goal where Human well being (22) and Environment pollution (12) are balanced. Increase in Human wellbeing (22) has the potential to increase the consumerism behaviour, where luxury and ownership trend tend to dominate the mobility system development, which is not desirable considering the current state of the environmental health. Increasing Human wellbeing (22) without the limit condition will lead to increased use of natural capital, which increases the Environmental pollution (12). Therefore increase in Human wellbeing (22) increases the Environmental pollution (12), which is an equal effect.

The effect system of safety and security

The variable Safety and security (13) is positioned in the weaker region of reactive component, which is a weak indicator of the system as shown in the variable's systemic role of the system in figure 6 in section 3.1.3. However the variable is indirectly influenced by many other system variables as shown in figure 61.

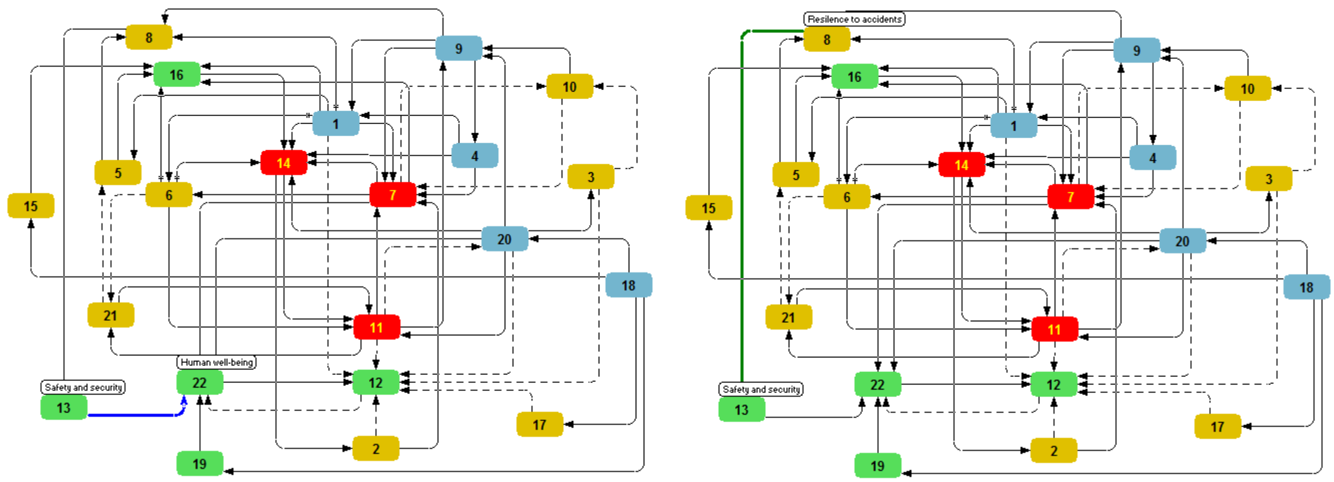

Figure 61: effect system of safety and security

The variable Safety and security (13) influences the variable Human wellbeing (22) and is influenced by the Resilient to accidents (8). Although Safety and security (13) is positioned in the weaker region as system indicator, the variable will strongly influence the quality of life. The following can be seen from the effect system of the variable Safety and security (13) from the figure 61.

- $13 \rightarrow 22$ Safety and security (13) play critical role in defining the quality of human life support conditions. The mobility system by virtue of its functional need is mostly the movable component which is subject to technical failure and human error for the movement of both people and goods. Therefore early precautionary measures are fundamental need for safe and secure movement of people, goods and services. The same condition of safety applies during the time of disaster and localized accidents. Increasing the precautionary measures increases the safety condition, which enables the confidence level of mobility product/service consumer. Improving the confidence level potentially enhances the human life quality. Therefore increasing or decreasing the Safety and security (13) proportionally increases or decrease the Human well being (22), which is an equal effect.
- $8 \rightarrow 13$ Although Safety and security (13) is fundamental need for the mobility system, they are strongly influenced by design of resilient physical and non-physical control support against failure and error. Therefore good physical enabling condition supported with strong rules and regulations are necessary for the control of Safety and security (13). Increasing or decreasing Resilient to accident (8)

mobility system proportionally increases or decrease the development of Safety and security (13) aspect of mobility for the movement of both people and goods, which is an equal effect.

Effect system of enabling condition

The variable Enabling condition (14) is positioned in the critical region of variable's systemic role in the mobility system as shown in figure 6 in section 3.1.3, which represents soft control leveraging variable of the system.

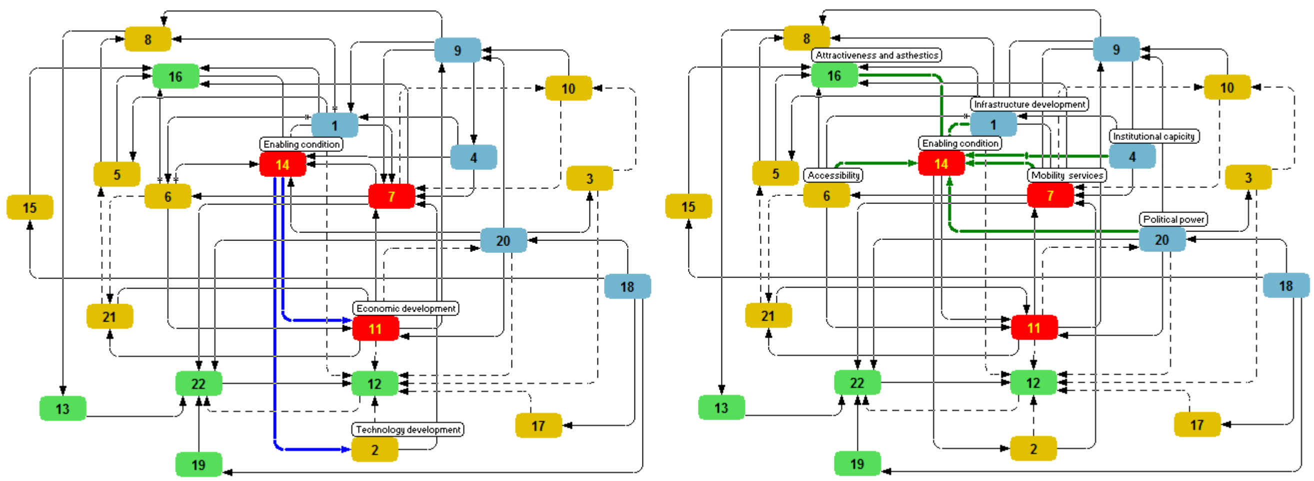

Figure 62: effect system of enabling condition

The variable Enabling condition (14) influences Technology development (2) and Economic development (11) whereas the variable Enabling condition(14) is influenced by the variables Infrastructure development (1), Institutional capacity (4), Accessibility (6), Mobility service (7), Attractiveness and aesthetics (16) and Political power (20). The variable Enabling condition (14) is a soft factor and can have strong control of the system goal definition. The following soft control of system goal can be seen from the effect system of Enabling condition (14) as shown in the figure 62.

- $14 \rightarrow 2$ The enabling policy support for the rollout of alternative technologies is necessary as the new development is always challenged by market monopoly and the built infrastructure that are not so easy for the penetration of new alternatives. The control of technology development is dependent on to the need assessment which is strongly influenced by the control condition, where consumer demand is properly taken care. The mobility technologies are those that attempt to ease the movement function by motorization. Creating more Enabling condition (14) for motorization potentially increases the Technology development (2). On the other hand uncontrolled technology development tend to decrease the de-growth strategy which is not the desired vision of the system development. Therefore selective Enabling condition (14) has the potential to increase the alternative to fossil fuel Technology development (2), which is an equal effect.

- $14 \rightarrow 11$ The control of external influence factor Economic development (11) is necessary for desirable mobility system development. The free and liberal conditions are key element to competiveness for the economic growth, where the quality control is determined by the competiveness. However uncontrolled competitive growth potentially increases the consumerism behaviour, where the economy is disposed to inevitably intensified dependency on the limited natural capital. Increased economic growth increases the demand for more mobility need if not carefully monitored. Therefore good Enabling condition (14) potentially increases the Economic development (11), which is desirable for economic growth that additionally demands for the optimized mobility system. Hence better Enabling condition (14) increases the Economic development (11)and demand more mobility system, which is an equal effect.
- $1 \rightarrow 14$ Although soft leveraging variable Enabling condition (14) is critical for the control of mobility system as a whole, they strongly depend on availability of relevant Infrastructure development (1) policy. Defining the Infrastructure development (1) policy that aim for the resilient Infrastructure development (1) has the potential to optimizes the Enabling condition (14). Therefore resilient Infrastructure development (1) potentially depends on the policy support that creates Enabling condition (14), which is an equal effect.
- $4 \rightarrow 14$ Although soft leveraging variable Enabling condition (14) is necessary for the system to function as desired, they strongly depend on the availability of competent human resources. On the other hand the human resource development is strongly influenced by the need to optimize the system. Therefore the influence of Institutional capacity (4) determines the initial goal or the target definition of the system, where the need of relevant skill sets is identified. Increasing the Institutional capacity (4) through relevant policy support creates Enabling condition (14) that supports the need criteria, which are subject to the goal and target setting on contextual basis. Therefore increase in the Institutional capacity (4) potentially increases the Enabling condition (14) that supports holistic system goal definition. Hence the effect is an equal effect.
- $6 \rightarrow 14$ The Accessibility (6) plan/design/policy for mobility system influences strongly the Enabling condition (14). However it depends on the need assessment that enable the access requirement. Therefore Accessibility (6) depends on the guiding policy. Access to different service can only be optimized with strong enabling support conditions. The current mobility system is faced with the challenge of lack of equitable access to mobility system by different population categories that will require strong policy support, which creates an Enabling condition (14). Thus increase in Accessibility (6) through regulatory intervention potentially increases the Enabling condition (14), where the enabling condition requires appropriate unbiased access requirement. Hence the increase in policy, supporting the Accessibility (6)creates increased Enabling condition (14), which is an equal effect.

- $7 \rightarrow 14$ The choice for mobility product or service consumption depends on the availability of either of them. The current trend of mobility system development is increased mobility product consumption where the ownership culture dominates the consumer behaviour. The desired mobility system aims to increase Mobility service (7) development, which is dependent on to the policy supporting them that creates the Enabling condition (14). The development of service curtails the inclusion of strong policy that enables the service development, where quality service requirement by the consumer remains unchanged. The influence of leveraging variable Mobility service (7) and influenced variable Enabling condition (14) require independently separate goal definition for their development. The variables open an alternative goal options on a contextual basis. Increase in Mobility service (7) proportionally increases the Enabling condition (14); whereas the reverse conditions are applicable depending on the contextual need. The influencing factor generates uncertainty condition for decision support, which needs careful consideration including the feedback effect. In the current case the influence is positive and therefore the equal effect.
- $16 \rightarrow 14$ Attractiveness and aesthetics (16) determine the consumer reaction on the availability of convenient mobility system. The convenient movement of people and goods are the desired dream and wishes of the consumer, which is depended on to availability of quality mobility services. The quality of system is defined by the user centric service development. In the current trend of mobility system development the status symbol of owning the mobility product dominate to fulfil the same mobility function especially for the movement of people. De-coupling the ownership culture strongly depend on Enabling condition (14) supporting policies that has the potential to remove the stigma of mobility product ownership as status symbol. Increasing Attractiveness and aesthetics (16) has the potentials to de-couple the current trend of mobility product consumption by the user that create Enabling condition (14) to shift the consumer behaviour. Therefore increase in Attractiveness and aesthetics (16) increases the Enabling condition (14) to de-couple mobility product ownership culture, which is equal effect.
- $20 \rightarrow 14$ The external influence factor Political power (20) strongly influences the Enabling condition (14) requirement for the development of desirable mobility system regulation. However the goal definition of the system that creates Enabling condition (14) is critical. The political support is necessary for the control condition, where reforms in mobility system policy and regulation will potentially control the development of desirable mobility system. The strength of stable and strong Political power (20) will potentially create strong Enabling condition (14) for the development of desirable mobility system policy. Hence increase in Political power (20) increases the Enabling condition (14), which is an equal effect.

Effect system of cultural values

The variable Cultural value (15) is intangible aspect of mobility system, which is positioned close to neutral section in variable's systemic role in figure 6 in section 3.1.3. Cultural values that describe mobility system will have long-term system's behaviour development. The variable Cultural value (15) influences Attractiveness and aesthetics (16), whereas it is influenced by the variable Participatory planning culture (18).

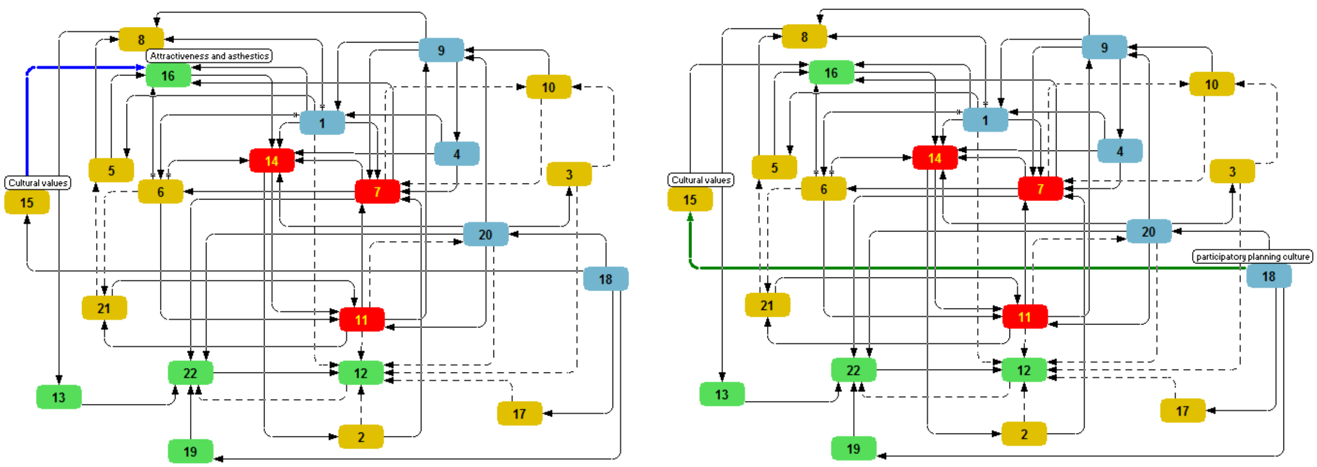

Figure 63: effect system of cultural values

The mobility system and human behaviour are strongly influenced by the societal culture which determines many different factors like settlement pattern, travel behaviour, consumption habits and economic model, which will directly impact the development of mobility need. The following can be seen from the effect system of the Cultural value (15) from the figure 63.

- $15 \rightarrow 16$ The Cultural value (15) determines the desire and wishes of the people which is built on the social norms and value system. Integration of social norms and value system in the mobility system potentially increases the willingness of the consumer to shift the mobility behaviour from private mobility system to public mobility system. Optional mobility for different religious-ethnicity, age group and gender categorisation will have strong value addition to public mobility system development as a measure to consumer behaviour change, which has the potential to increase the Attractiveness and aesthetics (16) of mobility system as a whole. Underestimation of Cultural value (15) at the time of mobility system planning will have strong influence on the consumer behaviour to opt for private mobility that potentially leads to ownership based mobility system development, which is not a desirable mobility system. Integration of cultural diversity in mobility system planning increases the Attractiveness and aesthetics (16), which is an equal effect.

- $18 \rightarrow 15$ Although the desirable mobility system that integrates Cultural value (15) has potential for consumer behaviour change, they are strongly influenced by the decision making process. The cultural values can only be known only if consumer cultural values and the desired mobility need are communicated well in advance. Reorganization of the cultural need strongly depend on the people's participation from different user group in free and fair condition. Thus increasing the Participatory planning culture (18) potentially increases the diversity and therefore the Cultural value (15) in mobility system, which is an equal effect.

Effect system of attractiveness and aesthetics

The variable Attractiveness and aesthetics (16) is an intangible aspect of mobility system, which is positioned close to neutral zone in the variable's systemic role in figure 6 in section 3.1.3.

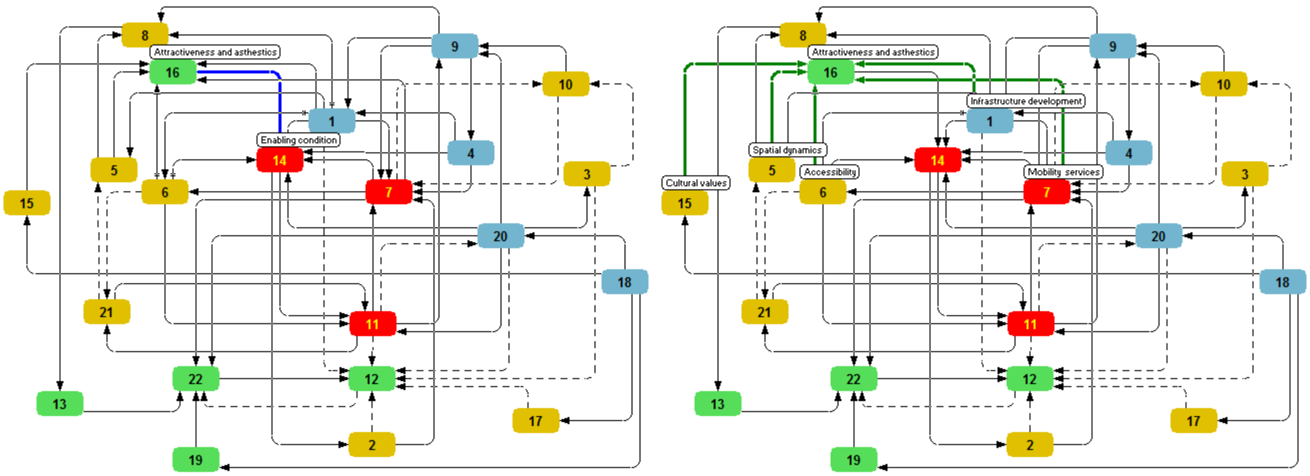

Figure 64: effect system of attractiveness and aesthetics

The intangible aspect of mobility system that address the consumer behaviour is important condition for alternative system development, which is often time underestimated as it is perceived to have been integral part of the system and receives less attention. However Attractiveness and aesthetics (16) is a soft factor that will significantly influence the mobility system especially the level of acceptance by the consumer. The variable Attractiveness and aesthetics (16) influences Enabling condition (14), whereas it is influenced by Infrastructure development (1), Spatial dynamic (5), Accessibility (6), Mobility service (7) and Cultural value (15). The following can be seen from the effect system of Attractiveness and aesthetics (16) as shown in figure 64.

- $16 \rightarrow 14$ Mobility system that offers desired movement requirement of goods and people depend on the timeliness, frequency, affordability, reliability, clean and safe mobility support system. The Attractiveness and aesthetics (16) increases by improving the timeliness, frequency, affordability, reliability, clean and safe movement of goods and people. Further the aspects like timeliness, frequency, affordability, reliability, clean and safe mobility support system creates an Enabling condition (14) for mobility system user decision on the choice of mobility options. Thus increase or decrease in Attractiveness and aesthetics (16) proportionally increase or decrease the Enabling condition (14), which is an equal effect.
- $1 \rightarrow 16$ Although desired mobility system that enables the user decision support by improving timeliness, frequency, affordability, reliability, clean and safe mobility support system is critical, they all depend on the availability of relevant infrastructure that fulfils those conditions. The infrastructure

that enables Attractiveness and aesthetics (16) of mobility alternatives is a basic requirement. Therefore increase in infrastructure such as, providing ICT facilities with the social media support enable the mobility choice playing field, which enhances Attractiveness and aesthetics (16) of new and alternative mobility system. Thus increase in Infrastructure development (1) proportionally increases the Attractiveness and aesthetics (16), which is an equal effect.

- $5 \rightarrow 16$ Availability of more space makes the movement function smooth and free. Further the availability of free space that enable commuter to engage and entertain is important condition for consumer behaviour change. The free space can potentially integrate the recreational facilities in the system design, which encourages non-motorized travel behaviour. Therefore land use change imbedded as recreational facilities increases the Attractiveness and aesthetics (16) of non-motorized mobility behaviour. Hence decongesting the mobility of people and goods by land use change and therefore the Spatial dynamic (5) potentially increases the Attractiveness and aesthetics (16) for the development of alternative mobility system, which is an equal effect.
- $6 \rightarrow 16$ The easy access to service, job location, school, health care with the built environment is important condition for Attractiveness and aesthetics (16). The re-orientation of settlement and relocation of service centres potentially optimizes the access where movement of people and goods is possible in short time and within radial distance of settlement. Further the access to ICT system for the choice of mobility mode for both short and long distance movement of people and goods increases the Attractiveness and aesthetics (16). Thus increase in Accessibility (6) potentially increases the Attractiveness and aesthetics (16) of the alternative mobility options, which is an equal effect.
- $7 \rightarrow 16$ Multimodal Mobility service (7) for the movement of people and goods offers multiple choices for the commuter to opt for the Mobility service (7), where consumer decisions on the choice of mobility mode depend on the availability of user-friendly services. Increasing the Mobility service (7) quality and user centric service development increases the Attractiveness and aesthetics (16) of alternative mobility options. Therefore increasing or decreasing the Mobility service (7) proportionally increase or decrease the Attractiveness and aesthetics (16), which is an equal effect.
- $15 \rightarrow 16$ Integration of Cultural values (15) such as individual behaviour in public, respect for ethnic religious community, respect for gender, and respect for elderly citizen is key criteria to encourage the shared mobility system development. Furthermore the clean, comfortable and reliable mobility system that supports the movement of people and goods make it aesthetically convincing for the mobility service consumer, which fully depend on the behaviour of the commuter. The cultural values (15) are imbedded in the day to day behaviour of the people, which is influenced by social norms and value system a community is exposed to. Public regulation that considers the value system as integral part defined by the variable Cultural values (15) potentially increases the Attractiveness and aesthetics (16), which is an equal effect.

Effect system of awareness on new mobility

The variable Awareness on new mobility (17) is positioned in very stable zone in the variable's systemic role in the mobility system in figure 6 in section 3.1.3.

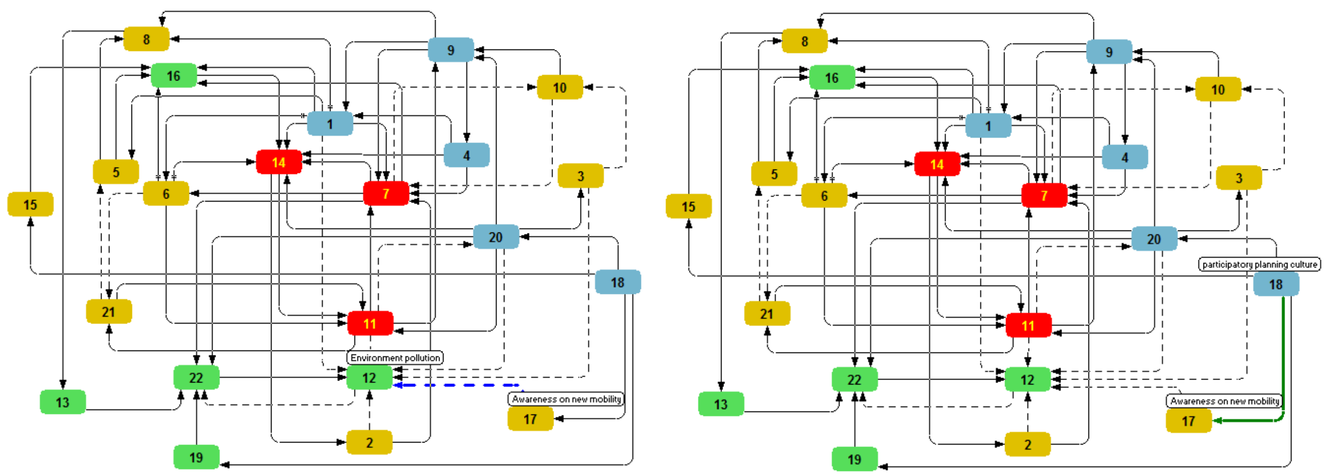

Figure 65: effect system of awareness on new mobility

The variable Awareness on new mobility (17) influences the variable Environment pollution (12) and is influenced by the variable Participatory planning culture (18). The following can be seen from the effect system of the variable Awareness on new mobility (17) from figure 65.

- $17 \rightarrow 12$ Communication is critical aspect for the change in any system and same applies to mobility system. The desire to transform current mobility system development into more sustainable system depends on the variables defining the system, which can only be implemented with good communication strategy. Awareness on new mobility (17) is a first step communication, where the alternatives that are available will have to be known by the mobility product/service consumer. Increasing the Awareness on new mobility (17) increases the potential for environment pollution reduction by mobility user. Therefore increasing the Awareness on new mobility (17) will have the potential to decrease the Environment pollution (12), which is an opposite effect.
- $18 \rightarrow 17$ Awareness on new mobility (17) depends on the role played by the consumer to implement them successfully. Inclusion of different population categories to identify the mobility system need and the potentials regarding alternatives options are important condition for new development. Thus increasing the public participation for collective decision on the choice of desired mobility system development has the potential to increase the Awareness on new mobility (17). Therefore increase in Participatory planning culture (18) potentially increases the level of Awareness on new mobility (17), which is an equal effect.

Effect system of participatory planning culture

The variable Participatory planning culture (18) is positioned in the region of potential lever of change in the variable's systemic role in figure 6 in section 3.1.3.

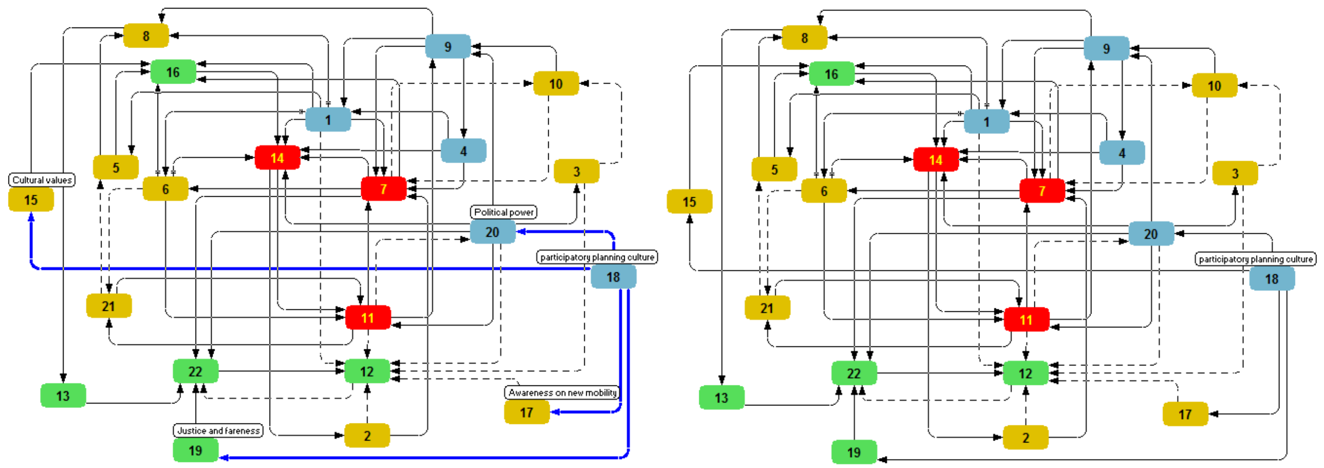

Figure 66: effect system of participatory planning culture

The variable Participatory planning culture (18) influences the variable Cultural value (15), Awareness on new mobility (17), Justice and fairness (19) and Political power (20) as shown in the figure 68. The following can be seen from the effect system of Participatory planning culture (18) from figure 66.

- $18 \rightarrow 15$ The control of any system development is influenced by the intervention made by the people that will require Participatory planning culture (18) for a successful system planning and implementation. The same is true for the mobility system development. The participation in planning has the potentials to include the contextual social norms and value system which is critical for the behaviour change of the consumer. Thus increasing the Participatory planning culture (18) potentially increases the social acceptance, where the Cultural value (15) play critical role for the alternative development. Hence increase in Participatory planning culture (18) potentially increases the inclusion of Cultural values (15) in designing mobility system, which is an equal effect.
- $18 \rightarrow 17$ The engagement of diverse group of participant during the planning process enables the holistic decision with the engaged stakeholders. The system that is free from feedback and comment from the stakeholder is an isolated system that tend to force the regulation on the mobility product/service consumer, which is neither sustainable nor fulfils the desired mobility system development. The participation process is an approach to create awareness where mobility product/service consumers take the active role, rather than the decision maker. Thus increase in the

Participatory planning culture (18) proportionally increases the Awareness on new mobility (17) development, which is an equal effect.

- $18 \rightarrow 19$ The system that addresses the concern of the useris more likely to be user friendly than those that are forced on to user, which is oftenenforced by the decision maker. The increased level of participation therefore justifies the need of the consumer in a holistic approach. The mobility system is a system that is determined by the user behaviour rather than that of the forced control conditions. Furthermore the control condition has to be fair with high degree of transparency for it to be functional. Therefore increasing the Participatory planning culture (18) potentially increases the Justice and fairness (19) to the mobility service/product consumer. Hence it is an equal effect in the system.
- $18 \rightarrow 20$ The participation of consumer group strongly influences the Political power (20), which is the fundamental requirement for mobility system control condition. The problematic mobility system development in the current situation although is well-known to almost every mobility product/service consumer and producer, they lack the decision support for the alternative choice in a participatory approach. Increase in Participatory planning culture (18) increases the collective decision making process which potentially enables the Political power (20), which in turn has the potential to increase the consumer acceptability. Thus increase in Participatory planning culture (18) proportionally increases the Political power (20), which is equal effect.

Effect system of justice and fairness

The variable Justice and fairness (19) is positioned midway between the reactive and neutral zone indicating a weak system indicator in the variable's systemic role in figure 6 in section 3.1.3.

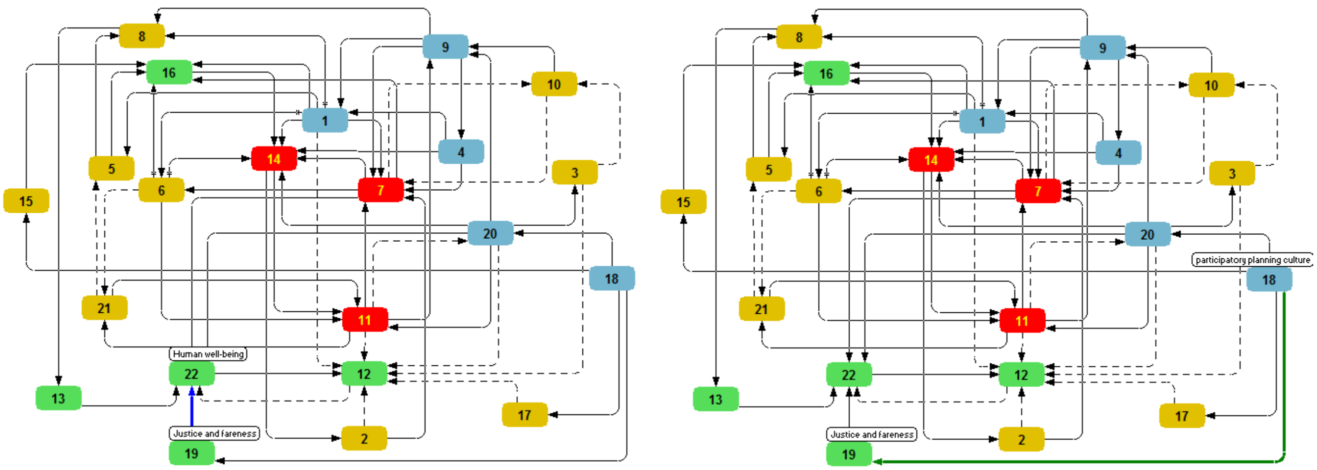

Figure 67: effect system of justice and fairness

The variable influences Human wellbeing (22) and is influenced by Participatory planning culture (18) as shown in figure 67. The variable Justice and fairness (19) is a generic external influence. The following can be seen from the external influence of the variable Justice and fairness (19).

- $19 \rightarrow 22$ Functioning of mobility system with equality in fair condition enables Justice and fairness (19). Equal distribution of mobility service to all population categories and to all location addresses the quality of life improvement as fundamental right for all population, which has the potential to fulfil the normal movement requirement of both people and goods in rural and urban environment. The variable expresses affordability, accessibility and equality that support normal movement function by either motorization or non-motorization. The indicators such as affordability, accessibility, and equality supports Human well being (22) measures. Thus increasing Justice and fairness (19) has the potential to enhance Human wellbeing (22), which is an equal effect.
- $18 \rightarrow 19$ The representation of stakeholders from different population categories that attempt to integrate the need of all mobility service/product for all consumer group including the decision maker and the taker will value add to Justice and fairness (19). Furthermore the performance indicator that includes the mobility system coverage for the contextual need can only be known through consumer participation. Thus increasing the stakeholder engagement in all level of communication and expression of need requirement through Participatory planning culture (18) will have the potentials to increase the

Justice and fairness (19) to different consumer categories. Hence increase in Participatory planning culture (18) increases Justice and fairness (19), which is an equal effect.

The effect system of political power

The Political power (20) is an external influence factor which is positioned in the region of active lever of change in the variable's systemic role in figure 6 in section 3.1.3.

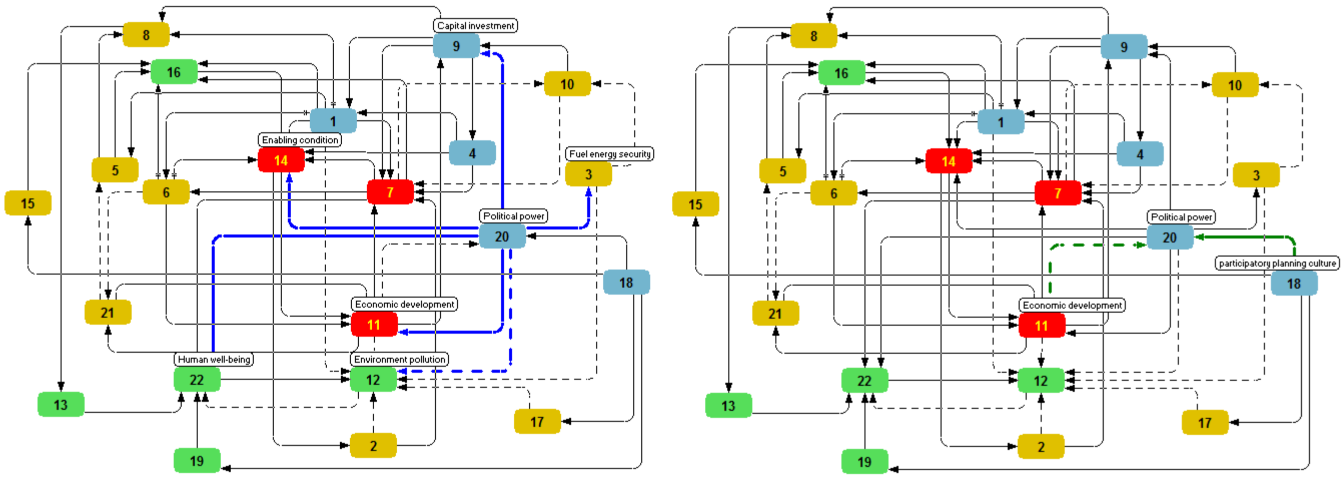

Figure 68: effect system of political power

The variable Political power (20) is a strong system change lever and influences the variables Fuel energy security (3), Investment capital (9), Economic development (11), Environment pollution (12), Enabling condition (14) and Human well being (22), whereas the Political power (20) is influenced by the variables Economic development (11) and Participatory planning culture (18) as shown in figure 68. The following can be seen from the effect system of Political power (20) in figure 68.

- $20 \rightarrow 3$ The external influence factor Political power (20) strongly influences the fuel economy and commitment to the development of self-reliant fuel source for mobility system development. The fossil fuel mostly dominates the share of fuel supply for mobility in the current state of the art mobility technology, which has created increased import dependency. On the other hand the hidden fuel import costs are politically structured in the form of tax subsidy schemes that are critical for the development of alternative fuel source. The reforms in the tax subsidy especially in energy economic are strongly influenced by the Political power (20). Strong and stable political support has the potential to shift the conventional fuel tax subsidy from the fossil fuel to alternatives fuel sources that are available and more yet to be known. Thus increase in the Political power (20) that supports the shift to alternative fuel source increases the Fuel energy security (3), which is an equal effect.
- $20 \rightarrow 9$ The availability of financial resources and human resources are the backbone for alternative mobility system development. Sourcing financial and human resources is strongly influenced by the political decision. Additionally the system that needs to be transformed requires political support for it

to be deployed. Strong and stable Political power (20) has the potential to strengthen development priorities that supports desired mobility system development. Therefore increase in Political power (20) proportionally increases the Investment capital (9) for alternative mobility system development, which is an equal effect.

- $20 \rightarrow 11$ The strength of Political power (20) has strong impact to initialize the development target and enable economic growth. Higher the political stability betters the chance for Economic development (11). Further if the strength of Political power (20) increases, it potentially stabilizes the planned development target. Thus the development of alternative mobility system is dependent on to the external factor Economic development (11), which is dependent on to political stability. The increase in Political power (20) increases the chance for Economic development (11) that potentially supports the mobility system development, which is an equal effect.
- $20 \rightarrow 12$ The political decision on protection of environment is an important condition for the development of alternative and environment resilient mobility system development. The political influence on Environment pollution (12) reduction has cascading effect on the development target and therefore the potential business model transition. Business model change will strongly influence the behaviour of people, which potentially decreases the Environment pollution (12). Higher the Political power (20) higher is the chance for environment resilient mobility system development that reduces the Environment pollution (12), which is an opposite effect.
- $20 \rightarrow 14$ The development of new system is dependent on to the availability of enabling environment, which is determined by social acceptability and economic viability. The level of acceptance and economic viability is strongly influenced by the political support for any changes. The desired mobility system development requires good Enabling condition (14) and social acceptance. They are strongly influenced by the political support especially on the reforms in laws and policy. Strong and stable Political power (20) has the potential to re-orient the existing laws and policy for their transition to new mobility system development. Thus increase in Political power (20) proportionally increases the Enabling condition (14), which is an equal effect.
- $20 \rightarrow 22$ The presence of stable political system indicates stable society who lives in greater degree of peace and fulfilled basic life requirements. The political decision on improving the quality of life further enhances the quality by improving all aspect of basic human needs. The desired mobility system development is part of quality life, which is strongly influenced by the stable political system. The development of alternative mobility system that will address the desire and wishes of the people for the movement of people and goods are important condition for basic life fulfilment, which is influenced by the existence of stable Political power (20). Therefore increase in Political power (20) that supports the desired mobility system development potentially increases the Human well being (22), which is an equal effect.

- $11 \rightarrow 20$ The growth of economy is strongly influenced by de-regulation and competitiveness. However de-growth of current economic power is not easily influenced by the political system unless the industries are willing to political norms. The change process is often time accompanied with risk factor and high degree of uncertainty, which leads to lack of people's participation for alternative political agenda that requires massive change. Therefore stronger the economic power weaker is the political commitment for change. Hence uncontrolled Economic development (11) potentially weakens the Political power (20), which is an opposite effect.
- $18 \rightarrow 20$ The political decision is influenced by willingness of the people. The expression of people is best understood by including those involved in the system directly and indirectly to define their own need. Hence Participatory planning culture (18) for development planning strongly influences the Political power (20) that supports alternative development. Currently need of consumer is influenced by industrial power, which can only be reformed by the consumer decision. Increase in Participatory planning culture (18) potentially increases the consumer's decision, which has the potential to increase the Political power (20) that supports the need of desired mobility system development. Hence increase in Participatory planning culture (18) increases the Political power (20), which is an equal effect.

Effect system of rural urban dynamic

The variable Rural urban dynamic (21) influences of mobility system development from outside. The variable Rural urban dynamic (21) is positioned closer to neutral zone in the variable's systemic role in figure 6 in section 3.1.3.

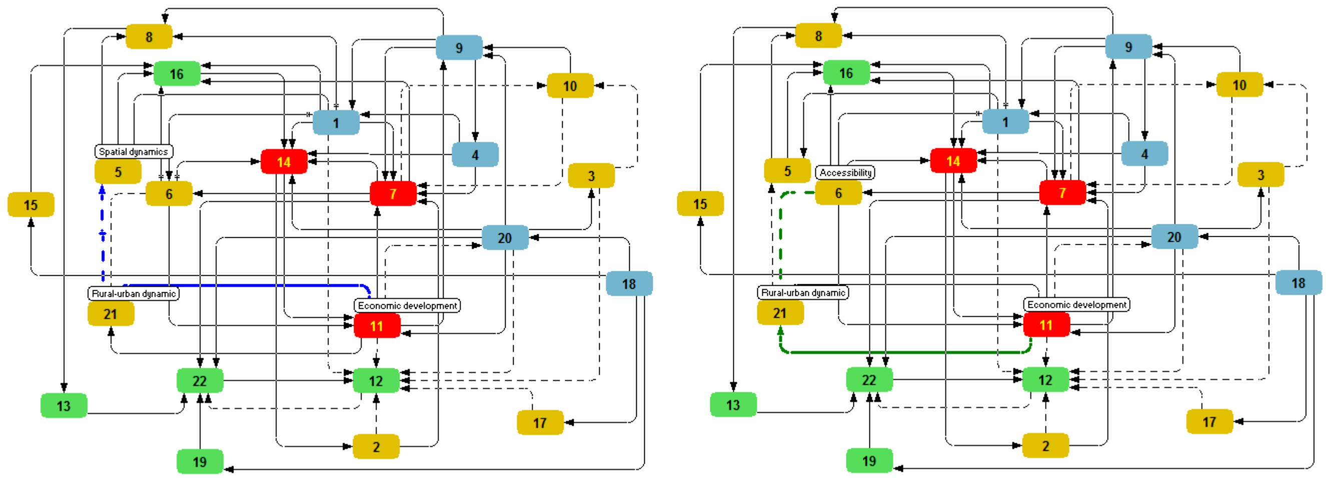

Figure 69: effect system of rural urban dynamic

The variable Rural urban dynamic (21) influences Spatial dynamic (5) and Economic development (11), whereas the variable Rural urban dynamic (21) is influenced by Accessibility (6) and Economic development (11).The following can be seen from the effect system of Rural urban dynamic (21) from figure 69.

- $21 \rightarrow 5$ Rural urban migration is influenced by various reasons such as being war victim, being natural calamities victim, and lack of facilities in rural areas. Rural-urban migration causes space congestion. Land use change in rural and urban areas is a common consequence of the migration, which has dual impact. Increase Rural-urban dynamic (21) increases mobility demand where people migrate that tends influence Spatial dynamic (5) of the region. In the current situation it is mostly seen that urban areas are congested and in addressing the need for free mobility, infrastructure are further developed. This causes the decrease in limited urban space. Thus increase in Rural-urban dynamic (21) decreases the availability of space and therefore the Spatial dynamic (5), which is an opposite effect.
- $21 \rightarrow 11$ The urbanization trend is influenced by the Economic development (11) in both rural and urban environment. Uncontrolled migration has the potentials for centralized and linear economic model development, which causes unidirectional movement of people and goods to urban environment. Hence increase in Rural-urban dynamic (21) proportionally increases the Economic development (11), which is oriented to centralized and linear system leading to higher requirement of motorization, which is an equal effect.

- $6 \rightarrow 21$ Although the Rural-urban dynamic (21) has the potential for urbanization of semi-urban region, they are strongly influenced by the mobility access for different service requirement. Therefore increased Accessibility (6) potentially decreases the urbanization trend. The Accessibility (6) also influences the regional economic value addition that localizes the mobility need of both people and good movement. Therefore increasing the Accessibility (6) has the potentials to localize the Rural-urban dynamic (21) thereby decreasing the demand for motorized mobility behaviour of people. Thus increasing the Accessibility (6) potentially decreases the Rural-urban dynamic (21), which is an opposite effect.
- $11 \rightarrow 21$ The linear economic growth potentially increases the Rural-urban dynamic (21), where the current trend of urbanization continues if not controlled. Uncontrolled and centralized economy increases the availability jobs and other life quality requirement that is urban centric, which further accumulates the population in region where economic growth is centralized. The centralized growth model increases the Rural-urban dynamic (21). Thus increase in Economic development (11) if not oriented properly will increase the Rural-urban dynamic (21), which is an equal effect.

Effect system of Human-wellbeing

The variable Human wellbeing (22) expresses the mobility need to fulfil life quality, which is important system indicator. The variable Human wellbeing (22) is positioned in the reactive region in the variable's systemic role in figure 6 in section 3.1.3.

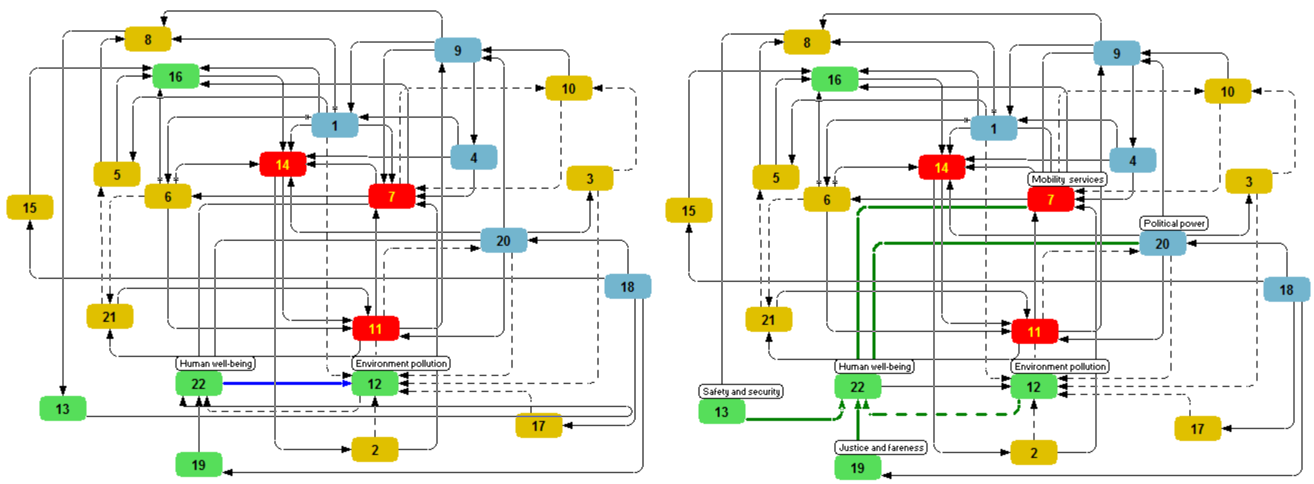

Figure 70: effect system of human well being

The variable Human wellbeing (22) addresses the need to define the right goal for mobility system development and the desired mobility system that expresses the dream and wishes of the mobility product/service consumer. Human wellbeing (22) influences Environment pollution (12) where as it is influenced by Mobility service (7), Environment pollution (12), Safety and security (13), Justice and fairness (19) and Political power (20). The following can be seen from the effect system of Human wellbeing (22) as shown in figure 70.

- $22 \rightarrow 12$ Human wellbeing (22) is an aspiration that expresses the need for better quality of life. The basic philosophy of good quality life is influenced by those conditions that fulfil the need of the body and the desire of the mind. They fundamentally depend on individual, community, society, organization and built environment. Mobility system is among others built environments that influence the life quality. The need of built environment for movement function to fulfil the aspiration of people is unlimited, which directly influence limited natural capital the environment. Thus increasing Human wellbeing (22) by promoting uncontrolled desire and wishes to enable movement function increases the consumerism behaviour especially the motorization trend, which causes exploitation of the natural capital the environment. Hence the motorization trend that increases the consumerism habit of people in the pretext of increasing Human wellbeing (22) has the potential to increase Environment pollution (12), which is an equal effect.

- $7 \rightarrow 22$ While the Mobility service (7) influences the life quality, they strongly depend on the limit condition and the desired mobility need by the consumer. Therefore enabling Mobility service (7) by defining the systemic goal that addresses Human wellbeing (22) is critical. Mobility service (7) has the potential to take any form if not controlled leading to behaviour change of the consumer for the basic movement function that will impact quality of life judgement. Thus increase in Mobility service (7) in general increases the Human wellbeing (22), which is an equal effect.
- $12 \rightarrow 22$ The availability of good quality, air, water and land will have direct influence on the Human wellbeing (22). The need for better quality life however depends on basic requirement for movement activities, which will fulfil all the daily needs. On the other hand increasing dependency on daily activities supported by motorization, which is based on ownership culture as status symbol is misleading judgement. The consequence of increased motorization potentially increases the Environment pollution (12). Thus increase in Environment pollution (12) decreases Human wellbeing (22), which is an opposite effect.
- $13 \rightarrow 22$ Safety and security (13) has direct influence on the desired mobility system development and therefore Human wellbeing (22). Enabling mobility system with the inclusion of early precautionary measures and human error avoidance increases the level of satisfaction. Satisfaction enables the physiological aspect of quality of life. Thus increase in Safety and security (13) increases the Human wellbeing (22) by fulfilling the consumer's aspiration to be more satisfied to avail mobility services, which is safe and secure. Hence increase in Safety and security (13) proportionally increases the Human wellbeing (22), which is an equal effect.
- $19 \rightarrow 22$ Justice and fairness (19) addresses equality, which defines quality of life and therefore Human wellbeing (22). Inclusion of Justice and fairness (19) for mobility system design addresses the requirement of different income categories, population group, and service choice by all involved in the system. Therefore defining the goal to improve life quality is important condition for Human wellbeing (22) improvement, which will have to be based on equal distribution of mobility need to all population categories in contextual basis. Hence increase in Justice and fairness (19) has the potential to increase Human wellbeing (22), which is an equal effect.
- $20 \rightarrow 22$ The external influence the Political power (20) is critical for the control of the system and their functioning, which is also applicable for mobility system development and therefore Human wellbeing (22). Peace, prosperity, economic growth, freedom of expression is key requirement for innovation and system transition to desired need. Stable political system strongly influences the quality of life. Aligning the political goal to consider Human wellbeing (22) is therefore important system change lever, which is applicable to the development of desired mobility system. Thus increasing the

strength of Political power (20) potentially supplements the desired mobility system development that enhances Human wellbeing (22) condition, which is an equal effect.

The positive feedback effect path $1 \rightarrow 5$

The feedback effect $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple alternative paths in the effect system of variables Accessibility (6), Economic development (11) and Enabling condition (14) as shown in figure 71.

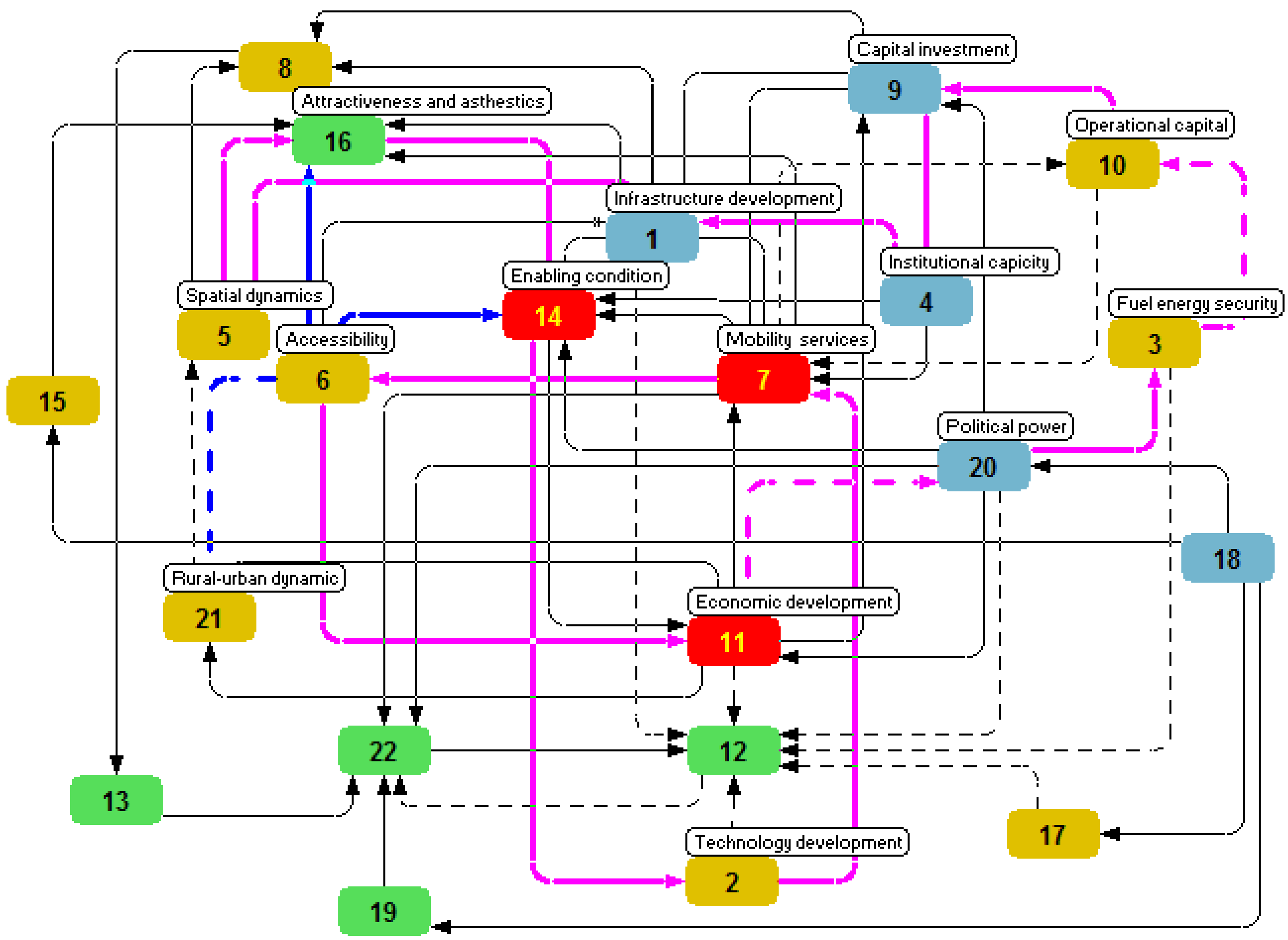

Figure 71: Feedback path deviation in Accessibility

a. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$

j. $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 1$

The feedback effect $1 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows 10 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore, the intervention on any one of the variables in the system leads to either growth or de-growth of mobility system.

The feedback-effects a, b, e, f, g and h from the above list shows it is a decreasing effect due to the presence of even number of negative effects, where the re-enforcing effect of de-growth can be seen from these feedback effect. Therefore, the system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. The feedback effect c, d, i, and j from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effect. Therefore, system can be initialized from these feedback effects on a contextual basis for their growth development. However, it is important to note if the goal for mobility system is to slow down their development then the feedback-effect path a, b, e, f, g and h are very useful. Therefore, it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for the de-growth development is determined by Fuel-energy-security (3), Accessibility (6), Operation capital (10), Economic development (11),Political power (20) and Rural urban dynamic (21) as a strong negative influencing effect from the effect system of the mobility system from the above feedback effect list.

The positive feedback effect path $1 \rightarrow 6$

The feedback effect $1 \rightarrow 6 \rightarrow 11 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple alternative paths in the effect system of variables Accessibility (6), Economic development (11), Enabling condition (14) and Rural-urban dynamic (21) as shown in figure 72. In figure 72 only one effect of Economic development (11) is shown as an example to avoid visual complexity.

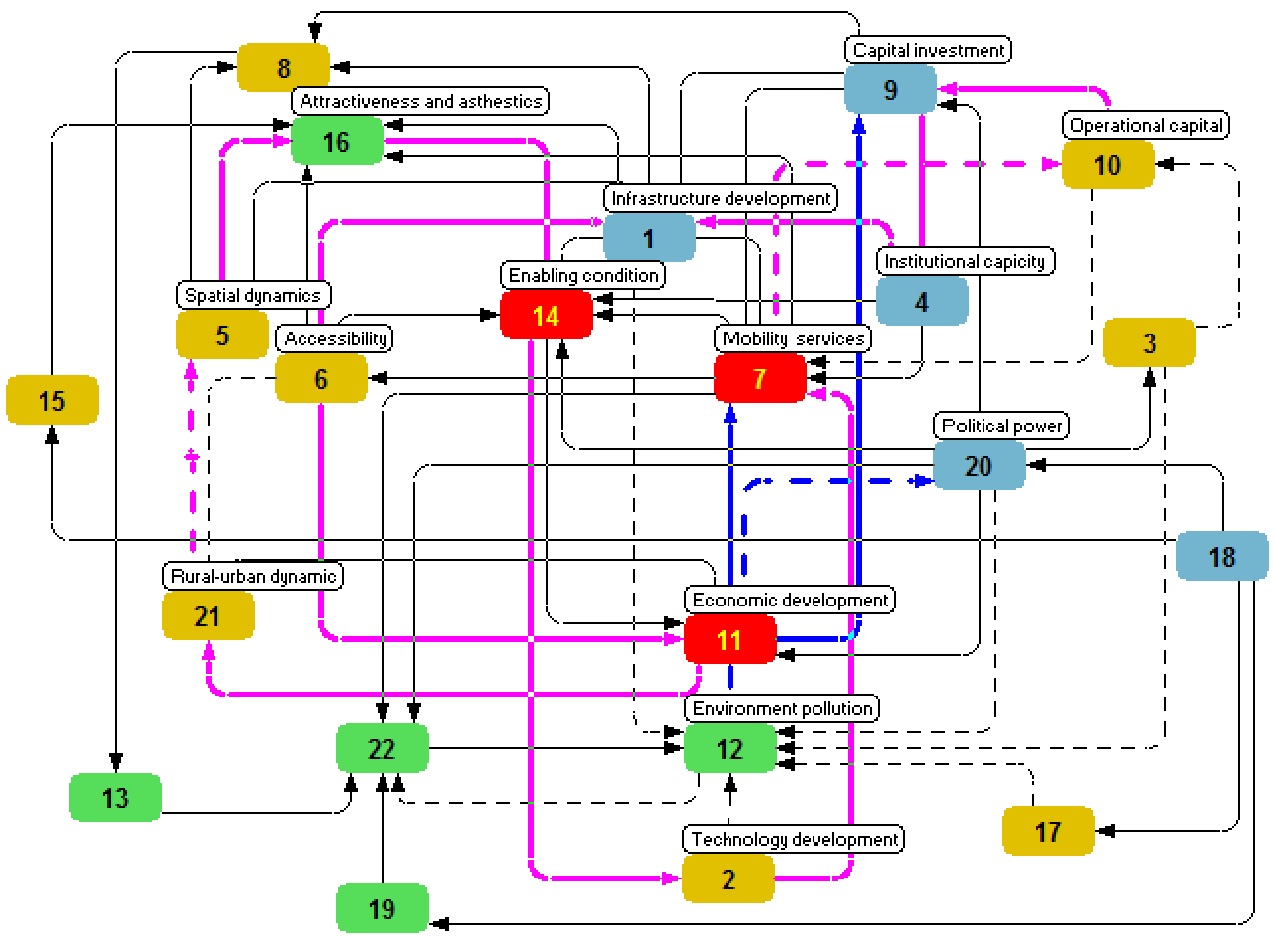

Figure 72: Feedback path deviation in Economic development

a. $1 \rightarrow 6 \rightarrow 11 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$

b. $1 \rightarrow 6 \rightarrow 11 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$

c. $1 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$

d. $1 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$

e. $1 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$

f. $1 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$

g. $1 \to 6 \to 11 \to 9 \to 4 \to 1$

h. $1 \to 6 \to 11 \to 9 \to 1$

i. $1 \to 6 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$

j. $1 \to 6 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$

k. $1 \to 6 \to 14 \to 11 \to 9 \to 4 \to 1$

l. $1 \to 6 \to 14 \to 11 \to 9 \to 1$

m. $1 \to 6 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$

n. $1 \to 6 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$

o. $1 \to 6 \to 16 \to 14 \to 11 \to 9 \to 4 \to 1$

p. $1 \to 6 \to 16 \to 14 \to 11 \to 9 \to 1$

q. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$

r. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$

s. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 9 \to 4 \to 1$

t. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 9 \to 1$

u. $1 \to 6 \to 21 \to 11 \to 7 \to 10 \to 9 \to 4 \to 1$

v. $1 \to 6 \to 21 \to 11 \to 7 \to 10 \to 9 \to 1$

w. $1 \to 6 \to 21 \to 11 \to 20 \to 9 \to 4 \to 1$

x. $1 \to 6 \to 21 \to 11 \to 20 \to 9 \to 1$

The feedback effect $1 \to 6 \to 11 \to 21 \to 5 \to 16 \to 14 \to 2 \to 7 \to 10 \to 9 \to 4 \to 1$ shows 24 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore, the intervention on any one of the variables in the system leads to either growth or de-growth of mobility system.

The feedback-effects a, b, c, d, e, f, i, j, m, n, q, r, s, t, u, v, w and x from the above list shows it is a decreasing effect due to the presence of even number of negative effects, where the re-enforcing effect of de-growth can be seen from these feedback effect. Therefore, the system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. The feedback effect g, h, k, l, o and p from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effect. Therefore, system can be initialized from these feedback effects on a contextual basis for their growth development. However, it is important to note if the vision for mobility system is to slow down their development then the feedback-effect path a, b, c, d, e, f, i, j, m, n, q, r, u and v are very useful. Therefore, it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for de-growth development is determined by Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural urban dynamic (21) as a strong negative influencing effect.

The positive feedback effect path $1 \rightarrow 7$

The feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple alternative paths in the effect system of variables Accessibility (6), Economic development (11), Enabling condition (14), Political power (20) and Rural-urban dynamic (21) as shown in figure 73. The effect of variable Accessibility (6) is only shown as an example to avoid the visual complexity.

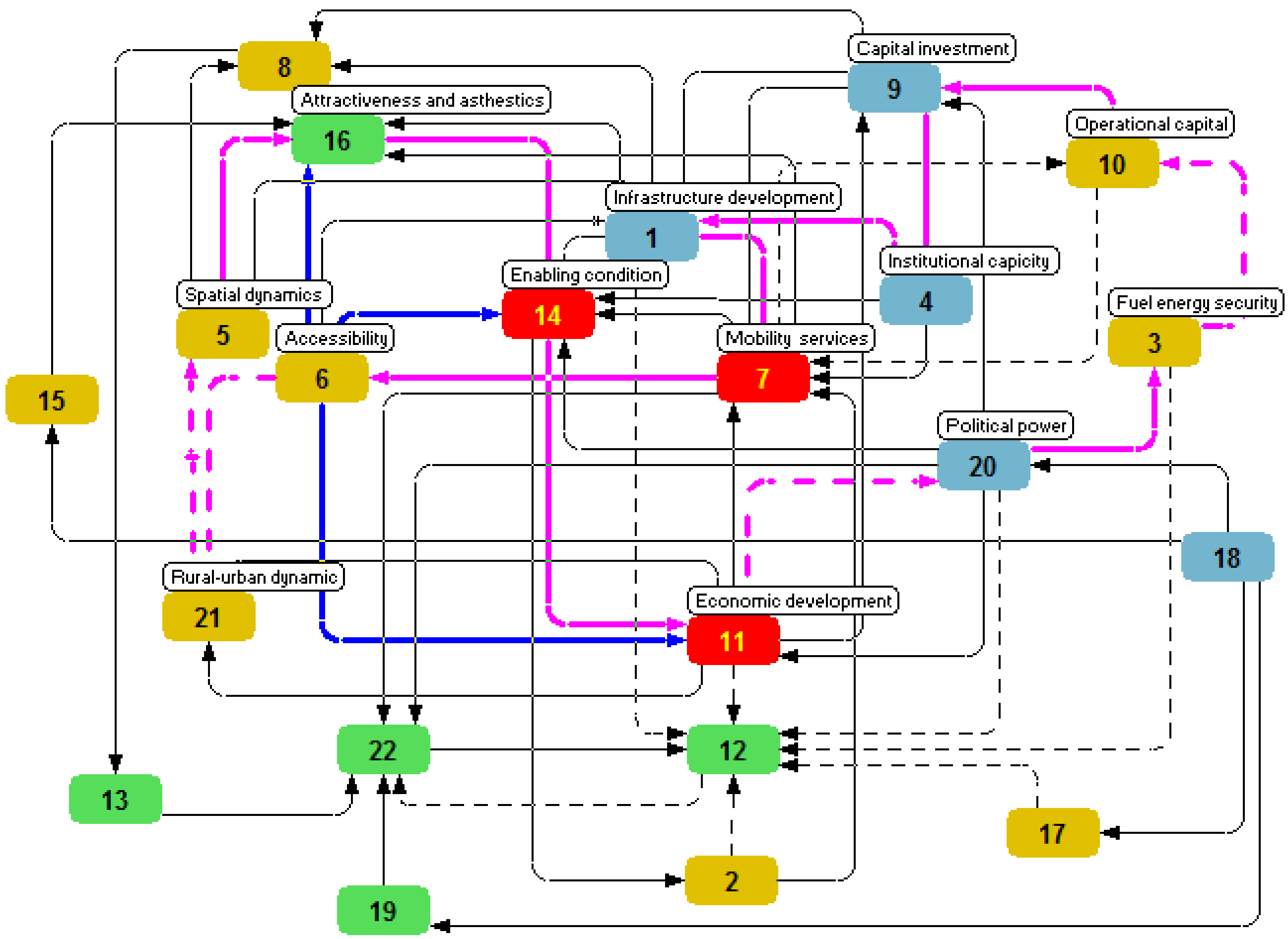

Figure 73: Feedback path deviation in Accessibility

a. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 1$

i. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
j. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
k. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
l. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 1$
m. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
n. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
o. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
p. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 1$
q. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
r. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
s. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
t. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
u. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
v. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 1$
w. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
x. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
y. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
z. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 1$

The feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows 26 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore the intervention on any one of the variables in the system leads to growth or de-growth of mobility system.

The feedback-effects a, b, e, f, i, j, m, n, o, p, q, r, s, t, w and x from the above list shows it is a decreasing effect due to the presence of even number of negative effect, where the re-enforcing effect of de-growth can be seen from these feedback effect. Therefore, the system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. The feedback effect c, d, g, h, k, l, u, v, y and z from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effect. Therefore, system can be initialized from these feedback effects on a contextual basis for their growth development. However, it is important to note if the vision for mobility system is to slow down their development then the feedback-effect path a, b, e, f, i, j, m, n, o, p, q, r, s, t, w and x are very useful. Therefore, it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for the de-growth development is determined by Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as a strong negative influencing effect from the effect system of the mobility system from the above feedback effect list.

The positive feedback effect path $1 \rightarrow 14$

The feedback effect $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple alternative paths in the effect system of variables Accessibility (6), Economic development (11) and Enabling condition (14), as shown in figure 74.

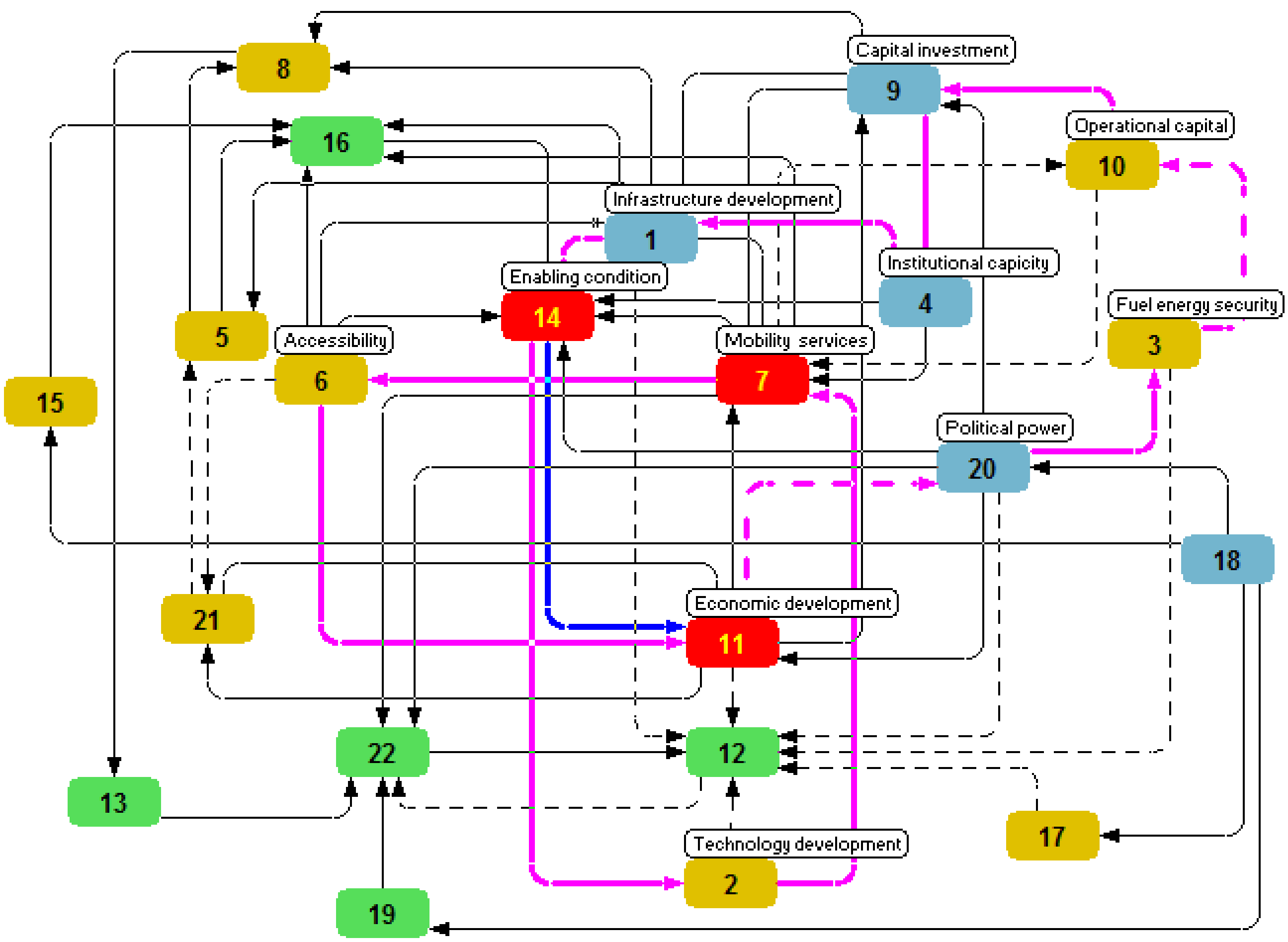

Figure 74: Feedback effect deviation in Enabling Condition

a. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$

j. $1 \to 14 \to 11 \to 9 \to 1$

The feedback effect $1 \to 14 \to 2 \to 7 \to 6 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows 10 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore the intervention on any one of the variables in the system leads to either growth or de-growth of mobility system.

The feedback-effects a, b, e, f, g and h from the above list shows it is a decreasing effect due to the presence of even number of negative effect, where the re-enforcing effect of de-growth can be seen from these feedback effect. Therefore the system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. The feedback effect c, d, i, and j from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effect. Therefore system can be initialized from these feedback effects on a contextual basis for their growth. However it is important to note if the vision for mobility system is to slow down their development then the feedback-effect path a, b, e, f, g and h are very useful. Therefore it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for the growth and de-growth development is determined by Fuel energysecurity (3), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural urban dynamic (21) as a strong negative influencing effect from the effect system of the mobility system from the above feedback effect list.

The positive feedback effect path $1 \rightarrow 16$

The feedback effect $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple alternative paths in the effect system of variables Accessibility (6), Economic development (11) and Enabling condition (14), as shown in figure 75.

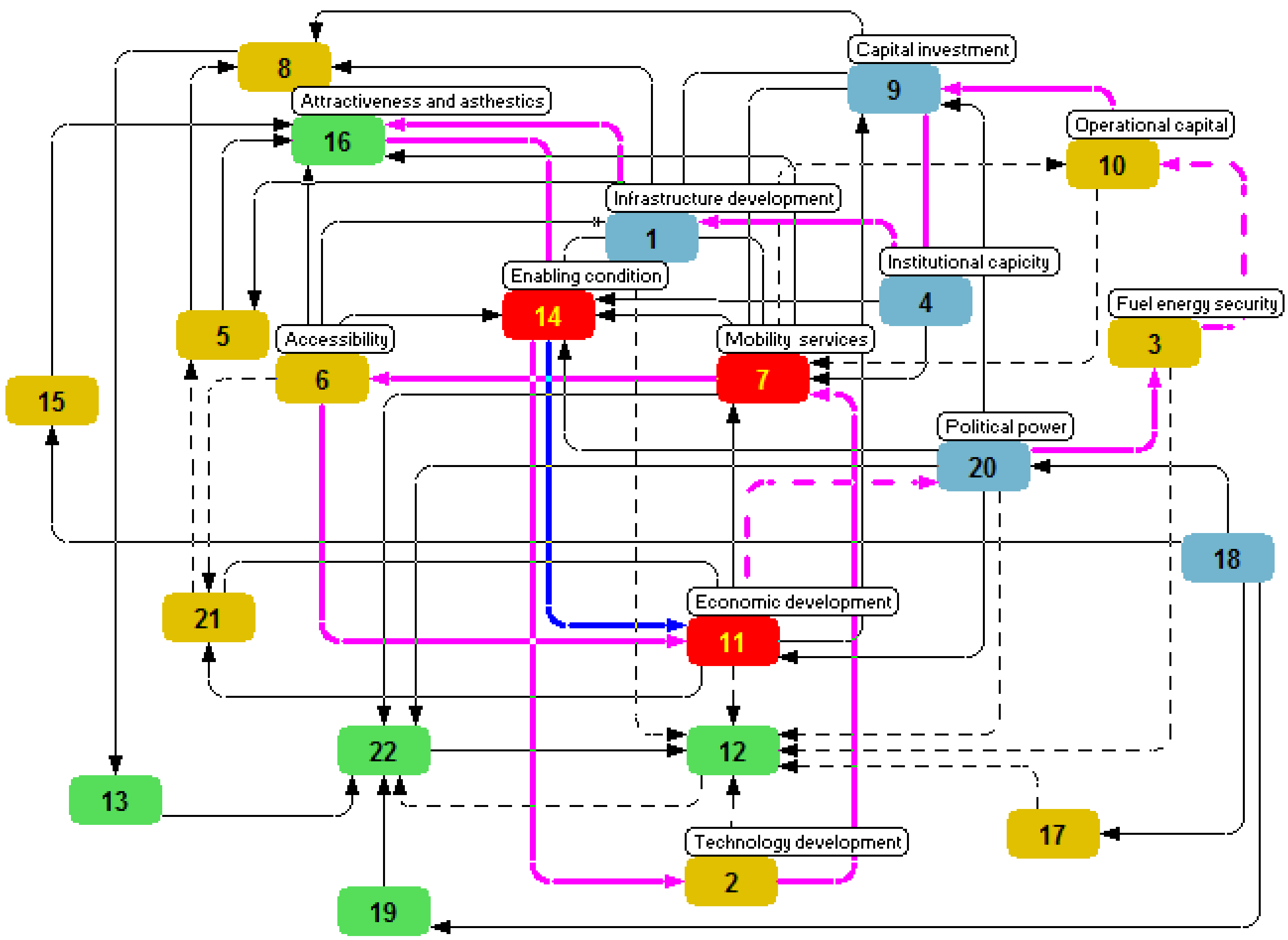

Figure 75: Feedback path deviation in Enabling Condition

a. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$

j. $1 \to 16 \to 14 \to 11 \to 9 \to 1$

The feedback effect $1 \to 16 \to 14 \to 2 \to 7 \to 6 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows 10 alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore the intervention on any one of the variables in the system leads to either growth or de-growth of the mobility system.

The feedback-effects a, b, e, f, g and h from the above list shows it is a decreasing effect due to the presence of even number of negative effect, where the re-enforcing effect of de-growth can be seen from these feedback effect. Therefore the system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. The feedback effect c, d, i, and j from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effect. Therefore system can be initialized from these feedback effects on a contextual basis for their growth development. However it is important to note if the vision for mobility system is to slow down their development then the feedback-effect path a, b, e, f, g and h are very useful. Therefore it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for the growth and de-growth development is determined by Fuel energy security (3), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural urban dynamic (21) as a strong negative influencing effect from the effect system of the mobility system from the above feedback effect list.

The positive feedback effect path $2 \rightarrow 7$

The feedback effect $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$ shows multiple alternative paths in the effect system of variables Mobility service (7) and Accessibility (6) as shown in figure 76.

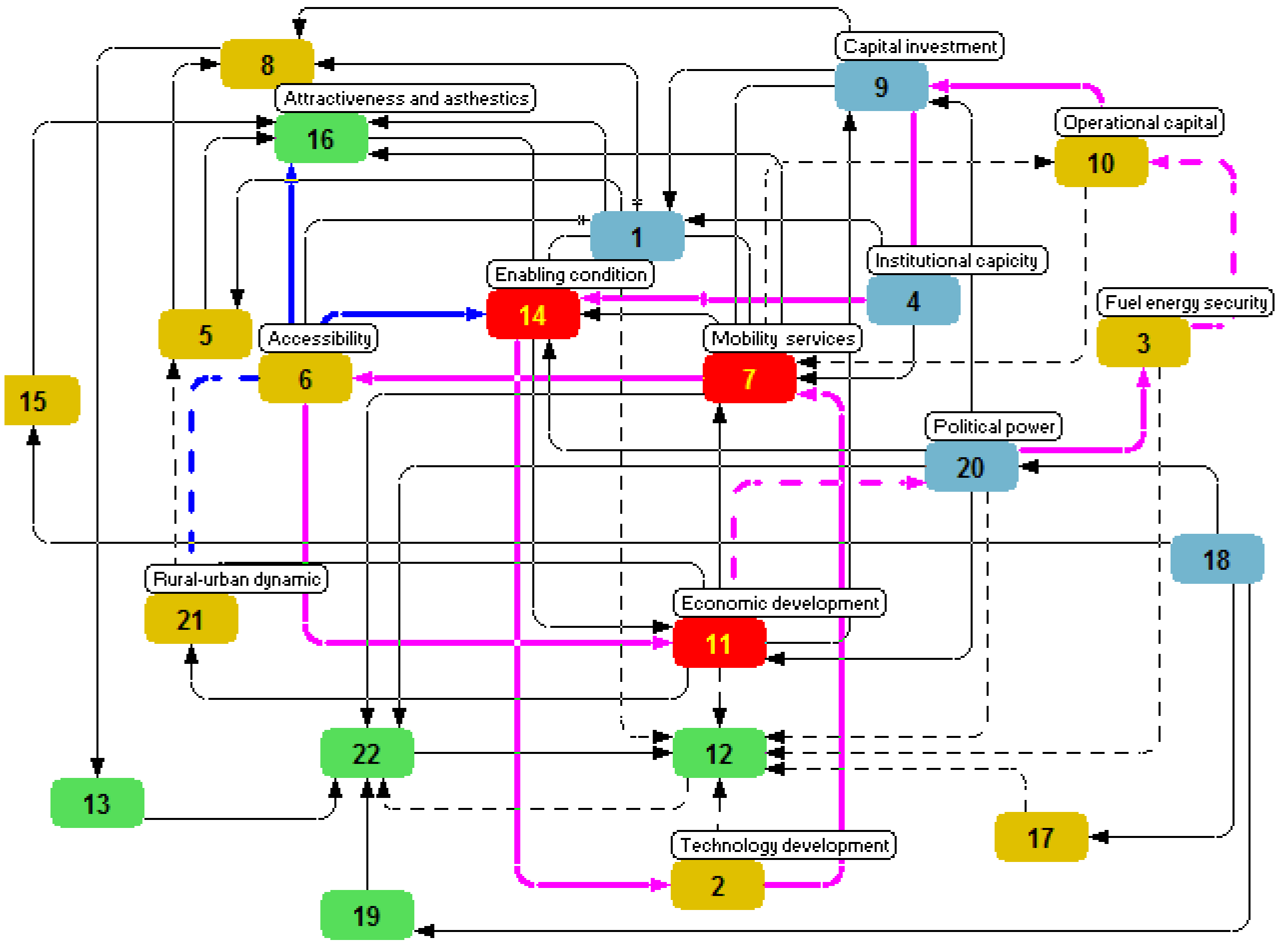

Figure 76: Feedback path deviation at Accessibility

a. $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
b. $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
c. $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
d. $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 14 \rightarrow 2$
e. $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2$
f. $2 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 2$
g. $2 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 2$
h. $2 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 2$
i. $2 \rightarrow 7 \rightarrow 14 \rightarrow 2$

The feedback effect $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$ shows 9 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. The intervention on any one of the variables in the system leads to either growth or de-growth development.

The feedback-effect a, c and d from the above list shows it is a decreasing effect due to the presence of even number of negative effect, where the re-enforcing effect of de-growth can be seen from these feedback effect. Therefore the system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. The feedback effect b, e, f, g, h and i from the above list shows it is an increasing effect, where the re-enforcing effect of growth can be seen from these feedback effect. Therefore system can be initialized from these feedback effects on a contextual basis for their growth development. However it is important to note if the vision for mobility system is to slow down their development then the feedback-effect path a, c and d is very useful. Therefore it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for the growth and de-growth development is determined by Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as a strong negative influencing effect from the effect system of the mobility system from the above feedback effect list.

The positive feedback effect path $3 \rightarrow 10$

The feedback effect $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$ shows multiple alternative paths in the effect system of variables Mobility service (7) and Capital investment (9) as shown in figure 77.

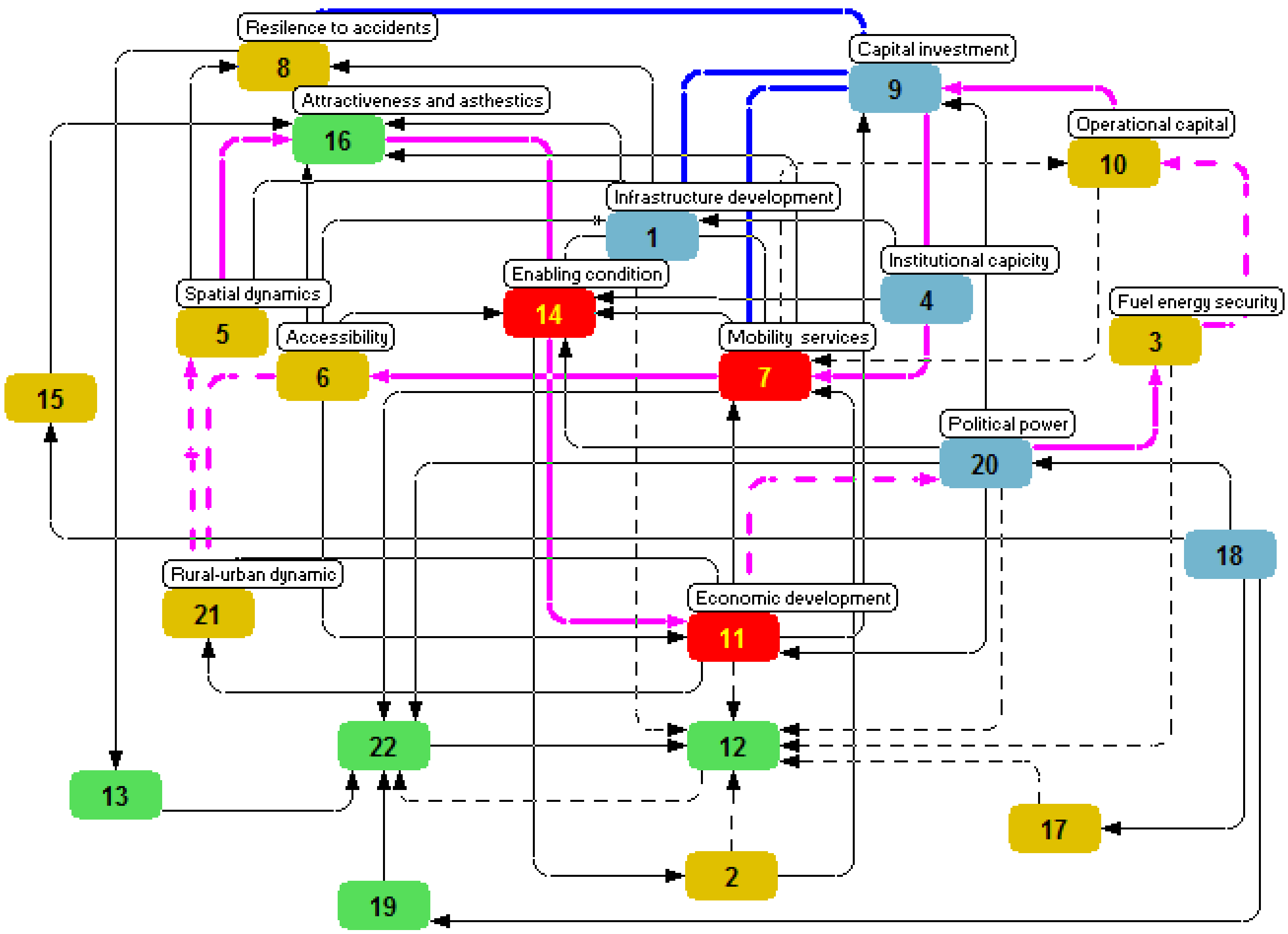

Figure 77: Feedback effect deviation in Capital Investment

a. $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3$
b. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
c. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
d. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
e. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3$
f. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
g. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
h. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
i. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$

j. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
k. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
l. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
m. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
n. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3$

The feedback effect $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$ shows 14 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. The intervention on any one of the variables in the system leads to the system de-growth from the above list of feedback effect. The feedback-effect 'a' to 'n' from the above list shows it is a decreasing effect due to the presence of even number of negative effect, where the re-enforcing effect of de-growth can be seen from these feedback effect. The system initialization for growth from this feedback effect is useless for future scenario development from this feedback effects. Therefore it depends on the choice of the feedback effect path as desired by the decision maker and the need of the system user. The important system control variable for the de-growth development is determined by Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Operation capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as a strong negative influencing effect from the effect system of the mobility system from the above feedback effect list. Therefore these feedback effects are important feedback for system control measure for de-growth development unlike the previous feedback effect path developed.

The positive feedback effect path $4 \rightarrow 7$

The feedback effect $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$ shows multiple alternative paths in the effect system of variables Mobility service (7) and Rural-urban dynamic (21) as shown in figure 78.

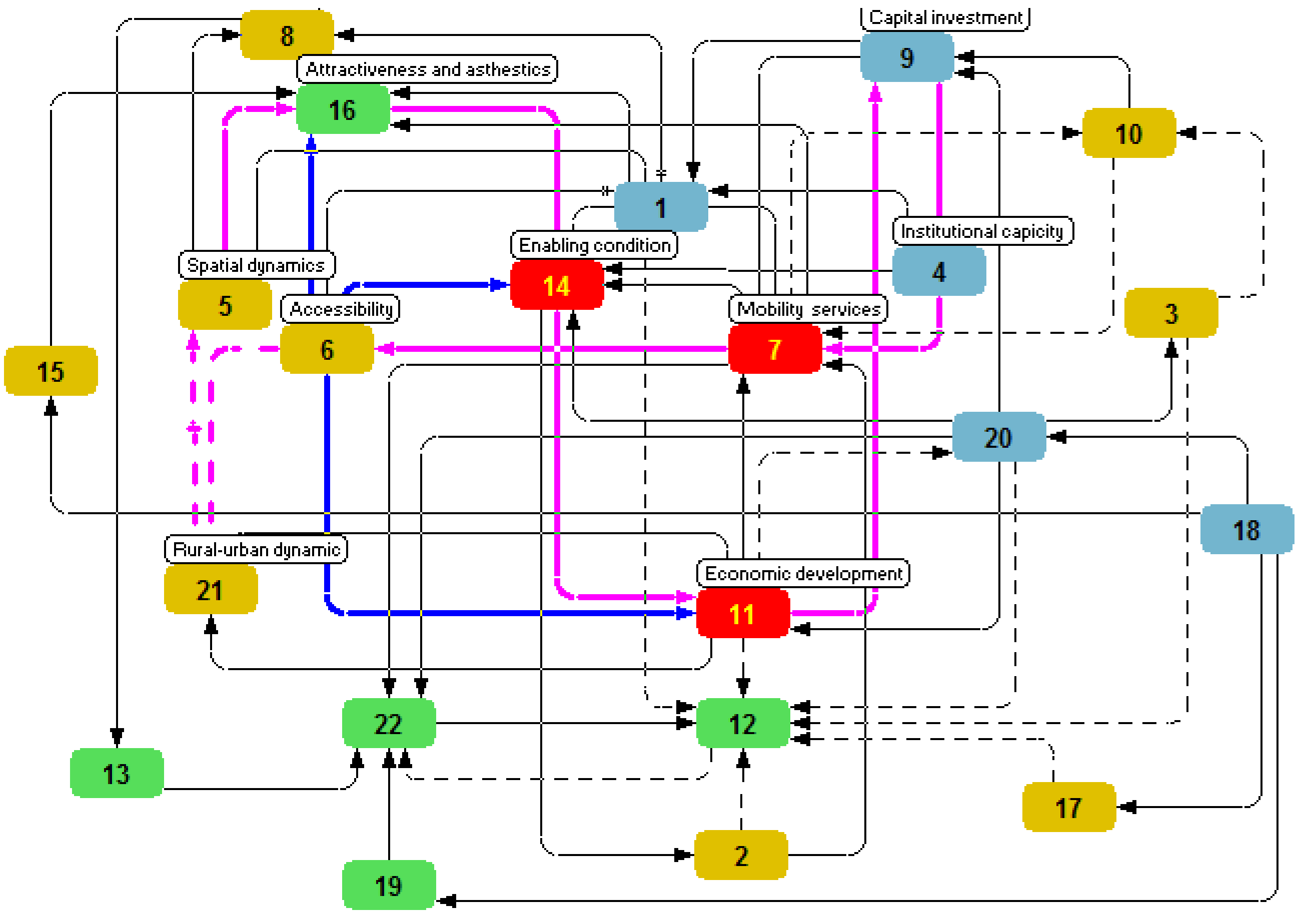

Figure 78: Feedback effect deviation in Mobility Service

a. $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$
b. $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4$
c. $4 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$
d. $4 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$
e. $4 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 9 \rightarrow 4$
f. $4 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$
g. $4 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$
h. $4 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$

The feedback effect $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 4$ shows 8 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system vision for their future development. Therefore the intervention on any one of the variables in the system leads to the system growth or de-growth potentials from above feedback list. The feedback effect a and b from the above list shows it a decreasing effect due to the presence of even number of negative effect. Therefore system growth scenario developments from these feedback effects are useless. The feedback effect c, d, e, f, g and h show the effect is an increasing effect which can be used as future scenario of growth potentials. However the variable a and b from the above lists are useful for system if the vision is to enable de-growth development. The control variable for de-growth development are Spatial dynamic (5), Accessibility (6), Economic development (11) and Political power (20).

The positive feedback effect path $5 \to 16$

The feedback effect $5 \to 16 \to 14 \to 11 \to 9 \to 7 \to 6 \to 21 \to 5$ shows multiple alternative paths in the effect system of variables Economic development (11) as shown in figure 79.

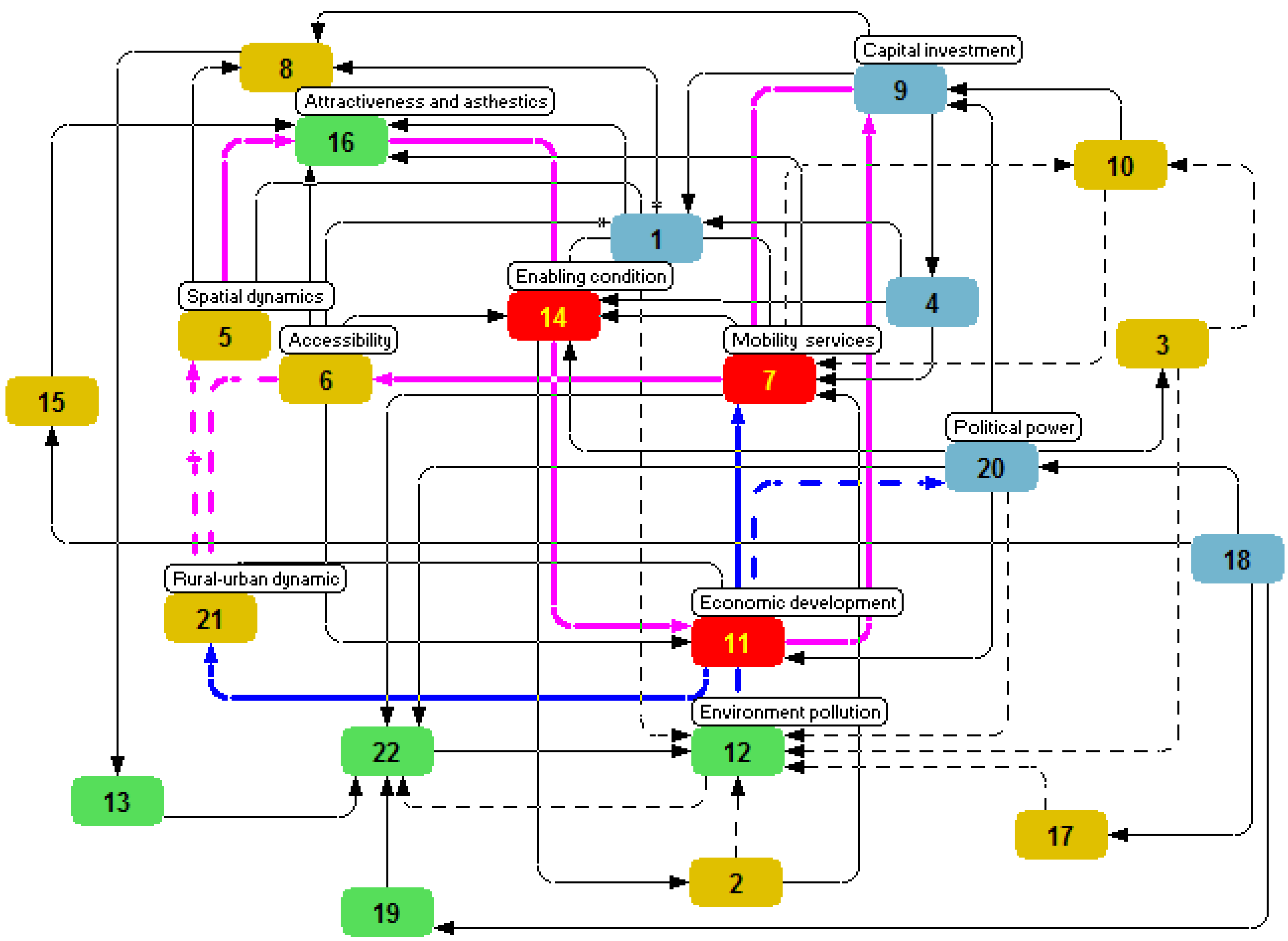

Figure 79: Feedback effect deviation in Economic Development

a. $5 \to 16 \to 14 \to 11 \to 9 \to 7 \to 6 \to 21 \to 5$
b. $5 \to 16 \to 14 \to 11 \to 7 \to 6 \to 21 \to 5$

The feedback effect $5 \to 16 \to 14 \to 11 \to 9 \to 7 \to 6 \to 21 \to 5$ shows 2 different alternative feedback effects, which can initialize de-growth of the system on a contextual basis depending on the mobility system vision for their future development. Therefore intervention on any one of the variables in the system leads to de-growth potential for the future scenario development depending on the desire of system planner and user.

The positive feedback effect path at node $6 \rightarrow$

The effect system of the variable Accessibility (6) shows multiple alternative paths in the effect system of variables Economic development (11) as shown in figure 80.

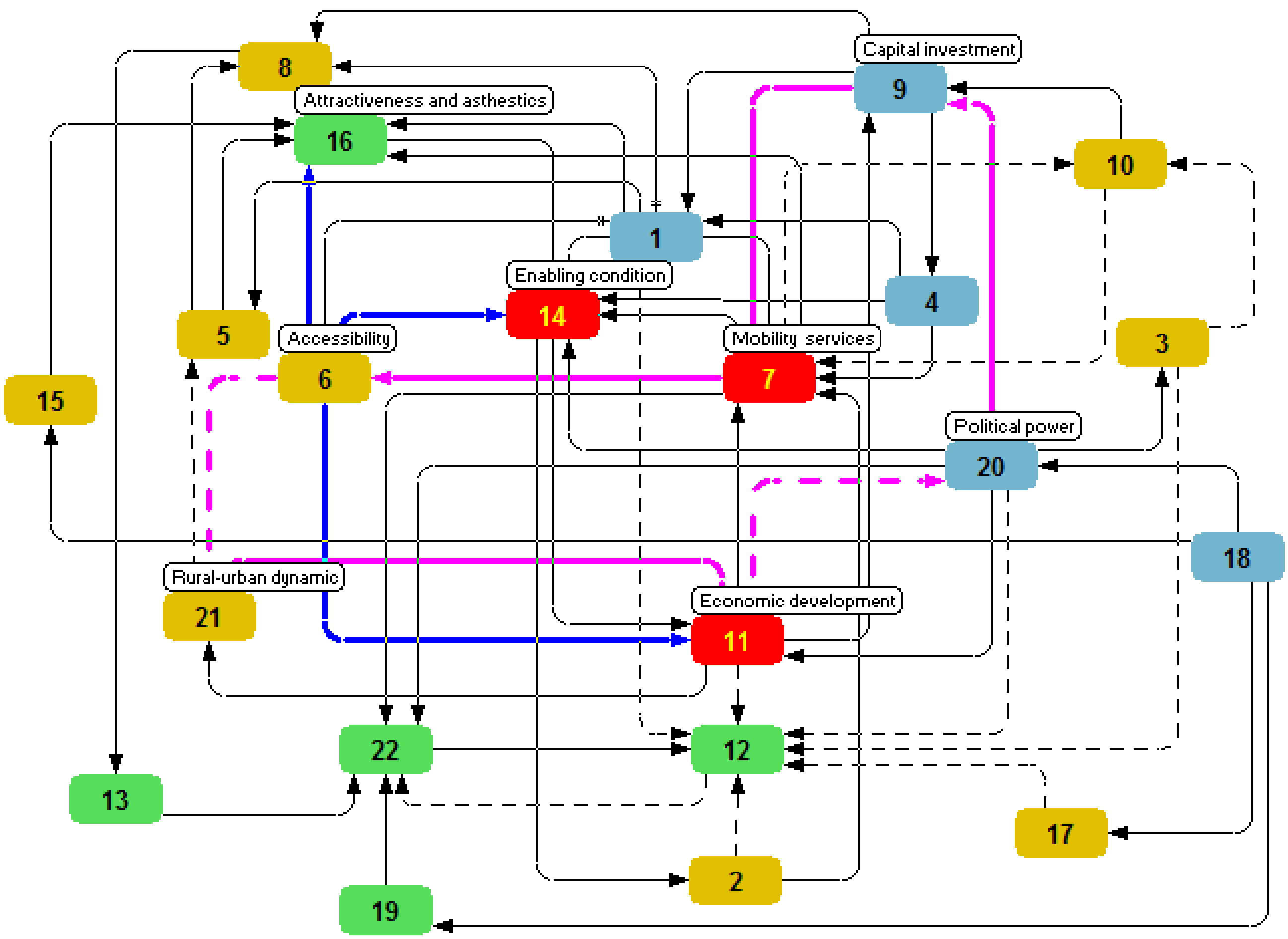

Figure 80: Feedback effect deviation in Accessibility

a. $6 \rightarrow 11 \rightarrow 7 \rightarrow 6$
b. $6 \rightarrow 11 \rightarrow 9 \rightarrow 7 \rightarrow 6$
c. $6 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7 \rightarrow 6$
d. $6 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 6$
e. $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7 \rightarrow 6$
f. $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 6$
g. $6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$

The feedback effects a, b, c, d, e, f shows it is an increasing effect, which can initialize the system on a contextual basis depending on the mobility system vision for their future development, where are feedback effect g show it a decreasing effect for de-growth development.

The positive feedback effect path at node $7 \rightarrow$

The effect system of the variable Mobility service (7) shows multiple alternative paths in the effect system of variables Economic development (11) as shown in figure 81.

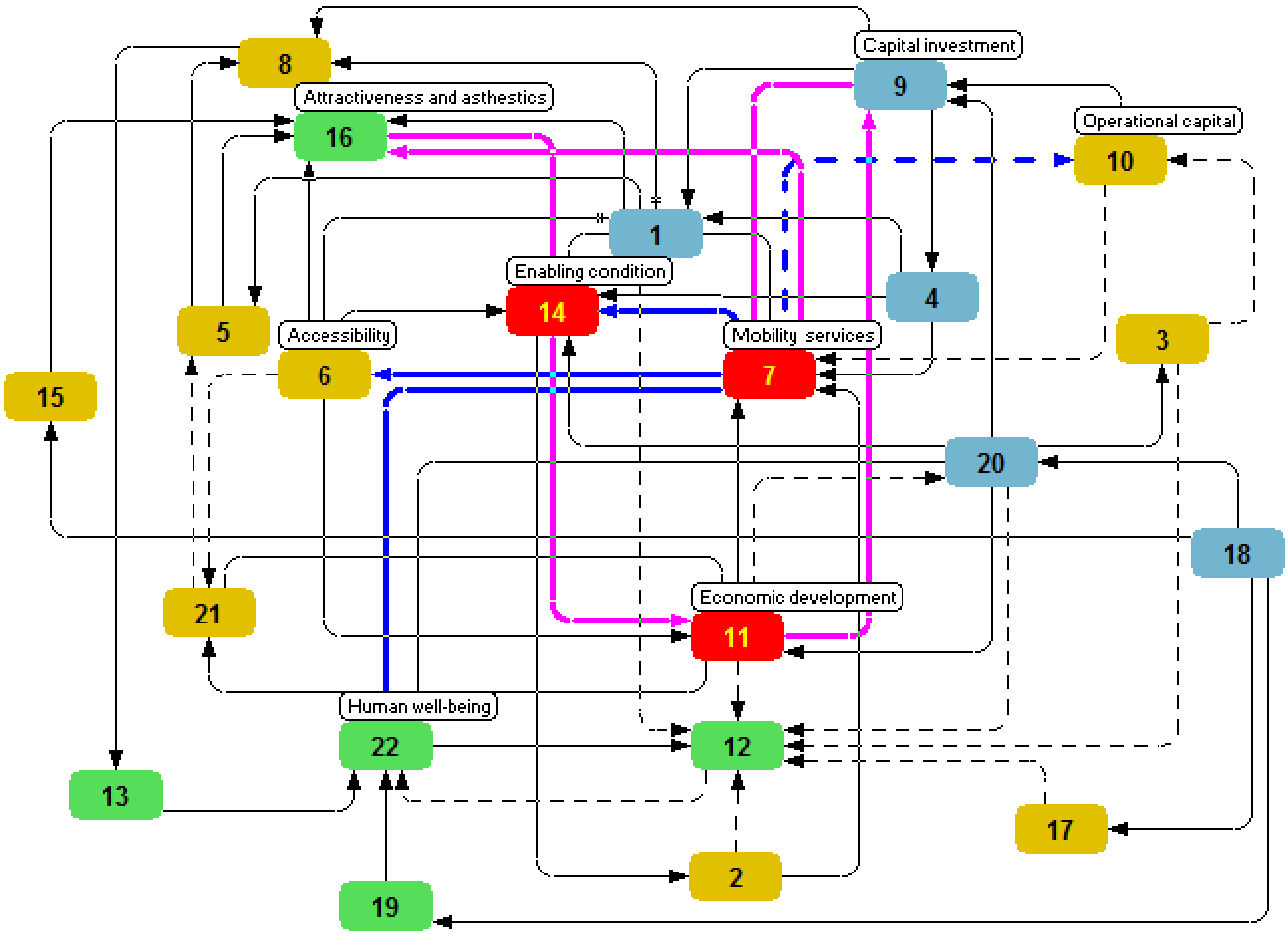

Figure 81: Feedback path deviation in Mobility Service

a. $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7$
b. $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 7$
c. $7 \rightarrow 14 \rightarrow 11 \rightarrow 9 \rightarrow 7$
d. $7 \rightarrow 14 \rightarrow 11 \rightarrow 7$

The effect system of Mobility service (7) shows 4 different alternative feedback effects, which can initialize the system on a contextual basis depending on the mobility system goal for their future development. Therefore the intervention on any one of the variables in the system leads to growth potentials for future scenario development.

The negative feedback effect path $1 \to 5$

The feedback effect $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows multiple paths in the effect system of the variables Accessibility (6), Economic development (11) and Enabling condition (14), as shown in figure 82. The effect system of Enabling condition (14) is only shown in the figure 82 to avoid the visual complexity.

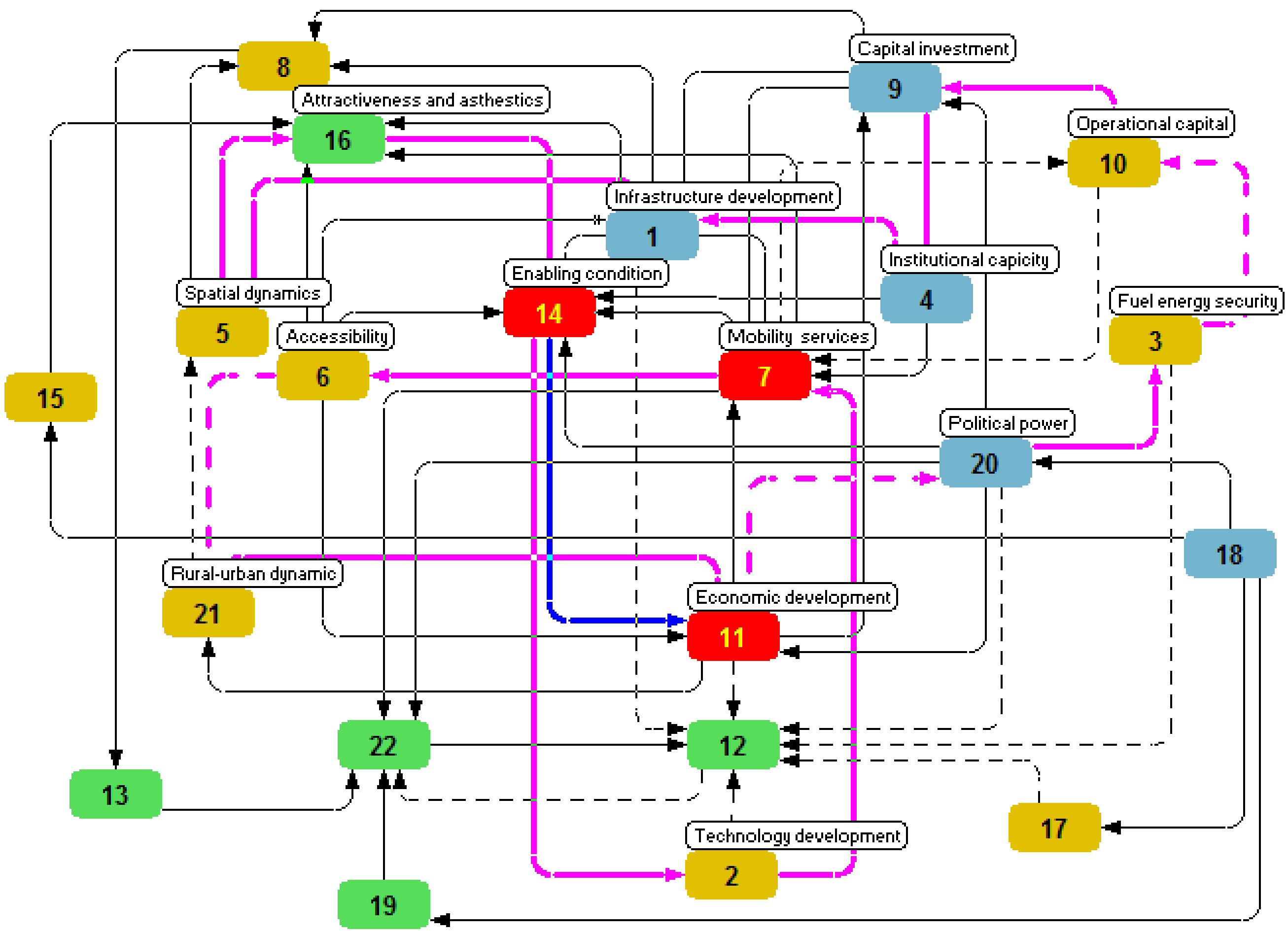

Figure 82: Feedback path deviation in Enabling Condition

a. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$
b. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 1$
c. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 11 \to 20 \to 9 \to 4 \to 1$
d. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 11 \to 20 \to 9 \to 1$
e. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 9 \to 4 \to 1$
f. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 9 \to 1$
g. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 10 \to 9 \to 4 \to 1$
h. $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 10 \to 9 \to 1$

i. $1 \to 5 \to 16 \to 14 \to 11 \to 7 \to 10 \to 9 \to 4 \to 1$
j. $1 \to 5 \to 16 \to 14 \to 11 \to 7 \to 10 \to 9 \to 1$
k. $1 \to 5 \to 16 \to 14 \to 11 \to 20 \to 9 \to 4 \to 1$
l. $1 \to 5 \to 16 \to 14 \to 11 \to 20 \to 9 \to 1$

The feedback effect $1 \to 5 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows 12 optional control feedbacks that have the potential to stabilize the system on a contextual basis and based on the choice of the positive feedback effect. Therefore, any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list. Identifying the control variable is critical for system self-regulation.

The negative feedback effect established from the effect system is strongly dependent on to the identified control variable, where the variability of control variable leads to system self-regulation. Therefore, identifying the control variable in all feedback effect is very necessary for decision support for planning and policy choice. The longest feedback effect a and b from the above list show Fuel-energy-security (3), Accessibility (6), Economic development (11), Political power (20), and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect d, c, k and l the control variables are Economic development (11) and Political power (20). In feedback effect e and f the control variables are Accessibility (6) and Rural-urban dynamic (21). Similarly, the control variables in feedback effect g, h, i and j the control variables are Mobility service (7) and Operational capital (10). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choice of the negative feedback effect depends on the system vision and the initializing positive feedback effect, whereas the control conditions are strongly dependent on to the identified control variable in the negative feedback effect.Thus, designing a sustainable system is three uniquely defined steps for the contextual need. The first step starts with the system vision definition, the second step the choice of positive feedback to initialize the visionand the third the control variable that regulates the system for their sustainability in future.

The negative feedback effect path $1 \to 6$

The feedback effect $1 \to 6 \to 21 \to 11 \to 20 \to 14 \to 2 \to 7 \to 10 \to 9 \to 4 \to 1$ show multiple path in the effect system of the variables Accessibility (6), Enabling-condition (14) and Rural-urban dynamic (21) as shown in figure 83.

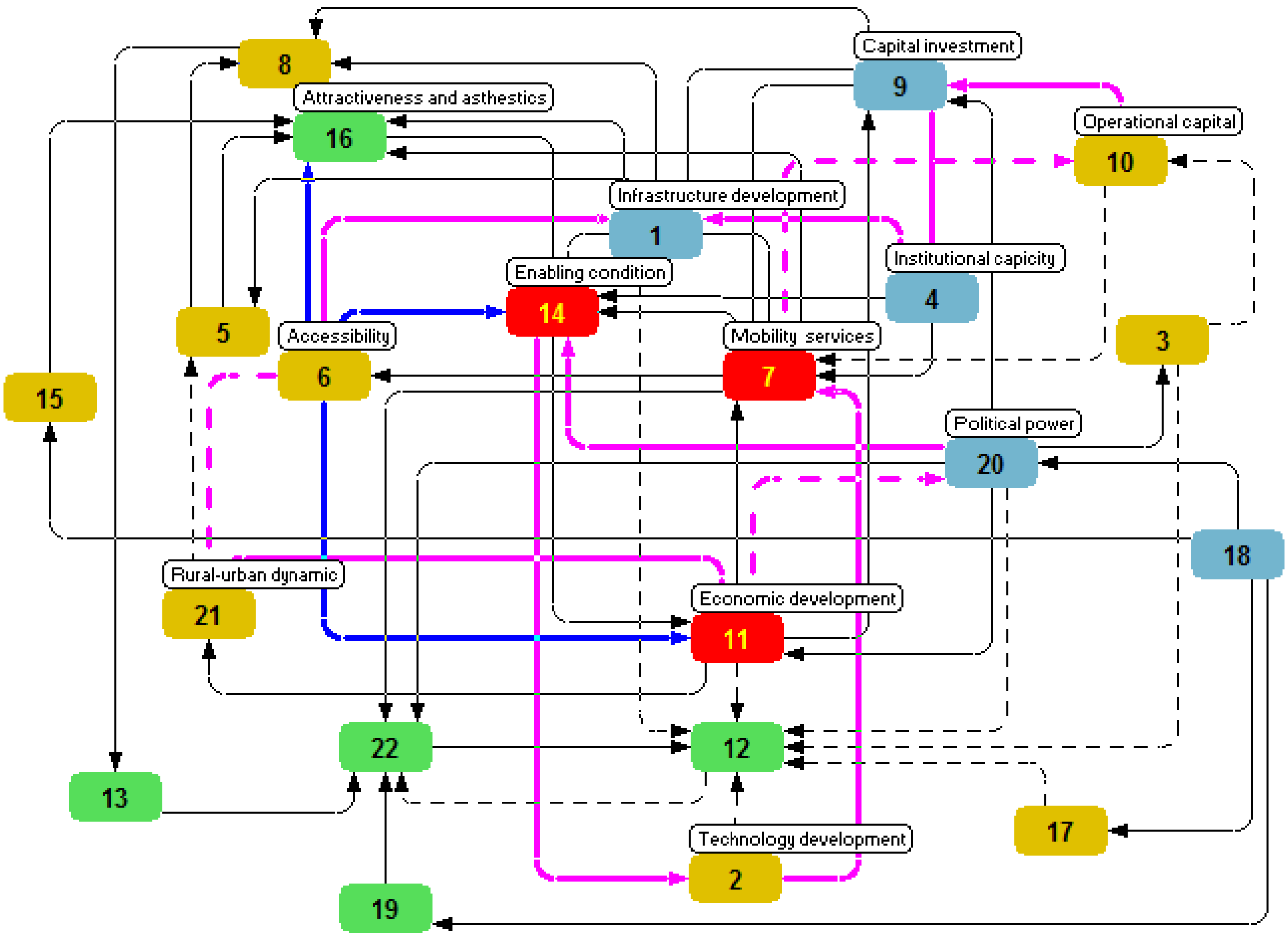

Figure 83: Feedback effect deviation in Accessibility

a. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 2 \to 7 \to 10 \to 9 \to 4 \to 1$
b. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 2 \to 7 \to 10 \to 9 \to 1$
c. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 9 \to 4 \to 1$
d. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 9 \to 1$
e. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 7 \to 10 \to 9 \to 4 \to 1$
f. $1 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 7 \to 10 \to 9 \to 1$
g. $1 \to 6 \to 21 \to 11 \to 20 \to 14 \to 2 \to 7 \to 10 \to 9 \to 4 \to 1$
h. $1 \to 6 \to 21 \to 11 \to 20 \to 14 \to 2 \to 7 \to 10 \to 9 \to 1$
i. $1 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$

j. $1 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
k. $1 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
l. $1 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 1$
m. $1 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
n. $1 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
o. $1 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
p. $1 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
q. $1 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
r. $1 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
s. $1 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
t. $1 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
u. $1 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
v. $1 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
w. $1 \rightarrow 6 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
x. $1 \rightarrow 6 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
y. $1 \rightarrow 6 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
z. $1 \rightarrow 6 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
aa. $1 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
bb. $1 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$

The control feedback $1 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows 27 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore, any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list.

The feedback effect a, b, e and f from the above list show Spatial dynamic (5), Accessibility (6), Mobility service (7), Operational capital (10) and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect c and d the control variables are Spatial dynamic (5), Accessibility (6), Economic development (11), Political power (20) and Rural-urban dynamic (21). In feedback effect g and h the control variables are Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21). The control variables in feedback effect i and j are Fuel energy security (3), Accessibility (6), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21). The control variables in k and l are Accessibility (6) and Rural-urban dynamic (21). The control variable in feedback effect m, n, q, r, s, t, w, x, y and z are Mobility service (7) and Operational capital (10). Similarly, the control variable for feedback effect u, v, z, aa and bb are Economic development (11) and Political power (20). While the choice of the negative feedback effect depends on the system vision and the initializing positive feedback effect, the control condition are strongly dependent on to the identified control variable in the negative feedback effect.

The negative feedback effect path $1 \rightarrow 7$

The feedback effect $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$shows multiple paths in the effect system of the variables Mobility service (7), Accessibility (6), Rural-urban dynamic (21) and Economic development (11) as shown in figure 84.

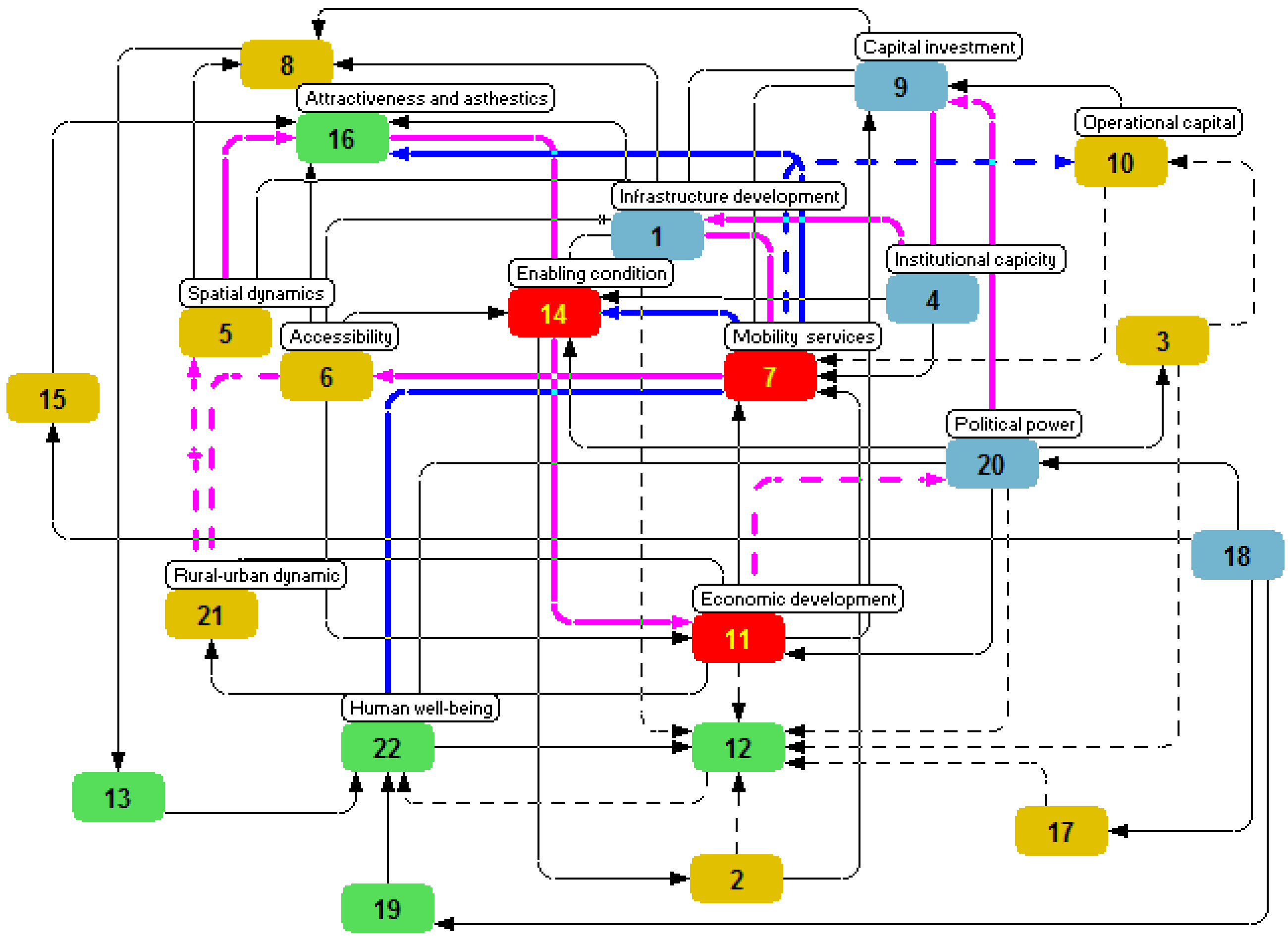

Figure 84: Feedback path deviation in Mobility Service

a. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$

j. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
k. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
l. $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 1$
m. $1 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
n. $1 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
o. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
p. $1 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
q. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
r. $1 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$

The control feedback $1 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows 18 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list.

Similar to that in section 4.6.4 the feedback effect a, b, c, d, e, f, o, p, q and r from the above list show Economic development (11) and Political power (20) as strong control variable for system stability and their sustainability. In feedback effect g and h the control variables are Spatial dynamic (5), Accessibility (6), Economic development (11), Political power (20) and Rural-urban dynamic (21). In feedback effect i and j the control variables are Fuel energy security (3), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11) and Political power (20). The control variables in feedback effect k and l are Accessibility (6) and Rural-urban dynamic (21). The control variables in m and o are Mobility service (7) and Operational capital (10). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choice of the negative feedback effect depend on the system vision and the initializing positive feedback effect, whereas the control condition are strongly dependent on to the identified control variable in the negative feedback effect. Thus designing a sustainable system will follow three uniquely defined steps on the contextual basis. The first step starts with the system vision, the second step the choice of positive feedback and the third the control variable that regulates the system for their sustainability in future. These feedbacks are useful for future scenario projections.

The Negative feedback effect path $1 \rightarrow 14$

The feedback effect $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple paths in the effect system of the variables Enabling condition (14), Accessibility (6) and Economic development (11) as shown in figure 85.

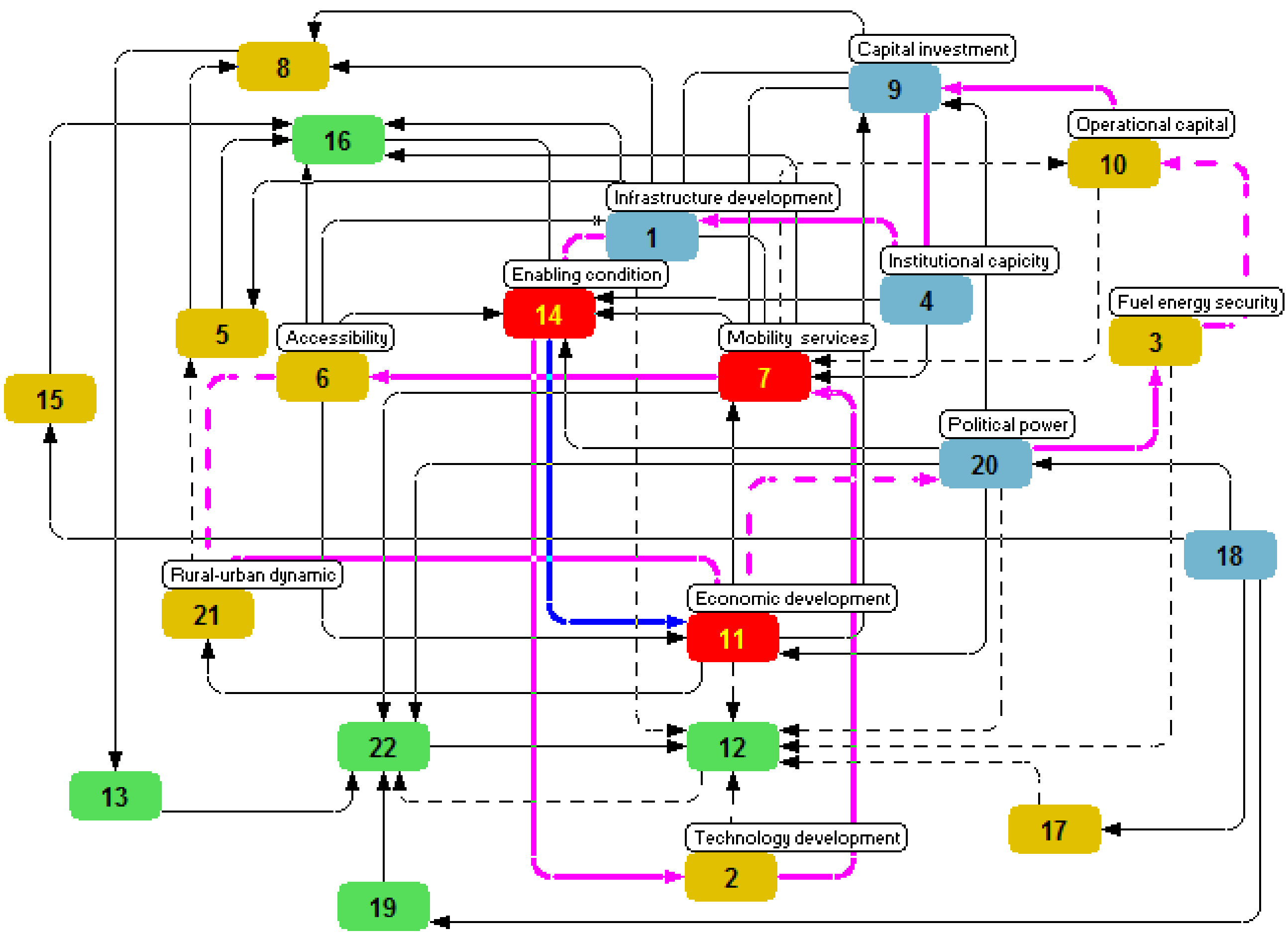

Figure 85: Feedback path deviation in Enabling Condition

a. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$

j. $1 \to 14 \to 11 \to 7 \to 10 \to 9 \to 1$

k. $1 \to 14 \to 11 \to 20 \to 9 \to 4 \to 1$

l. $1 \to 14 \to 11 \to 20 \to 9 \to 1$

The control feedback $1 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows 12 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect as seen in the above list.

Similar to that in section 4.6.4 the feedback effect a and b from the above list show Fuel energy security (3), Accessibility (6), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect c and d the control variables are Accessibility (6) and Rural-urban dynamic (21). In feedback effect e, f, k and l the control variables are Economic development (11) and Political power (20). The control variables in feedback effect g, h, i and j are Mobility service (7) and Operational capital (10). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choice of the negative feedback effect depend on the system vision and the initializing positive feedback effect, whereas the control condition are strongly dependent on to the identified control variable in the negative feedback effect. Thus designing a sustainable system will follow three uniquely defined steps on the contextual basis. The first step starts with the system vision, the second step the choice of positive feedback and the third the control variable that regulates the system for their sustainability in future. These feedbacks are useful for future scenario projections.

The Negative feedback effect path $1 \rightarrow 16$

The feedback effect $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$ shows multiple paths in the effect system of the variables Mobility service (7), Enabling condition (14), Accessibility (6) and Economic development (11) as shown in figure 86.

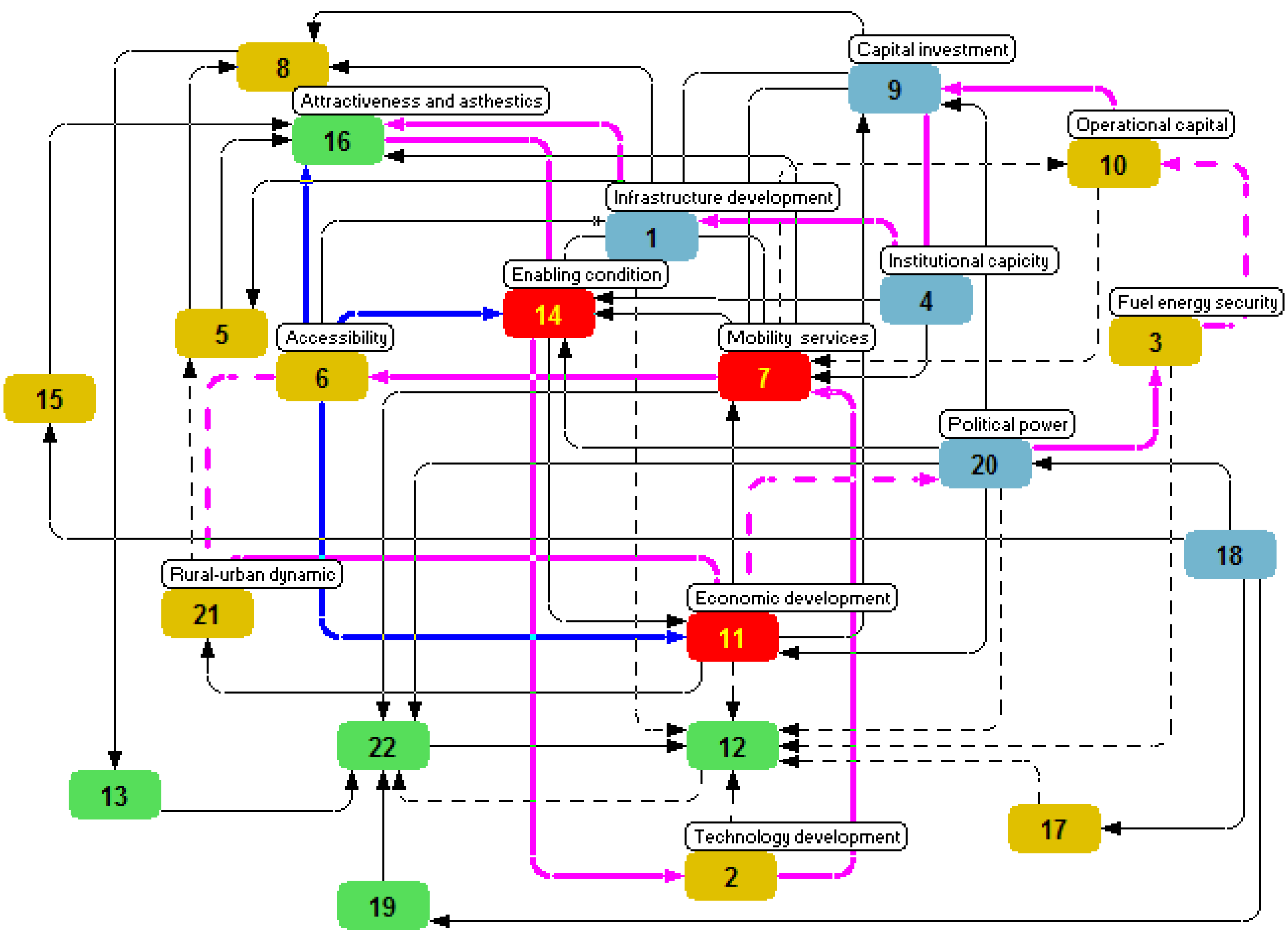

Figure 86: Feedback path deviation in Accessibility

a. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
b. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 1$
c. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 1$
d. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 1$
e. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 1$
f. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 1$
g. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$
h. $1 \rightarrow 16 \rightarrow 14 \rightarrow 2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 1$
i. $1 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 1$

j. $1 \to 16 \to 14 \to 11 \to 7 \to 10 \to 9 \to 1$

k. $1 \to 16 \to 14 \to 11 \to 20 \to 9 \to 4 \to 1$

l. $1 \to 16 \to 14 \to 11 \to 20 \to 9 \to 1$

The control feedback $1 \to 16 \to 14 \to 2 \to 7 \to 6 \to 21 \to 11 \to 20 \to 3 \to 10 \to 9 \to 4 \to 1$ shows 12 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect as seen in the above list.

Similar to that in section 4.6.4 the feedback effect a and b from the above list show Fuel energy security (3), Accessibility (6), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect c and d the control variables are Accessibility (6) and Rural-urban dynamic (21). In feedback effect e, f, k and l the control variables are Economic development (11) and Political power (20). The control variables in feedback effect g, h, i and j are Mobility service (7) and Operational capital (10). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choice of the negative feedback effect depend on the system goal and the initializing positive feedback effect, whereas the control condition are strongly dependent on to the identified control variable in the negative feedback effect. Thus designing a sustainable system will follow three uniquely defined steps on the contextual basis. The first step starts with the system vision, the second step the choice of positive feedback and the third the control variable that regulates the system for their sustainability in future. These feedbacks are useful for future scenario projections.

The Negative feedback effect path $2 \rightarrow 7$

The feedback effect $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$ shows multiple paths in the effect system of the variables Mobility service (7), Accessibility (6) and Economic development (11) as shown in figure 87.

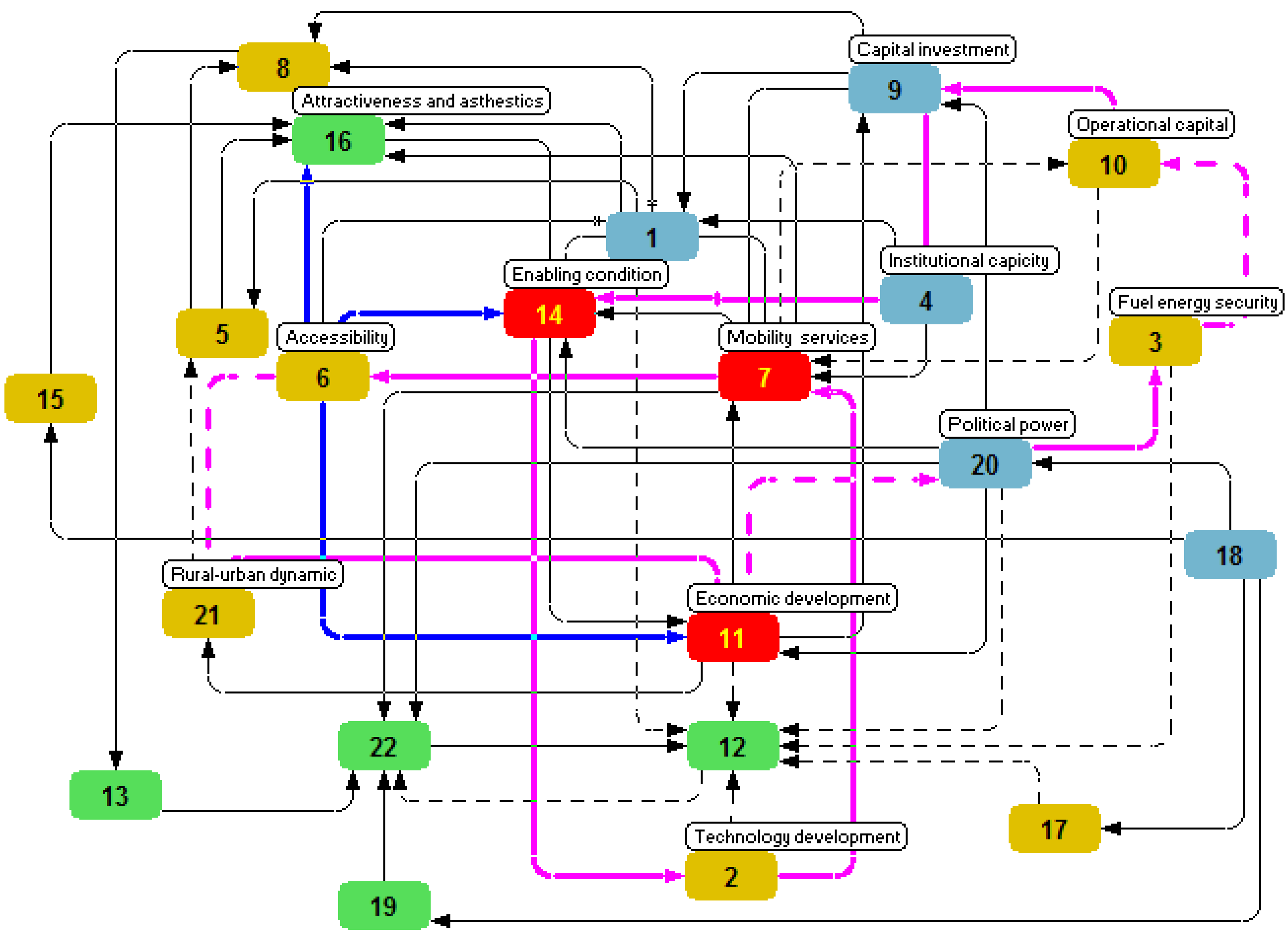

Figure 87: Feedback path deviation in Accessibility

a. $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
b. $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
c. $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$
d. $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 2$
e. $2 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 14 \rightarrow 2$
f. $2 \rightarrow 7 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$

The control feedback $2 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 14 \rightarrow 2$ shows 6 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect as seen in the above list.

Similar to that in section 4.6.4 the feedback effect 'a' from the above list show Fuel energy security (3), Accessibility (6), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect ' b' the control variables are Accessibility (6) and Rural-urban dynamic (21). In feedback effect c and e the control variables are Economic development (11) and Political power (20). The control variables in feedback effect 'd' are Spatial dynamic (5) and Rural-urban dynamic (21). The control variables in feedback f are Mobility service (7) and Operational capital (10). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choice of the negative feedback effect depend on the system vision and the initializing positive feedback effect, whereas the control condition are strongly dependent on to the identified control variable in the negative feedback effect. Thus designing a sustainable system will follow three uniquely defined steps on the contextual basis. The first step starts with the system vision, the second step the choice of positive feedback and the third the control variable that regulates the system for their sustainability in future. These feedbacks are useful for future scenario projections.

The Negative feedback effect path $3 \rightarrow 10$

The feedback effect $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$ shows multiple paths in the effect system of the variables Operational capital (7) and Accessibility (6) as shown in figure 88.

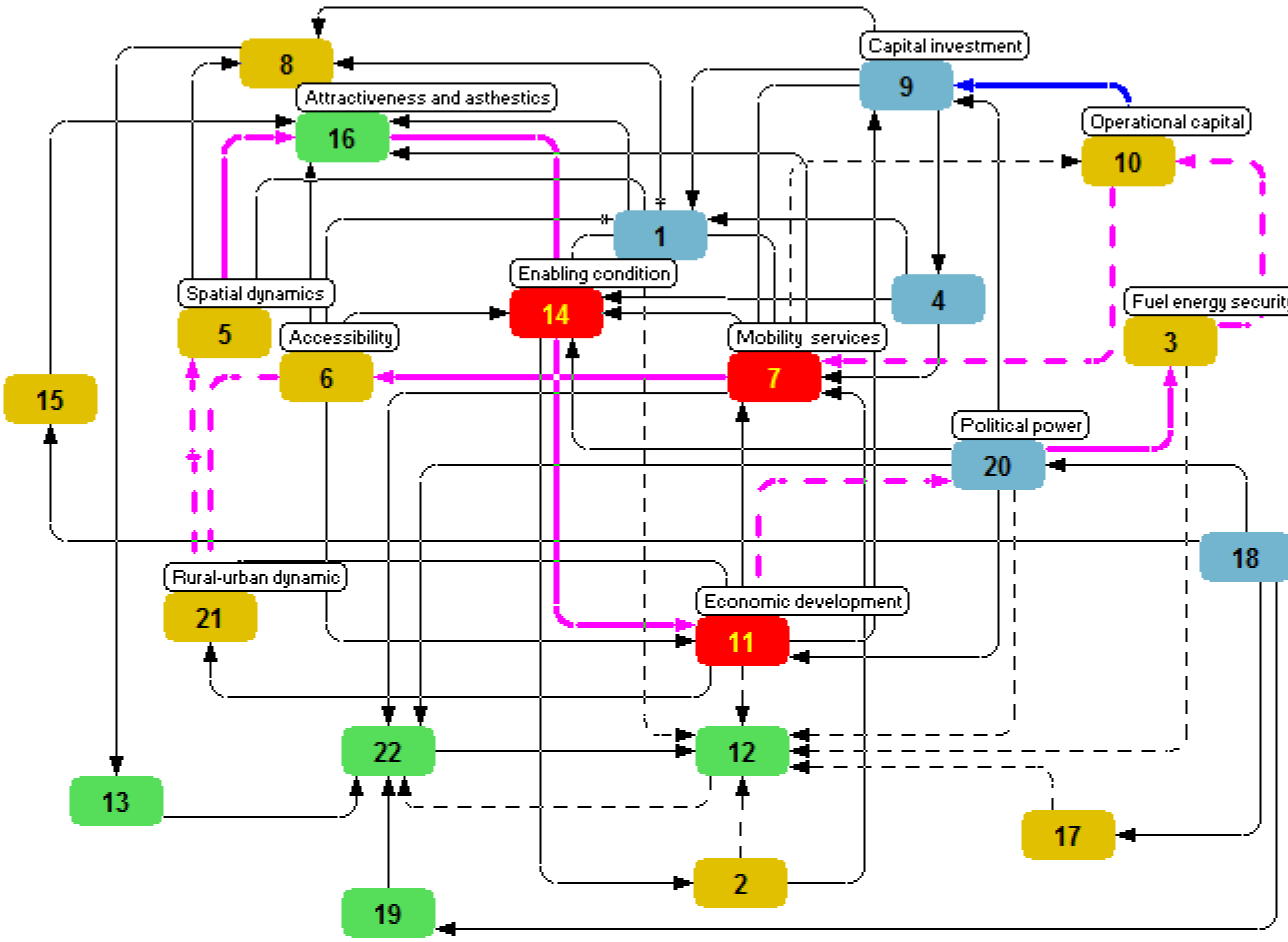

Figure 88: feedback path deviation in Operational Capital

a. $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
b. $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
c. $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
d. $3 \rightarrow 10 \rightarrow 7 \rightarrow 6 \rightarrow 11 \rightarrow 20 \rightarrow 3$
e. $3 \rightarrow 10 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
f. $3 \rightarrow 10 \rightarrow 7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 3$
g. $3 \rightarrow 10 \rightarrow 9 \rightarrow 4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3$
h. $3 \rightarrow 10 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 11 \rightarrow 20 \rightarrow 3$

The control feedback $3 \to 10 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 3$ shows 8 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect as seen in the above list.

Similar to that in section 4.6.4 the feedback effect 'a' from the above list show Fuel energy security (3), Spatial dynamic (5), Accessibility (6), Mobility service (7), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect 'b' the control variables are Fuel energy security (3), Mobility service (7), Operational capital (10), Economic development (11) and Political power (20). In feedback effect c, d and f the control variables are Fuel energy security (3), Mobility service (7), Operational capital (10), Economic development (11) and Political power (20). The control variables in feedback effect g and h are Fuel energy security (3), Accessibility (6), Operational capital (10), Economic development (11), Political power (20) and Rural-urban dynamic (21). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choice of the negative feedback effect depend on the system vision and the initializing positive feedback effect, whereas the control condition are strongly dependent on to the identified control variable in the negative feedback effect. Thus designing a sustainable system will follow three uniquely defined steps on the contextual basis. The first step starts with the system vision, the second step the choice of positive feedback and the third the control variable that regulates the system for their sustainability in future. These feedbacks are useful for future scenario projections.

The Negative feedback effect path $4 \to 7$

The feedback effect $4 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 9 \to 4$ shows multiple paths in the effect system of the variablesInstitutional capacity (4), Mobility service (7), Accessibility (6), Economic development (11) and Rural-urban dynamic (21) as shown in figure 89.

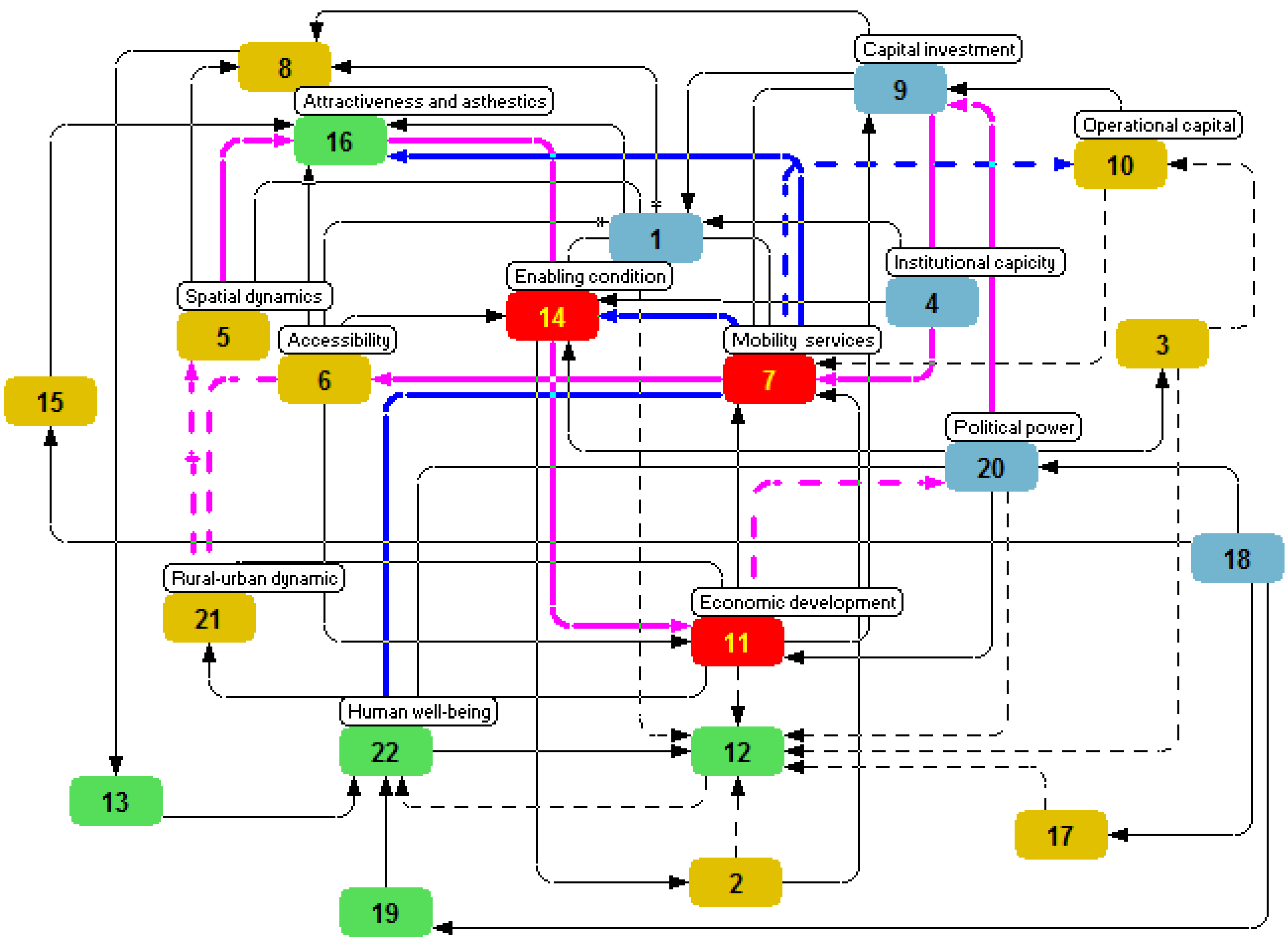

Figure 89: Feedback effect deviation in Mobility Service

a. $4 \to 7 \to 6 \to 21 \to 5 \to 16 \to 14 \to 11 \to 20 \to 9 \to 4$
b. $4 \to 7 \to 6 \to 16 \to 14 \to 11 \to 20 \to 9 \to 4$
c. $4 \to 7 \to 6 \to 14 \to 11 \to 20 \to 9 \to 4$
d. $4 \to 7 \to 6 \to 21 \to 11 \to 9 \to 4$
e. $4 \to 7 \to 6 \to 11 \to 20 \to 9 \to 4$
f. $4 \to 7 \to 14 \to 11 \to 20 \to 9 \to 4$
g. $4 \to 14 \to 11 \to 7 \to 10 \to 9 \to 4$
h. $4 \to 14 \to 11 \to 20 \to 9 \to 4$
i. $4 \to 7 \to 10 \to 9 \to 4$

j. $4 \rightarrow 7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4$

The control feedback $4 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 4$ shows 10 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list.

Similar to that in section 4.6.4 the feedback effect 'a' from the above list show Spatial dynamic (5), Accessibility (6), Economic development (11), Political power (20) and Rural-urban dynamic (21) as strong control variable for system stability and their sustainability. In feedback effect b, c, e, h and j the control variables are Economic development (11) and Political power (20). In feedback effect 'd' the control variables are Accessibility (6) and Rural-urban dynamic (21). The control variables in feedback effect g and i are Mobility service (7) and Operational capital (10). Identification of these control variables are critical for designing a system that tend to self-regulate in future. While the choices of the negative feedback effect depend on the system vision and the initializing positive feedback effect, the control conditions are strongly dependent on to the identified control variable in the negative feedback effect. Thus designing a sustainable system will follow three uniquely defined steps on the contextual basis. The first step starts with the system goal, the second step the choice of positive feedback and the third the control variable that regulates the system for their sustainability in future. These feedbacks are useful for future scenario projections.

The Negative feedback effect path $5 \rightarrow 16$

The feedback effect $5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5$ shows only one path for the feedback effect as shown in figure 90.

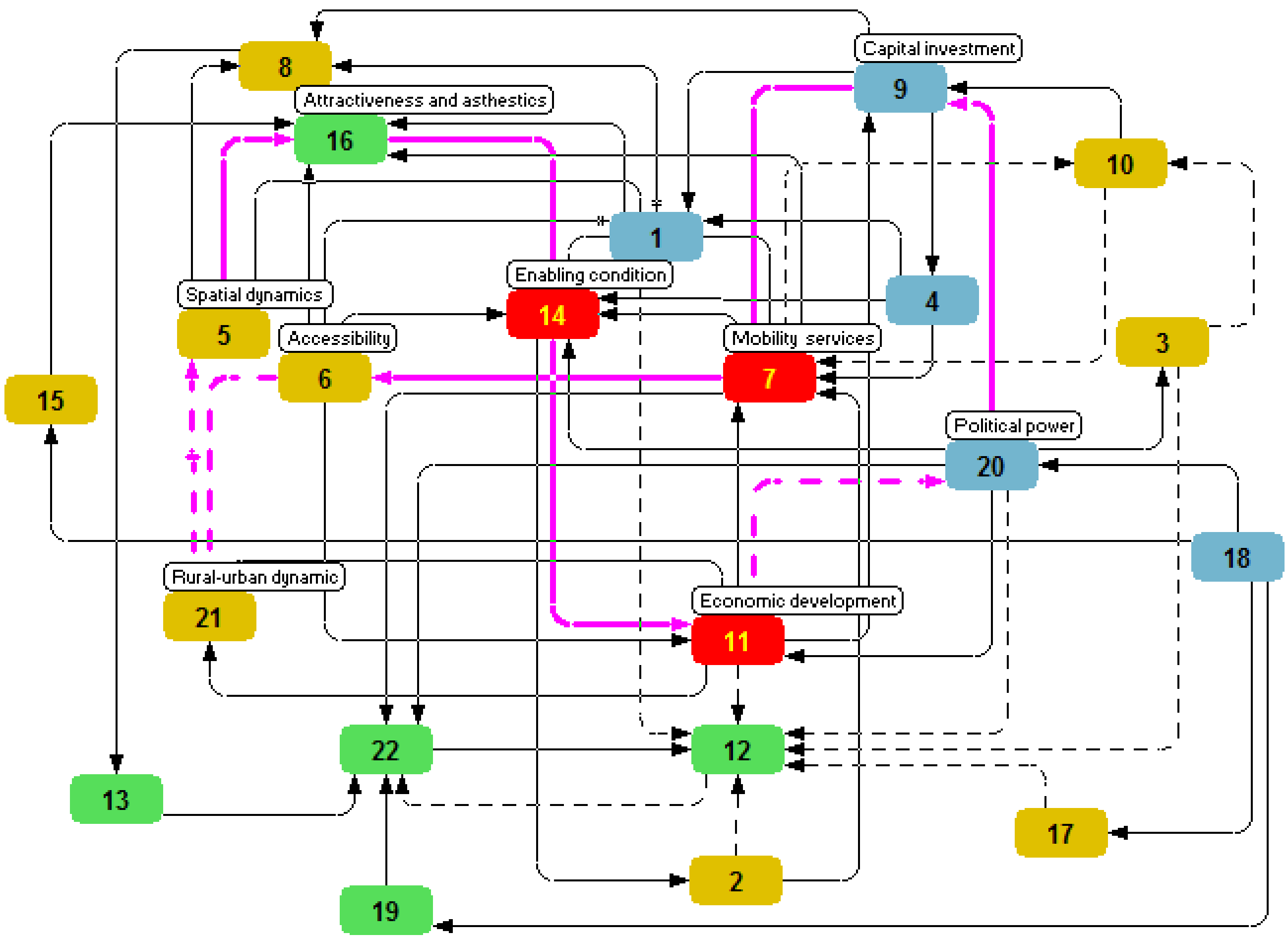

Figure 90: Feedback effect of Spatial Dynamic

a. $5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5$
b. $5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 21 \rightarrow 5$

The control feedback $5 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6 \rightarrow 21 \rightarrow 5$ shows only 2 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list. The control variable in feedback effect 'a' are Spatial dynamic (5), Accessibility (6), Economic development (11), Political power (20) and Rural-urban dynamic (21) whereas the control variable in feedback effect 'b' are Spatial dynamic (5) and Rural-urban dynamic (21) for the system self-regulation.

The Negative feedback effect path at node $6 \rightarrow$

The feedback effect $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$ shows multiple paths in the effect system of the variables Accessibility (6) and Economic development (11) as shown in figure 91.

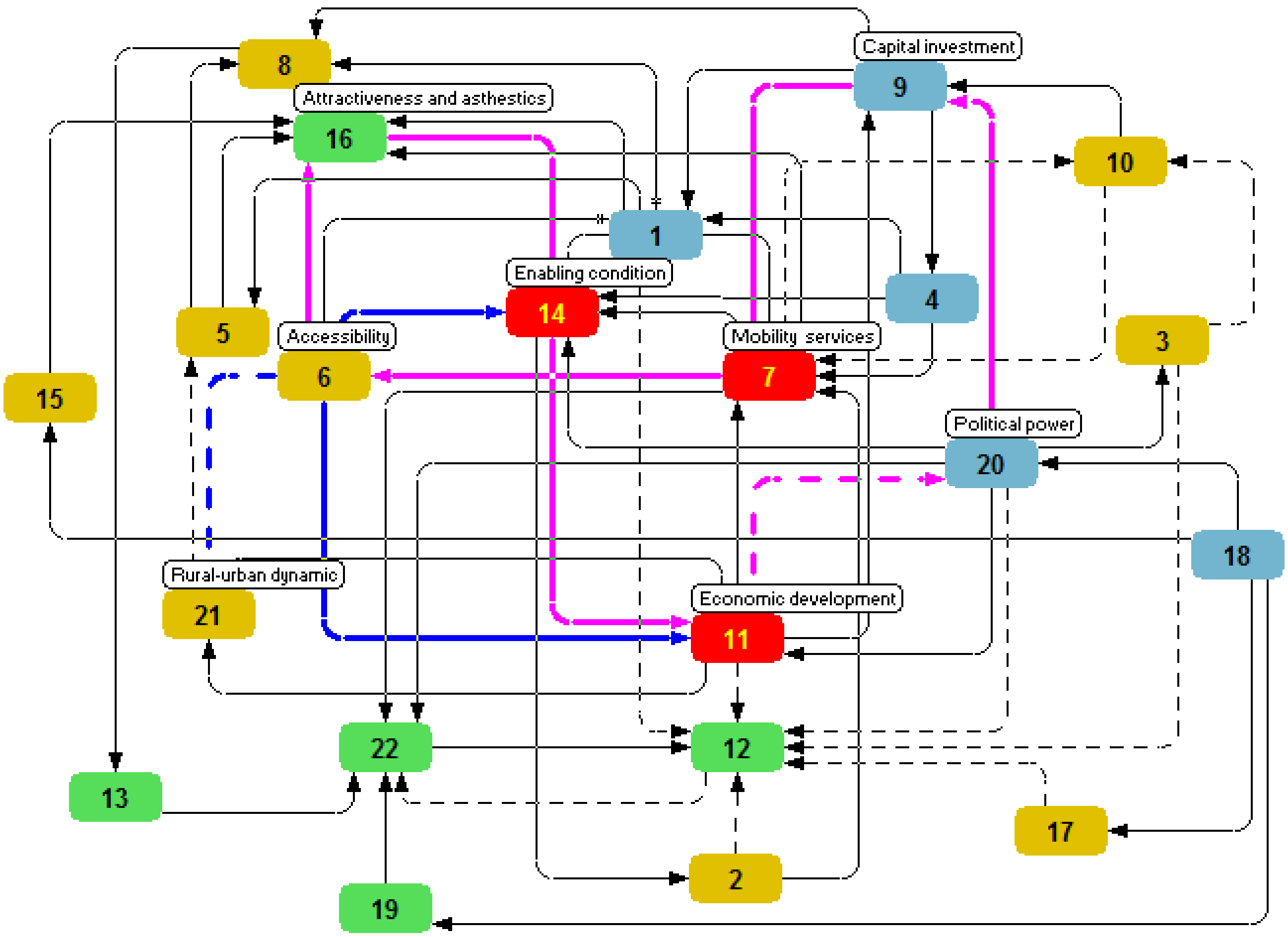

Figure 91: Feedback path deviation in Accessibility

a. $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$
b. $6 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$
c. $6 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$
d. $6 \rightarrow 21 \rightarrow 11 \rightarrow 9 \rightarrow 7 \rightarrow 6$
e. $6 \rightarrow 21 \rightarrow 11 \rightarrow 7 \rightarrow 6$

The control feedback $6 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7 \rightarrow 6$ shows 5 possible alternative feedback effects, which control the system on a contextual basis. The control variable for feedback effect a, b and c are Economic development (11) and Political power (20), whereas the control variable for feedback effect d and e are Accessibility (6) and Rural-urban dynamic (21) for the mobility system self-regulation and sustainability.

The Negative feedback effect path at node $7 \rightarrow$

The feedback effect $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7$ shows multiple paths in the effect system of the variables Mobility service (7) as shown in figure 92.

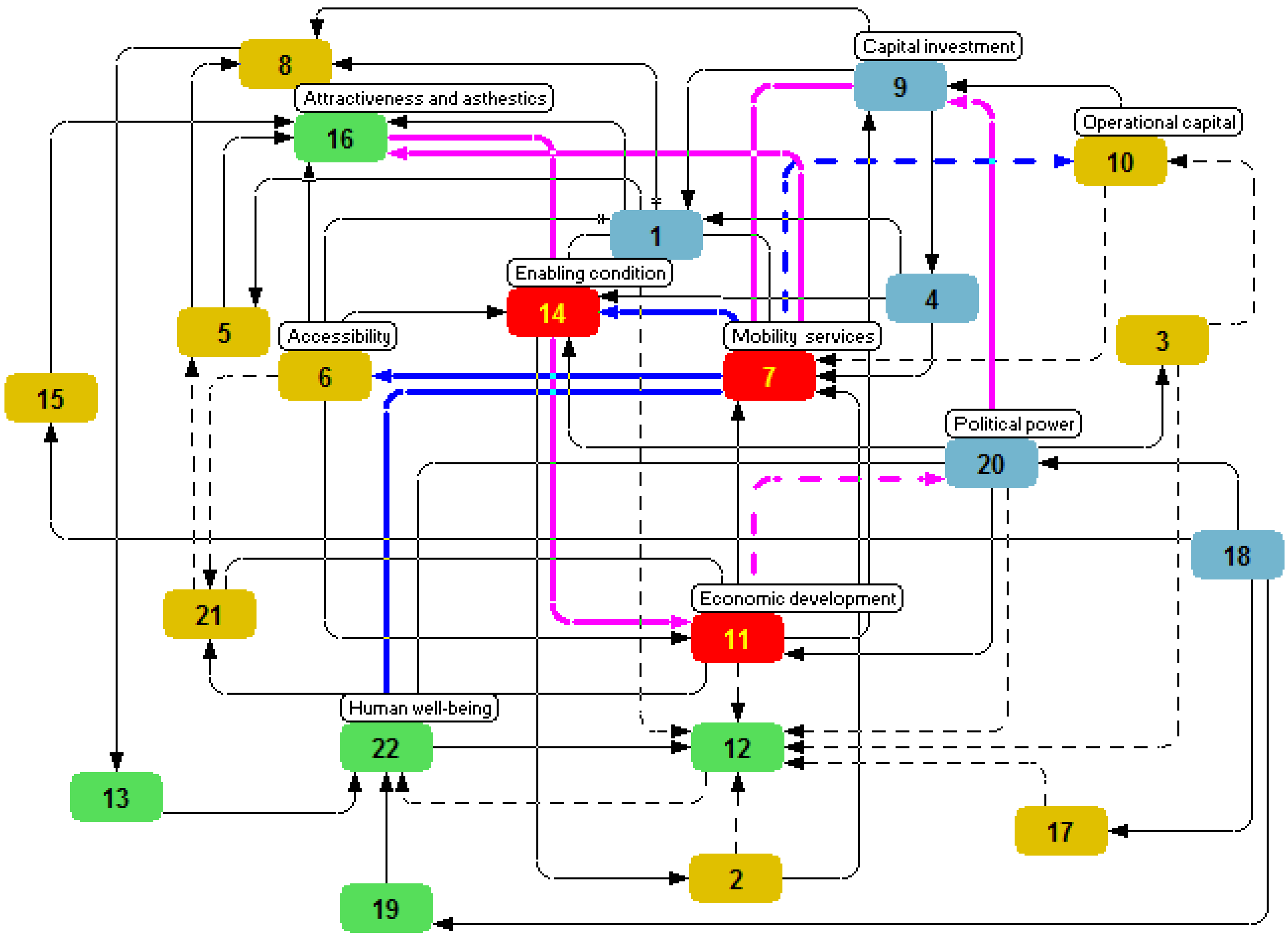

Figure 92: Feedback path deviation in Mobility Service

a. $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7$
b. $7 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7$
c. $7 \rightarrow 10 \rightarrow 9 \rightarrow 7$

The control feedback $7 \rightarrow 16 \rightarrow 14 \rightarrow 11 \rightarrow 20 \rightarrow 9 \rightarrow 7$ shows only 3 possible alternative feedback effects, which control the system on a contextual basis and depending on the choice of positive feedback. The control variables for feedback effect a and b from the above list are Economic development (11) and Political power (20), where as the control variables for 'c' are Mobility service (7) and Operational capital (10). Therefore any intervention on the variable in the system for control condition requires the consideration of the variables that form a feedback effect seen in the above list.