ROYAL INSTITUTE
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# Sustainable futures of mobility

## Transition narratives for policy design and assessment tools

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*"In my life I have found two things of priceless worth—learning and loving."*

Arthur C. Clarke, *Rama II*

# Abstract

The thesis explores a possible sustainable future of mobility and the transition pathway to it, focusing on the socio-cultural dimensions that shape and drive the way mobility is understood. Goal-driven, transition-oriented policy recommendations are provided as the main result, derived from a combined backcasting and forecasting methodology framework. The successful combination of backcasting and Causal Loop Diagrams is achieved by homogenising the outcomes of each assessment through the logic of the Multi-Level Perspective of transitions theory.

The research highlights that reinforcing feedback mechanisms and a deeply embedded culture of automobility are behind the enormous inertia and resilience of the current mobility system. If a transition to a sustainable mobility future is to happen, the insights gained from this study point to a necessary shift in cultural trends. The discourses of unrestricted individual freedom, private property and materialistic cultures that legitimise automobility must be challenged.

The thesis proves that the Multi-Level Perspective on transitions provides with a narrative capable of integrating results from inherently different approaches to future studies. The methodological framework developed in the study is generalisable and useful for situations where a normative goal in the distant future is pursued, while accounting for the reasons behind policy resistance in the current system configuration.

# Acknowledgements

Firstly, I would like to thank Dr. Rajib Sinha for his advice and guidance throughout the entire development of this thesis, as well as his continued support to help me achieve my goals. To him and all the professors I ever had, I am grateful of their will to teach and share their knowledge and sapience with all of us students; it is a great task you carry on your shoulders and for that you have my heartfelt gratitude.

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I could not stop to thank Dirk and Kathrin all their support and their wonderful reception at their home. It has been amazing to share your space for a year and a half. I wish we meet again in the future, to a cup of wine, to talk about the wonders of life.

To my parents and my brother, that have raised me and taught me. For the all the support and love.

To you, Raquel; words are not enough. Life by your side is so much brighter. Thank you.

# Foreword

This thesis, far from giving an accurate or specific set of sustainable mobility policy recommendations, is indeed more of a mental exercise. It is, above all, an exploration of new ways of doing sustainability research. Even though the original purpose is to analyse a transition towards sustainable future (personal) mobility, it is clear that no master thesis can comprehensibly tackle the issue. Not only due to time and resource constraints, but because such a transition requires highly participatory democratic processes to become a reality. This thesis does not, therefore, intend to provide with the ultimate truth with respect to sustainable mobility, but to raise to the challenge of coming up with new policy and research ways.

Some may find the title of this thesis misleading. There is, indeed only *one* possible future of sustainable mobility assessed here. However, the study is embedded in the field of *futures* research. Above all, the title is meant to convey that, despite the efforts in forecasting and research, the possibilities are many: a whole array of futures is ahead. It is in the hands of researchers, policy makers, stakeholders and everyone to follow one or another vision of the future and gain it for themselves.

The thesis also embraces a perspective on sustainability that is often avoided or regarded as biased: normative research. This is, the thesis diverges from descriptive studies and delves into *how* sustainable mobility can be achieved. Even though such research entails challenges to fundamental values of society and societal organisation patterns, one should not hurry to regard it as politically-biased. Instead, the question that must be raised is whether or not these challenges to values and lifestyles are well-founded and are effectively necessary to reach a sustainable form of existence. This is, can we truly achieve sustained human life on Earth with our current way of living? And with our current mental frames?

Finally, the thesis intendedly avoids using too many numeric figures in the assessments contained. This is for two reasons: (1) the inclusion of numbers for macroscopic trends, such as city density, in the long-term scope of the thesis would introduce a source of uncertainty and (2) the will to emphasise that qualitative research can be as good as quantitative science to answer sustainability questions. Sometimes, change for good is not about a particular figure, but a particular course of action, a final vision—an idea.

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# Chapter 1

# Introduction

This thesis report is an investigation of sustainable mobility futures. It is a theoretical exploration of how policy can deliver the necessary efforts and guidelines for a successful a transition to a sustainable mobility system. *What* is understood for "sustainable" and *how* the transition is to be managed and envisioned are the main foci of the document. Special emphasis is put on the *cultures* of mobility and on achieving the widest *system perspective* as possible. This being said, a clarification must be made already regarding a limitation in the scope of this study: the concept of "mobility" that is used throughout the thesis is bound to **personal travel**, i.e., not freight transport.

Overall, the report structure adheres the IMRAD+C paradigm, with the present Introduction chapter, followed by the Methods, Results, Discussion and, finally, the Conclusion. With regards to this introductory chapter, Section 1.1 presents an overview of the pressing issues of the current mobility system. A state of the art review with respect to policy approaches and design tools is given in Section 1.2. To conclude the chapter, Section 1.3 states the aims and objectives that motivate the rest of this research.

## 1.1 Unsustainable mobility

Several issues of the current mobility system make it qualify as unsustainable. Direct downstream impacts, e.g. greenhouse gas emissions, are the most directly perceivable hazards, but it is their combination with global future trends that increases the significance of mobility impacts on sustainability. Issues such as population growth (UN-DESA, 2015; KC and Lutz, 2017), peak oil (Kerr, 2011), expected impacts from climate change and growing economies in Asia, South-America and Africa, all highlight the acceleration and exponential expansion of the negative effects that high mobility poses to the environment, the economy and to human health and social systems.

Transport related airborne pollution is one of the main causes of respiratory diseases and associated increase in morbidity in densely populated areas (Vimercati, 2011; WHO, 2006). Ambient air pollution is estimated to cause 4.4 million premature deaths around

the globe (Forouzanfar et al., 2016) and the link from air pollution to both severe health problems and high traffic volumes is well known and thoroughly researched (WHO, 2006): $NO_x$ emissions that lead to increases in $PM_{2.5}$ particulate and ozone concentrations are directly linked to diesel combustion engines, in heavy duty but also light duty vehicles (Anenberg et al., 2017). The fact that regulations and emission limits are in place within the automotive industry has not alleviated the problem, due to ever-growing automobile use and because of the industry efforts to deceive such regulations, avoiding costly research and development investments, as is the case of the recent "dieselgate" scandal (The Guardian, 2017).

The current unsustainable mobility system not only causes respiratory health issues, but also congestion, accidents, noise pollution, infrastructure degradation and, finally, it is one of the sectors that most contribute to climate change (Korzhenevych et al., 2014). Congestion is, for example, the cause of massive costs in terms of reduced productivity, increased energy and fuel consumption, higher accident risk and its subsequent economic impacts which, for instance, are estimated at 4.2% of Beijing's 2010 GDP[1] (Li-Zeng, Hong-Ge, and Li-Ren, 2012). Road-related accidents alone (cars, buses and other vehicles aggregated) cause vehicle losses and damages and, most importantly, death rates that exceed 1.2 million worldwide per year or 28 077 in the European Union (EU) in 2015 (WHO, 2017). Safety in rail and aviation is much higher (especially per person kilometre travelled) than in roads, but they still take away 993 lives in rail-related accidents and 155 in aviation (EU data, 2015) (Eurostat, 2017b; Eurostat, 2017a).

The transport sector is responsible for 27.8% of the global final energy consumption (2014 data), with over 95% of this energy coming from fossil sources (oil, primarily, but natural gas and coal too) (IEA, 2017). Chapman (2007) already estimated that 26% of the total world's $CO_2$ emissions were borne in the transport sector, of which 65% are originated in road transport. Given the enormous pressure that climate change puts on the resilience of modern societies (IPCC, 2014) and the current undertaking to tackle this global challenge — take, for example, the recent Paris Agreement Framework Convention on Climate Change (Clémençon, 2016) —, transport (mobility) is one of the sectors that must be thoroughly examined, revised and challenged to deliver urgent greenhouse gas emissions mitigation.

## Automobility at the core

Automobility, as a personal mobility solution, has brought about many positive consequences, from the individuals point of view. However, its exponential growth and reliance on fossil fuels and massive infrastructures to work deem it as a global threat to the environment and, at a more local scale, to the quality of life of the very same individuals

[1] Gross Domestic Product

that make use of this transport mode. Given that automobility accounts for almost 36% of the travel demand (in person kilometres per year) (Vuuren et al., 2017), and that 65% of $CO_2$ emissions from all travel modes are attributed to road transport (Chapman, 2007), it is logical to state that automobility is, indeed, a major player in the sustainable mobility discussion. Therefore, this thesis will place a good deal of emphasis on this particular mode. The study scope encompasses the relation between this regime and public transport, or between automobility and urban planning, for example — limiting the scope of this research to the automobile system would certainly not be sufficient to address the broad concept of sustainable mobility.

## 1.2 State of the art

Historically[2], in the "advanced" economies of Europe and North-America, personal mobility issues such as congestion and accessibility[3] have been addressed through the development of infrastructure, through increased incentives for automobility and, to some extent, travel demand management (Lyons, 2012). Policy solutions for environmental social impacts of automobility have also been focused on technological improvement and, on a minor scale, modal shift[4] (Köhler et al., 2009).

However effective these policies were in the past—the paradigm of "predict-and-provide" for infrastructure development (to address congestion) has already been dismissed in the UK, being regarded as non-efficient and even counter-productive (Goodwin, 2012)—, it is clear that they are not so nowadays. Faced with pressing global trends like population growth and the fact that emergent economies in Asia and South-America are also embracing automobility as the paradigm of personal mobility, pressure keeps building on the natural and social environments. A new policy approach is needed; one that is capable of transforming the mobility system into a more sustainable one. Some efforts have been taken to fill this gap, through policy assessment tools like, for example, sustainability indicator frameworks (Castillo and Pitfield, 2010; Haghshenas and Vaziri, 2012; Litman, 2007; Shiau and Liu, 2013).

Despite the best of the intentions behind them, policy assessment tools such as indicators have not performed as expected. Most indicator frameworks are not used as they should, i.e., for their instrumental and operational roles. Instead, policy makers just use them as another source of information, because they claim that "sets of numbers" do not convey the necessary insights for policy design or formulation (Gudmundsson and SØrensen,

[2]The historical time-frame considered in the thesis goes back to the beginning of the 20th century.
[3]Accessibility is meant as the capacity of reaching (travelling) a destination from "any" other given point in a territory.
[4]Modal shift refers to changes in the shares of travel modes (reducing car use in favour or biking, for example)

2013). One of the main drawbacks of indicators is that they are focused on *impact* assessment. Policy design should not be focused on a responsive approach – a proactive, driver-based approach is the key to a sustainable mobility transition. There is a need to model and conceptualize the "engine" of the mobility system and, then, find leverage points for effective policy design. Other traditional policy assessment tools, such as Integrated Assessment Models, are much broader and do evaluate the drivers of the transport sector, but fail to capture the social dimension of the system (they tend to be focused on economic variables and trends such as fuel prices) (Creutzig, 2015). One hypothesis held in this study is that traditional policy assessment tools lack either the systems perspective necessary to avoid policy resistance[5] or a more normative approach to facilitate policy design.

One very important research development in the latest decades has been setting sustainable mobility *visions* for the future. They form the foundation of any further policy or socio-technical development and there are examples of such, like the seminal paper by Banister (2008), entitled "The sustainable mobility paradigm". However, the *path* from the current situation to the desired vision of mobility remains rather unexplored. Paradigm exploration papers like Banister's provide with general policy recommendations, but do not dive deep into this realm. Additionally, they sometimes fail to account for the dynamic behaviour of the system as a whole and the mechanisms through which policy resistance is created remain rather unexplored. This is, they do not fully investigate the actual reasons why policy is sometimes ineffective, through stability and change dynamics. Moreover, these studies rarely provide with analysis of cultures or of system agents relations, thus being centred in technological, institutional and behavioural[6] aspects of mobility.

Finally, a new field of research has emerged that aims to tackle some of the shortcomings discussed in the previous paragraphs: *transition studies* (or *theory*). Scholars like Frank Geels, René Kemp and Jan Rotmans have spearheaded this research community, albeit some differences among their approaches: the tradition of *socio-technical* transitions deals with retrospective and future studies of the changes suffered by socio-technical systems (F. Geels, 2001; F. Geels, 2005), while the tradition of *transition management* is focused on the governance of complex socio-technical systems that are meant to undergo a transition process (Rotmans, Kemp, and van Asselt, 2001). Even though this approach is explained in more detail in the Methods chapter, it is worth noting that the central focus of the theory is the stability and change dynamics of the systems under study. Following F. Geels (2001) and Rotmans, Kemp, and van Asselt (2001), transition

[5] *Policy resistance* refers to unexpected responses of a system to a certain policy measure, usually counter-acting the intended effect.

[6] Note that behaviour is conditioned by culture, but it is not equivalent. Behaviours can be changed within a certain practice space and still remain embedded in the same cultural framework of the previous behaviour.

studies investigate the co-evolution processes and multi-dimensional interactions occurring among agents (users, companies, policy makers, markets, culture, etc.) in a system. It is, therefore, a dynamics-centric, system-wide and possibly normative perspective that aims to understand how and why transitions take place in socio-technical systems.

## 1.3 Aim and objectives

The previous sections have covered the impacts caused by the current mobility paradigm, as well as some of the policy and research approaches to solving the damaging effects of the transport system. The major gap identified in the State of the art section is the poor performance of policy (and research) to deliver the expected improvements in the mobility sector. It is somewhat clear that there is a huge resistance to policy efforts and that research has been, so far, unable to identify its ultimate causes — at the very least, if the identification has ever been positive, policy makers have been unable to introduce the appropriate measures to tackle the problem. A *primary research question* remains thus open:

> *How can modern societies develop a sustainable mobility system?*

This broad question actually entails two specific issues to be addressed jointly: (a) *what* is a "sustainable" mobility system exactly (how is it defined) and (b) *how* to reach (develop) such a sustainable system, from the current configuration. While there is considerable amounts of literature on the topic of paradigm definition of sustainable mobility (Banister, 2000; Banister, 2008; HØyer, 2000; Burns, 2013, see, e.g.,), there is not that much regarding the actual development pathway to it, at least from a normative and/or social point of view. As reviewed in Section 1.2, a lot of the literature on pathways to sustainable mobility deals with efficiency improvements of specific technologies (especially that of automobiles) and on infrastructure optimisation (Creutzig, 2015; Köhler et al., 2009; Lyons, 2012)

The conjecture is that, regarding the historically observed policy resistance demonstrated by unsustainable mobility, none of these approaches challenges the fundamentals of the status quo of mobility. In particular, it is cultural frameworks and sociological interactions at multiple levels that have remained outside of the scope of policy making and policy advise in the past. The main *hypothesis* of this study can thus be formulated as:

> *Policy and research efforts have, so far, failed to account for and challenge the socio-cultural framework that underpins unsustainable mobility.*

The primary research question will therefore be answered from the point of view of

the stated hypothesis. By (1) drawing on the integrated socio-technical narrative[7] that transition studies enable and (2) acknowledging the importance of automobility as a key driver of impacts in the mobility system, the *aim of this thesis* is:

> *To investigate how policy can help to achieve a sustainable mobility system in the future, by studying the* dynamics *of a* socio-technical transition *away from the current dominant regime of automobility.*

The focus of this study is not so much on the concept of sustainable mobility, but on the *transition* pathway to it. It is not in technological improvements or demand management techniques either, but on the socio-technical and cultural *drivers* of (auto)mobility to understand what are the elements of resistance and enablers of change in the mobility system. Regarding the *target audience* of the thesis, the intention is to develop insights for governmental policy makers[8] and other stakeholders capable of decision making in the field of mobility, from the transition studies perspective — the ultimate goal of the thesis is the derivation of policy recommendations, informed by a transitions theory perspective.

Finally, this investigation of sustainable futures of mobility requires that the following sub-goals (objectives) are completed:

**Obj. 1.** Develop a description of a desirable future mobility system, this is, a *vision* that acts as the final goal of a transition process. The vision must incorporate socio-cultural, as well as technological and developmental, aspects of mobility.

**Obj. 2.** Analyse the *changes* that separate the desired distant future from the current mobility system. These changes must reflect the actual requirements for the transition to happen.

**Obj. 3.** Analyse the current mobility system to identify (a) its socio-cultural *mechanisms of resilience* (policy resistance) and (b) the *opportunity windows* for introducing changes to achieve a successful transition away from it.

**Obj. 4.** Develop long-term policy recommendations to implement the required changes for a transition that have been previously identified. Policy recommendations must be coherent with the transition goal itself, but also among them.

[7] Narrative is meant here as the discursive framework that a theory or science provides, as a way to structure explanations from a certain perspective.

[8] At either local, regional, national or international levels.

# Chapter 2

# Methods

This chapter provides with an overview of the methodological framework (the combination of methods) used to achieve the stated Aim and objectives in each of the following sections. Section 2.1 deals with the sustainable mobility vision development. The requirements (changes) for the transition were derived using the method described in Section 2.2. Section 2.3 explains the methodology that was used to identify the policy resistance mechanisms in the current system and, finally, Section 2.4 explains the analytical framework used to design the policy recommendations for the transition. A graphical overview of the methodological framework is given in Figure 2.1.

## 2.1 Qualitative narratives: setting the vision

Concerning the first of the objectives described in the Introduction chapter, no formal method is used to *obtain* the "vision" of a future mobility system. The vision is not derived from any kind of forecasting or modelling tool. Instead, a literature review was performed at the beginning of the thesis, searching for papers with the keywords "sustainable", "mobility" and "paradigm". While several articles were found (e.g., Banister (2008)), little or none of them actually gave a clear picture of a *future paradigm* of sustainable mobility. Most of the papers consisted only on discussions regarding some of the aspects that could conform a sustainable mobility paradigm. Therefore, the decision was taken to build a new vision on already existing research. The final choice for the basis of the vision is the long-term scenario framework by the International Panel on Climate Change (IPCC) (see Section 3.1 for more detail). This framework consists on five different qualitative narratives that are then translated into sets of (quantitative) assumptions in the global climate change assessment models (Integrated Assessment Model (IAM)).

The vision in this thesis is developed following the same method as O'Neill et al. (2017) did for the IPCC scenarios: through a *qualitative narrative* in which the aspects of the sustainable mobility paradigm are explained qualitatively. With respect to how the vision is developed, it is done so by building upon the foundations of the SSP1 scenario by the IPCC, in combination with insights gained from the literature. However, the structural

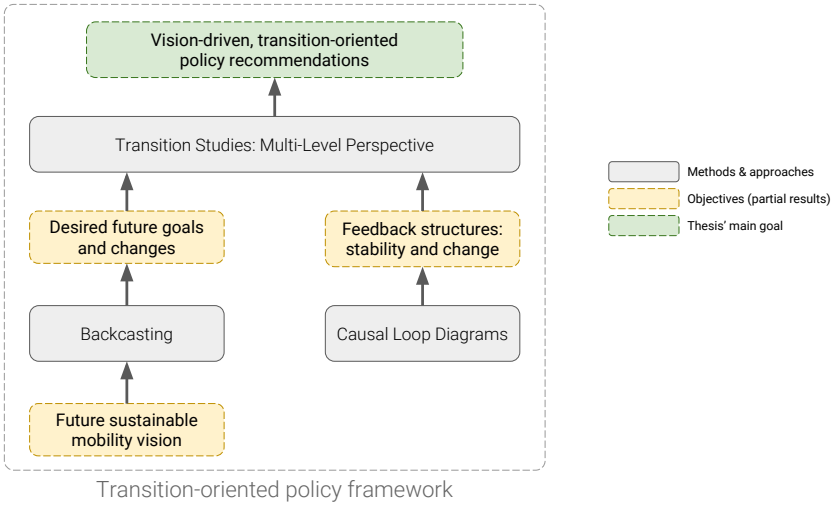



**Figure 2.1** Methodological framework, linking methods to objectives and showing the flow of information until the final aim (policy recommendations) is reached.

elements of the narrative are withdrawn from the IPCC's storyline.

The fact that the IPCC scenarios are developed from a set of narratives actually makes them easier to transform into a "vision" than more traditional scenarios: the IPCC scenarios explore final *states*, rather providing with forecasts. Drawing on the scenario typology built by Börjeson et al. (2006), IPCC's would fall under the "exploratory" scenarios category, while the actual approach of the backcasting process (see Section 2.2) in this thesis would fall under the "normative" category. Despite these seem not to fit, the truth is that in order to build the vision for the backcasting in Subsection 3.1.2, it is very useful to start from the ground of an already developed, consistent and acknowledged exploration of a *possible* future. This way, a lot of assumptions are already justified and the whole vision frame is not purely speculative in nature.

## 2.2 Backcasting: analysing the transition pathway

Next, in order to obtain the desired pathway (Obj. 2) of the transition to the vision, a *backcasting* methodology is used. Backcasting processes are, intuitively, the inverse of forecasts. Instead of extrapolating current trends into the future, they start from a defined end-state or goal that represents a desirable (and somehow plausible) future. Then, either through stakeholder participatory workshops, experts panel consultation or "in-house"[1] processes, a set of intermediate goals are set at whatever time-frames are

[1]Done by the researchers themselves.

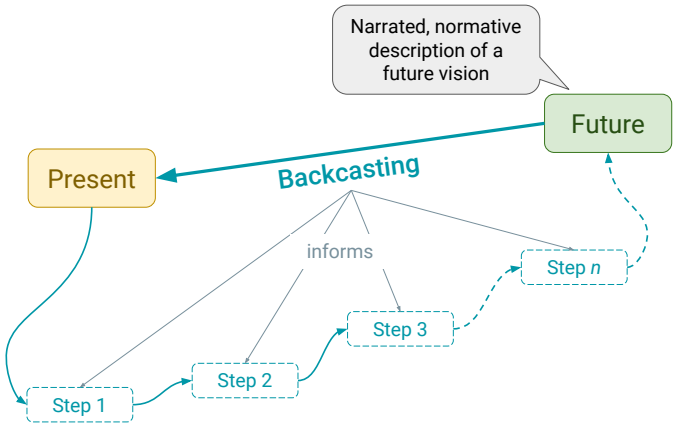



**Figure 2.2** A graphical representation of what the backcasting process entails.

required. The backcasting process is finalised with the identification of the trends and changes that separate the desired future and the current state of the system under study, as seen in Figure 2.2 (Dreborg, 1996). Backcasting usually serves a normative purpose and, most importantly, it is are usually rhetorical in nature, rather than analytical. The strength of this methodology lies in the ability to extend the range of possibilities under consideration (McDowall and Eames, 2006).

The main reason behind this method choice is the fact that backcasting is, in itself, a normative methodology for futures analysis (Börjeson et al., 2006; McDowall and Eames, 2006), something required for (1) filling the gaps identified by this thesis and (2) to help in the derivation of the policy recommendations for Obj. 4. Additionally, backcasting is also a more promising method when great changes are expected or required (Höjer and Mattsson, 2000), which is the case of a transition to sustainable mobility. Note that, due to resource limitations and time budgets, the backcasting process is not based in a participatory approach. No stakeholders are involved, nor an expert panel, thus becoming a limitation in the power of the study, as discussed in Chapter 4. Instead of the participatory approach, the backcasting is based on literature references and insights gained from the IPCC assessment of the SSP1 scenario itself.

## 2.3 Causal Loop Diagrams: analysing current policy resistance

The third objective of the thesis is the analysis of policy resistance mechanisms of the current mobility system (Obj. 3). The chosen method to do this is the development of *Causal Loop Diagrams (CLDs)*. CLDs are the first of the steps used in the broader methodological framework of System Dynamics (Ghosh, 2015). Due to the difficulty

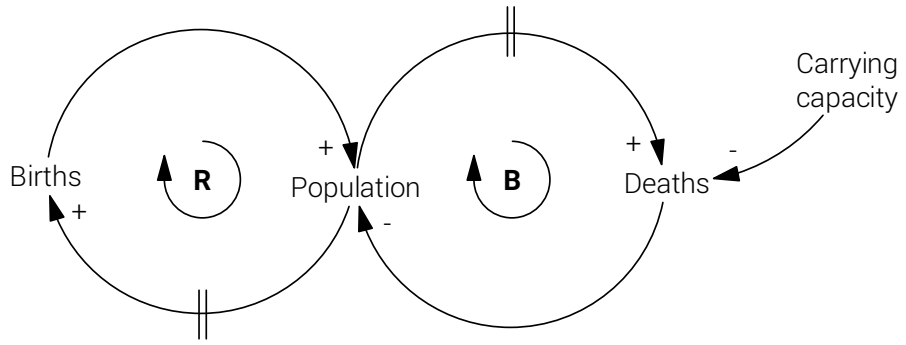



**Figure 2.3** An example Causal Loop Diagram, with reinforcing and balancing loops, that generate dynamic behaviour in the system.

of dealing with entire systems, their internal dynamics and the emergent systemic behaviour patterns, such as feedback loops, rebound effects and hidden causalities, simple linear/mechanistic (conceptual) models are simply insufficient to provide a complete system picture (Forrester, 1972). In this regard, the field of System Dynamics can help capture such structures and cause-effect chains (Hjorth and Bagheri, 2006). An interesting and relevant example of what System Dynamics modelling can achieve is the World3 model in *The Limits to Growth* report from the Club of Rome (Meadows, 1972), where the global food, industrial, population, non-renewable resources and pollution systems were assessed with regards to the limits of the Earth's ecosystems.

CLDs consist of variables linked by causal relations, which can either be positive (directly proportional) or negative (inversely proportional), as displayed in Figure 2.3. Note that these causal links are not quantified in a CLD: the quantification step (attaching equations to the relations) is performed in a further modelling stage, giving rise to "stock-flow" models (Sterman, 2000). An important concept is necessary to interpret the diagrams in the Results chapter: feedback *loops*. These structures are cycles of causes and effects (variables) that are behind the dynamic behaviour of systems. These feedback mechanisms can either *reinforce* or *balance* the overall behaviour of the system. Reinforcing loops are responsible for the exponential growth (or shrinkage) of the involved variables, whereas balancing loops orient the variables asymptotically towards a "target" level (Sterman, 2000).

With regards to how the CLDs were developed in this thesis specifically, the methodology followed was very similar to the process described by Laurenti, Sinha, et al. (2015). A first step was taken to "frame the challenge", this is, to decide what was the problem or issue to tackle—in the case of this thesis, the goal was to identify feedback structures within the socio-cultural dimensions of mobility that reinforce and stabilise the current system. After this, a "core" conceptual model (the CLD) was developed on the basis of insights

gained from the literature. System boundaries were expanded from the core model in order to capture enough causal links as to understand the system's feedback structure. The final step was to "prune" the model, shrinking the boundaries so that it became simpler and easier to convey to the reader. The analysis of the resilience mechanisms and windows of opportunity for change (Obj. 3) is embedded both in the section where the CLDs are developed (Section 3.3) and in the integration through the transitions perspective (Section 3.4) that gives birth to the policy recommendations (Section 3.5).

## 2.4 Multi-Level Perspective: deriving transition-oriented policy recommendations

Regarding the ultimate goal of deriving policy recommendations (Obj. 4 in Section 1.3), no particular welfare (economic) assessment tool was used. The recommendations are general guidelines, not specific numbers on, for example, environmental taxes, thus the decision was made to avoid using a formal economic assessment method. Instead, the policies were *informed* by the transition studies perspective (Kemp, Loorbach, and Rotmans, 2007), which integrates the results of the backcasting process (the transition pathway) and the analysis of the feedback structures in the current mobility system through the use of CLDs.

The integration of the rest of the results through a transitions perspective was done by analysing those same insights through a different *discourse*. The formal method used for rising the CLD and backcasting outcomes to the same discursive level is the so called *Multi-Level Perspective (MLP)*. This analytical framework defines three levels that characterise a socio-technical system (F. Geels, 2001). These levels are associated with micro, meso and macro perspectives, as portrayed in Figure 2.4 (Rotmans, Kemp, and van Asselt, 2001):

(a) The socio-technical *niche* level, at the most microscopic level of the system, is the location where radical innovation occurs. Several processes occur within the niches: the articulation of expectations (visions), the construction of stakeholder networks and learning on different dimensions (organisational, policy, technological, etc.) (F. W. Geels and Kemp, 2012).

(b) The socio-technical *regime* level is situated at the mesoscopic level. It is the virtual space formed by all the actors within a socio-technical system, their shared practices, rules and cultures. Infrastructure supporting the socio-technical system, as well as regulation, and technology belong to the regime level too. In the case of regimes, innovation is not radical. Instead, it is incremental and rather slow, following a pattern of "dynamic stability". Resilience is, thus, a key characteristic of regimes (F. W. Geels and Kemp, 2012).

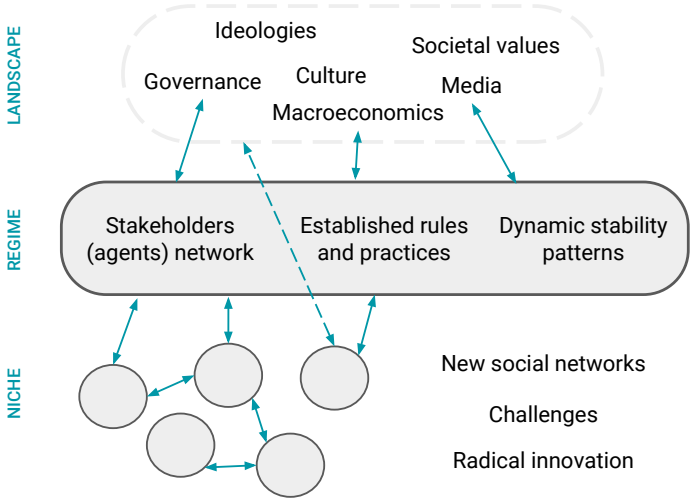



**Figure 2.4** The Multi-Level Perspective analytical framework, with the macro, meso and micro levels visible.

(c) The socio-technical landscape, at the macroscopic level, is the context in which both regimes and niches are embedded. Ideologies, culture, value hierarchies, beliefs, macroeconomic trends, the media, governance systems, etc. belong to this level. The landscape shapes, through pressures and support relations, the regimes and the niches. A characteristic of this level is the slow changes it suffers: regimes come and go, even more so niches, but it can take several decades or even centuries for change in the landscape to become apparent (Rotmans, Kemp, and van Asselt, 2001; Kemp, Loorbach, and Rotmans, 2007; F. W. Geels and Kemp, 2012).

The MLP allows for a multi-dimensional analysis of mobility, because it deals with more than just technologies (or any other aspect of the system: economics, environmental impacts, regulation, etc.). This is ideal to overcome the limitations in scope of traditional transport research identified in the State of the art section. The MLP also addresses structural change by analysing how socio-technical innovations fight for dominance against established regimes. Structural change is an important element in transitions that previous mobility research (or policy) tends to obviate. The MLP also stresses the importance of the patterns of co-evolution between the landscape and regimes and niches. In particular, the MLP (and transitions studies in general) addresses the dynamics of stability and change of regimes and niches (F. Geels, 2011). This specific feature of the MLP serves very well the aim of the thesis of understanding why mobility presents policy resistance and what can be done to tackle it.

Finally, the way in which the MLP is used in the thesis is as follows: the backcasted

changes (Objs. 1,2) that conform the transition pathway are described in the terms of the MLP. The feedback mechanisms that cause policy resistance in today's mobility system (Obj. 3) are then incorporated to the description and also translated into the language of the MLP. Thus, the narration of the transition path contains: (1) normative elements on a broad range of dimensions, stemming from the backcast and (2) a dynamic analysis of the forces that can hinder the transition nowadays. This MLP-inspired analysis is finally used to design a set of policy recommendations that focuses both on the long term goals and on breaking the resilience of the current mobility system that poses an obstacle to its own radical transformation (Obj. 4).

# Chapter 3

# Results

This chapter presents the main results in a logical succession, corresponding with the objectives defined in the Aim and objectives section. The development of a *narrative* of a future sustainable mobility system is given in Section 3.1. In Section 3.2, this storyline or vision is used as the basis of a *backcasting* process to determine the necessary changes to achieve the described sustainable mobility paradigm. Section 3.3 presents a *causal loop model* to build insights on the current state of the (auto)mobility system with respect to its dynamics of change and stability. These dynamics are put in opposition to the necessary changes derived in the backcasting process, discussing and characterising them from the point of view of *transition studies* in Section 3.4. Finally, transition-oriented long-term policy recommendations are given in Section 3.5. A summary of the outcomes of each of the chapter's sections is provided in Table 3.1.

**Table 3.1** Results sections and their outcomes.

| Section | Outcome |
|---|---|
| 3.1 The SSP1-MOB narrative | Description of a sustainable mobility paradigm through a qualitative narrative for the future (2100). |
| 3.2 Backcasting SSP1-MOB | Backcasted necessary changes to achieve the future mobility vision, including an intermediate 2050 mobility paradigm narrative. |
| 3.3 The AUTOLOCK conceptual model | Feedback structure and mechanisms of stability and change of the current (auto)mobility system |
| 3.4 Transitions theory integration | Discussion of the backcasted changes, from a transitions studies perspective, taking into account the feedback structure and mechanisms. |
| 3.5 Transition-oriented policy recommendations | Transition-oriented, long-term policy recommendations to achieve a successful transition to sustainable mobility. |

## 3.1 The SSP1-MOB narrative: a mobility extension of the SSP1 sustainable development storyline

In order to develop a future vision that tells us how mobility is conceived in the year 2100, two main options are available: (a) write and justify a new vision from the ground up or (b) building upon already developed visions found throughout the literature. Both to reduce the time spent on this task and to increase the legitimacy[1] of the result, the second option is chosen. Subsection 3.1.1 deals with the selection of the scenario that forms the basis of the future mobility vision, which is actually developed in Subsection 3.1.2. Finally, a discussion of the vision follows in Subsection 3.1.3, regarding why it is indeed a fundamentally different concept of mobility and in what way is it more sustainable than the current transport system.

### 3.1.1 The SSP scenarios and the selected candidate

The IPCC has recently developed several scenarios that are the basis of their integrated climate change assessments (O'Neill et al., 2017; Vuuren et al., 2017; Fricko et al., 2017; Fujimori et al., 2017; Calvin et al., 2017; Kriegler et al., 2017). These scenarios are called Shared Socio-economic Pathways (SSPs) and are defined on the basis of *qualitative narratives* that contain all the necessary information on globally important issues (demography, governance, economic frames, etc.) to enable a further quantification step, using IAMs, such as the IMAGE model (Vuuren et al., 2017). Given that SSPs are not designed solely for the purpose of climate change studies, but are rather a description of world futures, they can be used in other disciplines and, particularly, in any kind of sustainability studies (O'Neill et al., 2017).

Among the five IPCC SSP scenarios[2], SSP1 "*Sustainability – Taking the green road*" is the one that implies a lower level of both adaptation and mitigation challenges with respect to climate change. Moreover, it is the one that is more aligned with the concept of Sustainable Development, due to its relatively high performance in all three pillars of sustainability: environmental conservation, social and economic sustainability (at least, economic *growth* per capita). Therefore, it is the selected SSP to extend by covering the mobility sector, in order to perform the backcasting process that will be used in Section 3.2 to identify the necessary changes and development goals to reach a sustainable transport system in the future. The extension of the scenario, developed as a qualitative narrative is called *SSP1-MOB*, from here on.

[1] Given that no participatory process is carried to describe or develop the future vision and the corresponding backcasting, expert opinions, in the form of widely accepted scientific scenarios, are used.

[2] The original narratives of all SSP1, SSP2, SSP3, SSP4 and SSP5 scenarios and the explanation of the assumptions taken to develop them can be found in O'Neill et al. (2017).

To help understanding the reference frame of the SSP1-MOB narrative, a brief summary of the original SSP1 storyline is given below. The most relevant items are highlighted here, but it is nonetheless highly suggested to read the narrative and the summary tables in O'Neill et al. (2017). The main aspects upon which SSP1-MOB is built upon are:

- A shift in development patterns towards a more environmentally friendly and socially inclusive society.
- High levels of well-managed *urbanisation*, globally.
- *Effective governance* at all (international, national and local) political levels, as well as increased collaboration between major society stakeholders: private companies and the civil society.
- An accelerated demographic transition that makes population peak at around 2050 to *decrease* to current levels in 2100 (see the population scenario on which SSPs are based in KC and Lutz (2017)).
- Importantly, a change in the political focus, from economic growth-driven policies to *human well-being* ensuring policies.
- *Reduced inequality* intra- and internationally.
- A shift in *investment patterns* for environmental technologies and renewable energies.
- *Low-material and low-intensity* consumption patterns come to dominate.

Furthermore, Vuuren et al. (2017) provide in their paper a more complete frame of the SSP1 narrative, by using it to build a fully quantified energy and economic scenario. Importantly, the model used to derive the figures of such scenario actually provides insights on important mobility-related aspects. The trends they identify in the energy system are also part of the basis on which the SSP1-MOB vision is built:

- Rapidly declining costs for electric batteries and photo-voltaic energy technologies.
- A higher demand for electricity than other scenarios (a necessary increase from the baseline demand levels).
- A thorough decarbonization of the power system (65% of the generation is from renewable energies in 2100).
- Rising dominance of alternative fuels in transport: biofuels in 2050 and electricity and hydrogen in 2100.

### 3.1.2 The SSP1 mobility extension: a narrative for the sustainable future

A particular *vision* of a future sustainable mobility system is outlined in SSP1-MOB. Note that it is not comprehensive description of the myriad of elements composing the system, because it would not be feasible and too many sources of uncertainty would be introduced. Rather, it deals with travel patterns and which travel modes are most common, provided the necessary elements and configurations that make these patterns possible. The intention is that the SSP1-MOB storyline fits within the assumptions of the IPCC's SSP1 scenario as much as possible. The following is the narrated version of SSP1-MOB, describing the global situation of the mobility system in the year 2100, while the features and trends of the narrative, *concerning mobility*, are summarised in Table 3.2.

**SSP1-MOB narrative**

Driven by an increasing level of awareness of the environmental and socio-economic impacts of the transportation system, the world has adopted a series of changes throughout the decades to reduce those. Technology-wise, vehicles have become more efficient and liquid hydrocarbon fuels are less carbon intensive and renewable (based on biofuels). More importantly, though, there has been a major shift in travel modes and, most importantly, total travel demand per capita has been reduced. However, the global absolute total demand has increased, due to economic growth and increases in the living standard of countries in Africa, Asia and South America.

An increase in urban density (1st), a change in land use patterns (2nd) and a de-centralisation of economic development hotspots (3rd) are at the core of the substantial change in travellers' needs and, thus, behaviour. More concentrated urban centres allow for a shortening of trip lengths, up to a point where cycling and walking are feasible alternatives. The size of cities, however, is kept below certain thresholds that permit, in principle, for a more livable and sustainable way of life. This indeed means that a de-centralisation process has taken place, from huge, unwieldy metropolis to medium-sized cities, allowing for (and requiring) a more horizontal[3] governance structure. Moreover, there has been a generalised backlash against single-use urban development, this is, there has been a move towards mixing cultural, residential, work, institutional and commercial uses of the built environment. This form of urban development acknowledges the limitations of single-use schemes, such as isolation and automobility dependence. These de-centralisation and mixing trends allow people to avoid the need for

[3] *Horizontal* governance is meant here as an approach to policy in which cooperation and collaboration across institutions is the norm, in clear opposition to rigid hierarchical power structures. Horizontal governance is also meant here to signify the decentralisation of power and, thus, economic development, in a spatial sense.

relocation to find a job or, for the same matter, commute long distances. Instead, short to medium distances and travel times are the norm when commuting, thus preventing the further need and use of automobiles.

High education levels, widespread access to fast internet and changes in consumption patterns also contribute to lower travel demand. Teleworking is increasingly adopted by companies and in other office-based jobs, allowing people to work from shared co-working facilities that are near home or to avoid commuting altogether. IT access also facilitates the spread of information systems to make car sharing, carpooling and, most importantly, intermodal travel possible (and feasible) — users can access and use travel information to plan their routes easily, reducing both travel time and cost. Less travel intensive consumption patterns have emerged, such as a reduction in long distance tourism. Due to the fact that common consumption objects, such as food and other amenities can be found within the local area, the need to travel far away has been reduced.

When it comes to travel mode alternatives, most of the demand is supplied through public transport, be it in the form of passenger rail, buses or aviation. An increased and continuous heavy investment in public transport infrastructure (an extensive railway network, for example) has enabled fast, secure and low-carbon transport options for the majority of the population, which lives in more concentrated urban areas. High speed trains cover the demand for regional and national trips and even international trips (whenever the distance is not excessive). Regular electric trains and trams are the main mode of transport for interurban commuters and travellers. For less accessible areas, efficient, bio-fuelled, hybrid and electric buses are used. Fast and reliable hybrid or electric buses are also used for relatively short trips within cities. Aviation is used primarily for international travel, but the demand per capita has decreased. With regards to energy carriers for aviation, the main feasible alternative are highly energy-dense biofuels. In general, public transport poses to be a cheaper and more affordable option than automobile-based mobility, both for commuting and for leisure travel. Moreover, the perception of public mobility has changed and is now regarded as the best way to travel, due to higher levels of comfort, security and high reliability.

Even though public transport is the main and dominant travel mode, private mobility (automobility) is still a relevant mode in terms of total travel demand. The main reason for the long term survival of this mode is the higher degree of accessibility it provides, especially in remote, rural areas. This is, automobility fulfils a very specific niche, rather than acting as a mobility "silver bullet". While accessibility is kept at a high level thanks to this travel mode, automobile (cars or two-wheelers) ownership rates are low. Car sharing is common and most urban communities benefit from reduced fleets thanks to carpooling, which is

also commonly available and well accepted by the public. Within the specific mobility market that automobility now occupies, battery electric vehicles are the main car-based technological option used for short to medium ranged trips, such as commuting. Hydrogen-fuelled vehicles take the lead for longer trip distances. The cultural perception of the automobile as a status symbol has declined, in favour of the more environmentally sustainable public transport and slow modes like cycling and walking. Furthermore, the discourse around individual freedom that once legitimised automobility has been deeply challenged by the increasingly sustainability-concerned population.

Finally, slow travel modes such as walking and cycling have been adopted by many to cover the shortest inner-urban trips, especially amongst the youngest. Cycling lanes are an integral part of every urban area road network and public cycling facilities, such as secured parking stations or even public bike rental service schemes, are commonplace. Traffic regulation has been changed to prioritise and ensure the safety of both cyclists and pedestrians. Ample footpaths (sidewalks) provide not only the space for walking but also a more "livable" urban environment. Pedestrian (only) streets are also a common feature of urban neighbourhoods. This allows for a higher degree of community integration, which builds up social capital and increases social networks and safety nets.

### 3.1.3 The sustainable mobility paradigm of SSP1-MOB

The narrative presented in the previous section is meant to be a description of a *sustainable mobility paradigm* of the future. It is important to stress that this paradigm is indeed radically different from, and not solely a continuation of, the current mobility system. The fundamental difference lies not in the transport technologies available (there is no way to forecast or backcast a possible technological breakthrough of the future), but in how mobility is understood and how it is related to lifestyles, how it is embedded in cultural frames and, in turn, how does it shape lifestyles and the infrastructure supporting them.

The SSP1-MOB paradigm is built around an important, but often overseen[4], aspect of sustainable mobility: the overall *reduction in travel demand per capita*. This is, one of the keys to a sustainable future transport system is actually a cut in mobility, which is rooted in (a) land use patterns and (b) urban and economic organisation. Extending from what Moriarty and Honnery (2008) argue in relation to a low-mobility future, by having people's daily activities (jobs, facilities and entertainment areas) closer the need

[4]Many institutions and researchers envision sustainable mobility through the lenses of technological improvements and efficiency gains, deeming them sufficient to tackle the wide range of hazardous impacts of the current transportation system.

**Table 3.2** Qualitative variables underlying to the SSP1-MOB narrative.

| Variable or feature | State |
|---|---|
| **Development scenario** | |
| Societal sustainability awareness | High |
| Total travel demand (Tpkm/yr) | Higher than the baseline (2017) |
| Travel demand per capita (Tpkm/yr) | Lower than the baseline (2017) |
| **Land use (urban development)** | |
| Urban density | High (higher than 2017 baseline) |
| Urban use patterns | Mixed-use development paradigm |
| Economic centralisation | Medium; cities are hotspots, but jobs are spread amongst them |
| City sizes | Medium; avoidance of megacities or (sub)urban sprawl |
| **Travel modes share** | |
| Intermodal travel | Facilitated, high acceptancy and usage |
| Public transport (rail, bus, aviation) | Majority of demand supply; much higher than the baseline (2017) |
| Automobility (private vehicles) | Still relevant, but much lower than the baseline (2017) |
| Slow modes (walking and cycling) | Higher than the baseline (2017) |
| **Cultural perception** | |
| Mobility | Accessibility, local in scale, slowed down, managed, reasonable travel time and reliability, integrated |
| Public transport | Public mobility as a reliable, comfortable, enjoyable and accessible service |
| Automobility | Automobility as a utility to serve a special need |
| **Public transport** | |
| Reliability | High |
| Consumer cost | Low |
| Accessibility | High |
| Safety | High |
| Public transport infrastructure investments | High and continuous |
| **Automobility** | |
| Reliability | High |
| Consumer cost | High |
| Accessibility | High (especially in rural or remote areas) |
| Safety | High (higher risk than public transport) |
| Automobility infrastructure investments (roads, fuel stations, etc.) | Low to medium; maintenance covers the majority of the investments; capacity is not increased |
| **Fuel technology** | |
| Automobiles | Battery electric vehicles for short-medium ranged trips; hydrogen fuelled for long range |
| Rail | Full electrification of the network |
| Bus | Electric or hydrogen-fuelled |
| Aviation | Renewable biofuels |

for mobility is reduced. In turn, a lower need for travel ends up shaping the lifestyle in which the mobility paradigm is embedded, by reinforcing the urban "re-localisation" pattern.

Therefore, in the future of SSP1-MOB, mobility is conceived no longer as a right that must be guaranteed nor as a "fundamental human desire" to be pursued. Mobility is understood for what it really is: a service/activity whose demand is *derived* from the activities that are performed at the end of the trips themselves. Following this mental framing of mobility, together with the (assumed) wide acknowledging of the impacts derived from this demand, it is both the activities that drive mobility and the transport system itself that are conceived differently: the era of private, pervasive, cheap, long-distance travel has been left behind in SSP1-MOB. Lifestyles have been accommodated to (a) avoid the need of (high) mobility, (b) take advantage of extensive and highly reliable public transport networks and (c) embrace active transportation (cycling and walking) as soon as the circumstances allow for it.

Urban planning is not the only cause of reduced travel demand and automobility independence. Low-mobility social and entertainment activities are dominant in SSP1-MOB, in clear opposition to, for example, the current trends of increased intercontinental tourism (which is taken by many as a yearly option for their holidays). Local, cultural or social activities are engaged by the majority of the population, which enhances the social bonds of the community, further decreasing the desire of individuals to "flee" from dense urban areas to be "left on their own".

Finally, with regards to the direct environmental impacts of transportation, the SSP1-MOB paradigm also contains insights into what a sustainable form of mobility entails. Air pollution is kept to the absolute minimum in the SSP1-MOB vision: the only carbon-intensive means of transportation are aviation and biofuelled vehicles. However, these are assumed to be rare and account for a small proportion of the total mobility demand. In this regard, the extensive electrification of the transport network (both train and electric buses and cars) has meant a true technological revolution. Other hazardous impacts of mobility, such as accidents and noise pollution, are kept at very low levels too, since the automobility demand has vastly reduced.

## 3.2 Backcasting SSP1-MOB: intermediate goals to achieve a sustainable transition

The SSP1-MOB vision of the future described in Section 3.1 is used in the following sections to synthesise the changes that the mobility paradigm must undergo[5] to reach the desired form. The synthesis is done using backcasting approach, for which an "intermediate step" is presented in Subsection 3.2.1. This halfway step is described in terms of the same variables highlighted in Table 3.2, but adding information for the year 2050. The baseline "scenario" status of 2017 is also provided in Subsection 3.2.1. The changes between the 2100 and 2050 storylines, along with the ones between the 2050 narrative and the baseline are then provided in Subsection 3.2.2.

### 3.2.1 SSP1-MOB 2050: an intermediate step to sustainable mobility

In order to ease the identification of changes and trends within the backcasting process of Subsection 3.2.2, an intermediate step for the year 2050 is developed and displayed in Table 3.3. The comparison table contains the variables for the 2100, 2050 and 2017 (baseline) years. With regards to the baseline, numerous data sources have been consulted, with as high as possible quality standards. The list of sources mainly consists of databases from global agencies or multinational regions, like the International Energy Agency (IEA) or the European Commission (EC). Even though there are some inconsistencies regarding the data collection years, the range is considerably limited: only data from 2005 is considered. However thorough the baseline data research was, some variables were actually assumed to have some (qualitative) value, which is generally aligned with the insights that authors dealing with sustainable mobility provide. For those variables where an estimation was infeasible or supporting data was unavailable, an "assumed" label is displayed.

**Table 3.3** Comparison of SSP1-MOB qualitative variables (2017, 2050 and 2100).

| | Trend or status | | |
|---|---|---|---|
| Variable or feature | 2017 | 2050 | 2100 |
| **Development scenario** | | | |
| Societal sustainability awareness | Low (assumed) | Medium | High |
| Total travel demand (Tpkm/yr) | approx. 50 Tpkm/yr[1] in 2010 (Vuuren et al., 2017) | Higher than the baseline (2017) | Higher than the baseline (2017) |
| Travel demand per capita (Tpkm/yr) | approx. 7300 pkm/yr in 2010 (Vuuren et al., 2017; KC and Lutz, 2017) | Similar to the baseline (2017) | Lower than the baseline (2017) |

[5] The changes are not "suffered" by an autonomous and disconnected system of mobility, but are introduced by all the agents that play a part in it: users, industries, governments, decision makers, researchers, planners, etc.

(*continued*) Comparison of SSP1-MOB qualitative variables (2017, 2050 and 2100)

| | Trend or status | | |
|---|---|---|---|
| Variable or feature | 2017 | 2050 | 2100 |
| **Land use (urban development)** | | | |
| Urban density | 0.9% urban pop. in >40000 p/km2 areas; 4.8% in 20000-40000 p/km2; 18.3% in 10000-20000 p/km2, 51.4% in 4000-10000 p/km2; 15.2% in 2000-4000 p/km2 and 9.4% in <2000 p/km2 (Cox, 2017) | Medium-high and increasing | High (higher than 2017 baseline) |
| Urban use patterns | Single-use is widespread, mixed-use for cities (assumed) | Mixed-use development paradigm | Mixed-use development paradigm |
| Economic centralisation | High; metropolis accumulate a big share of the activity (assumed) | High; metropolis accumulate a big share of the activity | Medium; cities are hotspots, but jobs are spread amongst them |
| City sizes | 8.4% >10M[2], 4.2% 5-10M, 5.4% 2.5-5M, 6.5% 1-2.5M, 4.8% 0.5-1M, 70.7% <0.5M (Cox, 2017) | Medium to large; megacities and (sub)urban sprawl beginning to shrink | Medium; avoidance of megacities or (sub)urban sprawl |
| **Travel modes share** | | | |
| Intermodal travel | Long distance (>100 km) travel is mostly (80%) by car. Intermodality is confined to urban and regional mobility. (Riley et al., 2010) | Facilitated, but still not common | Facilitated, high acceptancy and usage |
| Public transport (rail, bus, aviation) | 40.17% share (pkm/yr) approx. from (Vuuren et al., 2017) | Increasing demand supply; higher than the baseline (2017) | Majority of demand supply; much higher than the baseline (2017) |
| Automobility (private vehicles) | 35.90% share (pkm/yr) approx. from (Vuuren et al., 2017) | Lower than the baseline (2017) | Still relevant, but much lower than the baseline (2017) |
| Slow modes (walking and cycling) | 23.93% share (pkm/yr) approx. from (Vuuren et al., 2017) | Moderate increase compared to baseline (2017) | Higher than the baseline (2017) |
| **Cultural perception** | | | |
| Mobility | Understood as a right and an individual-social emancipation mechanism (through tourism and recreational mobility) (Sheller, 2008) | Accessibility as a focus, managed, reasonable travel time, integrated | Accessibility, local in scale, slowed down, managed, reasonable travel time and reliability, integrated |
| Public transport | PT as an affordable solution, but marginal and regarded as a low-status form of mobility (assumed) | Public mobility as an affordable and accessible service | Public mobility as a reliable, comfortable, enjoyable and accessible service |
| Automobility | Shaped by structured stories of "joy of driving", freedom and individuality discourses (Gartman, 2004; Sheller, 2012) | Automobility fills accessibility gaps; symbolic status decreasing | Automobility as a utility to serve a special need |
| **Public transport** | | | |
| Consumer cost | Medium-High (in many countries, public transport is not affordable for the 20% lowest-in-income population (Carruthers, Dick, and Saurkar, 2005)) | Low | Low |
| Accessibility | Low (assumed) | Medium-high | High |
| Safety | Fatalities (EU): 993 railway (27 passengers, 34 employees, 932 other[3]), 155 aviation, (2015) (Eurostat, 2017a) | High | High |
| Public transport infrastructure investments | Rail: approx. 30% of total infrastructure investments in Europe (2010, average for WECs[4] and CEECs[4]) (Kauppila, 2012) | High and continuous | High and continuous |
| **Automobility** | | | |
| Consumer cost | Low-Medium (assumed) | Medium | High |
| Accessibility | High (assumed) | High | High (especially in rural or remote areas) |
| Safety | 1.2M road deaths in the world, 28077 in the EU (2013) (WHO, 2017) | Medium (especially Low Income Countries) | High (higher risk than public transport) |
| Automobility infrastructure investments | Roads: approx. 70% of total infrastructure investments in Europe (2010, average for WECs and CEECs) (Kauppila, 2012) | Medium; maintenance dominates in HICs[5]; capacity increased in LICs[5] | Low to medium; maintenance covers the majority of the investments; capacity is not increased |

(*continued*) Comparison of SSP1-MOB qualitative variables (2017, 2050 and 2100)

| | Trend or status | | |
|---|---|---|---|
| Variable or feature | 2017 | 2050 | 2100 |
| **Fuel technology** | | | |
| Automobiles | 96% fossil fuels (oil products & natural gas), 4% biofuels (IEA, 2017) | Battery electric vehicles and hybrids for short-medium ranged trips; biofuelled for long range | Battery electric vehicles for short-medium ranged trips; hydrogen fuelled for long range |
| Rail | 57.3% oil, 5.6% coal, 36.4% electricity (Cazzola, Gorner, and Schuitmaker, 2016) | Full electrification of the network | Full electrification of the network |
| Bus | 96% fossil fuels (oil products & natural gas), 4% biofuels (IEA, 2017) | Hybrid, or biofuelled | Electric or hydrogen-fuelled |
| Aviation | 100% fossil fuels (IEA, 2017) | Renewable biofuels | Renewable biofuels |

[1]Tpkm/yr stands for "tera passenger-kilometers per year"
[2]M stands for millions (population)
[3]Only 12% of the total 993 reported fatalities linked to rail in the EU were passengers or employees. The remaining 88% were people at, e.g., level-crossings or unauthorised people at rail premises (Eurostat, 2017b)
[4]WECs: Western European Countries; CEECs: Central and Eastern European Countries
[5]HICs: High Income Countries; LICs: Low Income Countries (considered in terms of the baseline situation)

### 3.2.2 The backcasted path to SSP1-MOB

The path to the sustainable mobility paradigm represented by the SSP1-MOB vision is made of several trends that can be organised in the categories that the following paragraphs cover: (a) development scenario and land-use changes, (b) cultures of mobility, (c) travel mode shifts: enablers and (d) vehicle and fuel technologies.

#### Development scenario and land-use changes

The transition path to the world of SSP1-MOB entails profound changes beyond the traditional (and certainly narrow) scope of many transport studies[6]: it involves changes in land-use patterns, especially with regards to urbanisation, as well as a parallel transition in the energy system. The most important changes identified with respect to the trends that surpass the mobility system are summarised in the enumeration below, while Figure 3.1 provides with a visualisation of the change in the qualitative levels of some of the development scenario variables.

1. The societal awareness level concerning sustainability issues such as, but not limited to, climate change, pollution, biodiversity loss, material resources depletion and fossil fuels depletion, *must rise significantly* (O'Neill et al., 2017; Vuuren et al., 2017). Environmental, economic and social concerns must be put at the forefront of the political discourses all across the civil society, governments, institutions and

[6]According to Creutzig (2015), two of the three main low-carbon transport research communities focus on: (a) transport sector models and (b) place-based models for behavioural management. Both these approaches fail to either up-scale beyond the analysed system or to analyse inter-systemic (cross-sectoral) interactions.

companies in the private sector. Mobility, as an intrinsic element of a sustainable lifestyle, must occupy a more central role in the political arena, discussed and planned more carefully and thoughtfully by all the involved stakeholders.

2. Following the SSP1 original storyline, the overall level of urbanisation *must increase*, but it has to do so in a well managed way (Jiang and O'Neill, 2017). This involves, among other aspects:

   a) Urbanised areas have to become *denser* in many parts of the world, in order to reach a more efficient form of living — highly dense populated areas contribute to diminishing the aggregated travel demand. In other parts, such as large megacities, a lower density is desired and required for a more socially livable environment (Camagni, Gibelli, and Rigamonti, 2002).

   b) City sizes (in terms of population) must be accommodated to achieve a high level of efficiency, such that travel distances become smaller for a majority of the population — thus decreasing the overall travel demand. However, avoidance of unwieldy huge metropolis must emerge as an urban planning norm as well, due to the associated inefficiencies of such schemes, in terms of transport infrastructure and personal mobility (too long distances and unacceptable travel time and/or congestion levels) (Verhoef and Nijkamp, 2002; Camagni, Gibelli, and Rigamonti, 2002).

3. Urban and infrastructural planning must also suffer a shift of paradigm: single use landscapes must be abandoned in *favour of mixed use urban areas*. The blend of living, work, recreational, educational and commercial spaces will allow for (a) a lower travel demand and (b) a shift in travel patterns towards slow modes (walking and cycling) and public transport (Banister, 2008; Muñiz and Galindo, 2005).

4. Economic centralisation must be progressively abandoned in order to de-centralise the need for mobility, potentially reducing travel demand. Planning and de-centralising strategies must be put in place, in clear opposition to the current trends of building technology hubs or similar economic structures (Banister and Berechman, 2001).

5. In order to favour a de-centralisation of the economy, as well as reducing inequalities in mobility access across urban areas, the structure of governance must become flatter and more horizontal (O'Neill et al., 2017). A more localized and less hierarchical governance scheme can distribute resources aimed at mobility in a more spatial-efficient way, thus improving public transport networks everywhere, instead of just the metropolis. Moreover, infrastructure can be turned into a more efficient distributed network, instead of the current trend to build and support radial pattern.

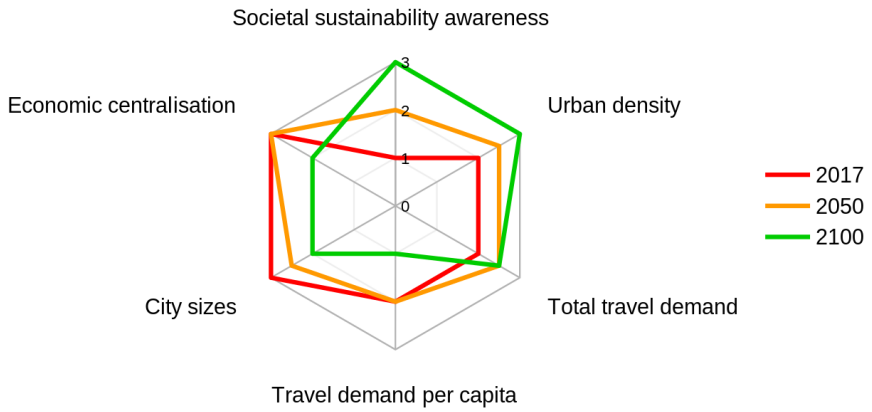



**Figure 3.1** Radar graph showing the shifts in development trends and land-use patterns found in SSP1 and SSP1-MOB for the years 2100, 2050 and 2017 (baseline). The following values are given to the qualitative variables: 3 for high, 2 for medium and 1 for low.

6. Another very important feature of the original SSP1 storyline is mandatory for the decarbonisation of the transport system and for enabling a cleaner and more efficient form of mobility: the transition from a carbon-intensive to a low-carbon, extensive energy system. Electrification of the transport system is simply not possible without a more extended power grid. Furthermore, in order to cut down the indirect $CO_2$ emissions, the power system must also be built around renewable energies as much as possible (Vuuren et al., 2017).

### Cultures of mobility

As already highlighted in the Section 3.1.3, one of the key preconditions for the transition to a sustainable mobility paradigm is a change in the *cultural perception* of mobility (how is it understood). The currently generalised notion of privately owning the means of transportation, namely automobiles, must be challenged if support for public transport is to grow. It is evident that such a challenge goes beyond the culture of mobility, into the general frame of material and ownership cultures. A reduced desire for both private ownership and private freedom of mobility —which are in opposition to collective ownership and collective freedom— would also pave the way for car sharing and carpooling schemes, which are currently deemed as lower-status, inconvenient alternatives. Therefore, it is the discourses around personal freedom and private property that must be radically challenged (Zijlstra and Avelino, 2012).

Another key aspect of the mobility culture that must be challenged in the future is the conceptual link between movement and (again) the omnipresent discourse on freedom that forms the ideological core of the (neo)liberal society. The mental connection between freedom and freedom of movement must be broken if a reduction in travel demand is desired for the future of SSP1-MOB. The dissociation proves to be difficult, though, since the connection between freedom and mobility is strongly supported by the capitalist economic and ideological framework (Freudendal-Pedersen, 2009; Sheller, 2012). However, the detachment of mobility from the general concept of freedom is promising from the sustainability point of view; if individual freedom is to emerge from other "sources" other than free movement, it is expected that the travel demand per capita gets lower. This is indeed related to the desired reduction of demand in SSP1-MOB, as portrayed in Figure 3.1.

Particularly, with regards to the most prevalent form of transportation nowadays, the automobile, a lot has to change in its perception from a cultural perspective. If the share of automobile demand has to drop so dramatically as portrayed in SSP1-MOB (from a dominant position to a niche-filing solution), a number of its cultural "components" (Urry, 2004) must be contested and changed:

1. Cars must not be conceived as technological marvels to be worshipped. Instead, they must be understood for what they are: tools for mobility.
2. A change in the value attributions to automobiles is necessary as well, in order to stop it being the second most item of individual consumption, after housing. Values such as freedom, safety, sexual drive or speed must be dissociated from automobiles.
3. Cultural discourses, imagery and symbolic status of automobiles as constituents of the "good life" must be contrasted with the impacts that it actually causes; they must be culturally subverted.
4. The subordination of other forms of mobility, such as slow modes, to automobility has to be contested. A new hierarchy of mobilities is needed for a future of denser, bigger and more compact urban areas.

Finally, the shift of cultural perspective must happen not only at the user level, but also at the urban/traffic planner's. Banister (2008), drawing from Marshall (2001), presents some of the foundation stones of the change to such a sustainable mobility planning paradigm:

1. Instead of speeding up traffic, slowing it down must be the new target for both users and planners.
2. Streets have to be seen as a space for urban life, rather than just public spaces occupied by private automobiles only.

3. Social and environmental multicriteria analyses regarding mobility need to be performed in addition to the already dominant (and only) economic assessments in urban planning.

4. Larger travel *times* for similar or reduced travel *distances* must become acceptable, in contrast to the current ever accelerating pace of society and mobility.

5. In general, attention has to shift from vehicles to people: human, personal mobility should be at the core of the frame, opposed to purely vehicle mobility.

One last remark is worth to be discussed here, with regards to point 4 in the previous enumeration. An important and overseen aspect of sustainable mobility is the different conception of time. Drawing from the analysis that Zijlstra and Avelino (2012) make about cultural trends that support automobility, *time* has played a central role in modern (capitalist) societies. The concept of time *gaining* is so deeply embedded in modern cultures that acceleration, be it in production lines, communications, shopping activities or, relevantly, transport, has become a paradigmatic goal for almost any development effort in our society. Although not being explicit in the SSP1-MOB narrative, a change of mindset with respect to time is also desirable, since it would flatten the path for slow modes to take over. An example of such a change in lifestyles is already portrayed by *slow cities* (Mayer and Knox, 2006).

### Travel mode shifts

One of the key aspects of the path to SSP1-MOB is travel mode shifting. This is, the relative reduction or increase in the demand share of the various travel modes available until 2100. This shift is visually shown in Figure 3.2, where the desired shares for 2050 and 2100 are portrayed, in accordance to the estimates given by Vuuren et al. (2017).

With respect to the previously discussed components of the backcasted path, culture and land-use patterns are not the only means to achieve the kind of transport mode shift shown in Figure 3.2. Two more patterns of change are identified in the SSP1-MOB narrative that should enable faster mode shift rates:

1. Demand management should play a more central role in traffic/urban planning. Following the terminology by Goodwin (2012), planning should evolve from a road-centered "predict-and-provide"[7] approach to a truly multi-modal "predict-and-manage" perspective. Traffic calming, road and congestion pricing mechanisms, multi-modal demand modelling and public transport facilitating policies (through, e.g., subsidies) should become commonplace in the future, in order to gradually shift travel demand towards the more sustainable transport modes.

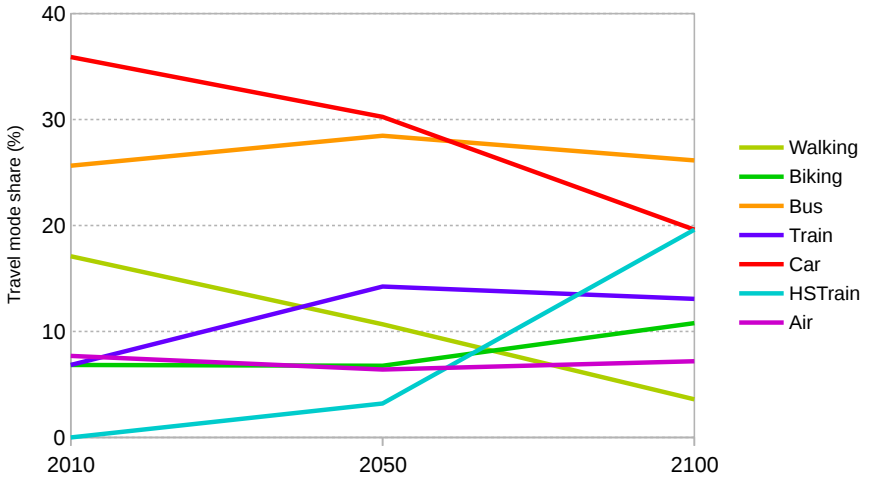
[7] Goodwin (2012) originally refers, specifically, to infrastructure (roads/urban) planning approaches.

2. Intermodal travel must become a reality in the SSP1-MOB world: it is the most prominent way to reduce unsustainable car usage in long-distance trips settings. Automobility is predominant in this type of trips, due to the (perceived) inconvenience of public transport, high costs of non-integrated public transport networks and lack of proper travel information for the end user (Riley et al., 2010). Therefore, public transport networks must become integrated at much larger scales, with affordable fares and, very importantly, technologies must be developed to convey the necessary information to the users.

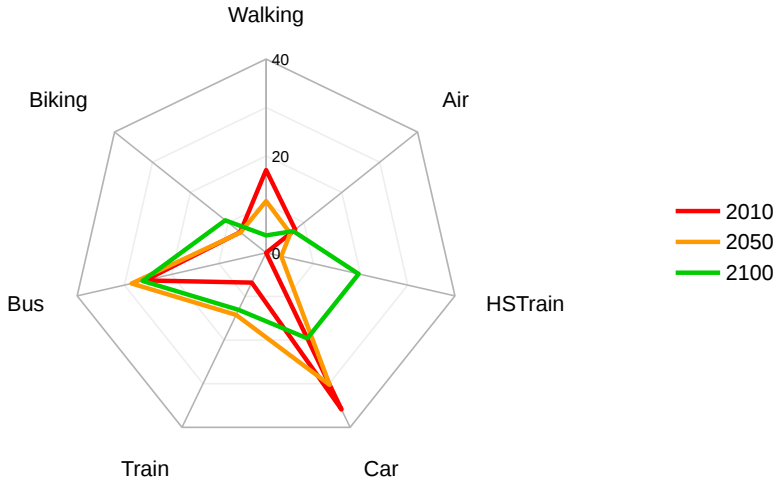
#### Vehicle and fuel technologies

Finally, there is another key category of changes within the transport system that must be tackled in order to follow the path of SSP1-MOB: efficiency increases and technological progress. This applies mostly to the transport technologies themselves: vehicles must be made much more efficient if they are to be run on carbon-based fuels. An extensive electrification of the vehicles is also desired to reach not only low-carbon technologies, but also low-noise, low-emission vehicles that stop polluting the urban areas' air.

With regards to vehicle and fuel technologies, the SSP1-MOB narrative assumes the very high efficiency gains also assumed by Vuuren et al. (2017) in their implementation of the SSP1 storyline. SSP1-MOB also draws from this implementation the higher share of renewable (bio)fuels in the transport sector and the emergence of hydrogen powered vehicles from 2050 onwards. Needless to say, these technological advances are linked to broader changes in the political and industrial arenas. A political will to devote resources into research and development of key technologies must be developed and, in turn, transport companies must embrace and push for a change in the technological bases of their products.




(a)




(b)

**Figure 3.2** Evolution (a) and comparison (b) of total travel demand per transport mode (shares), in percentages, across the SSP1-MOB futures and the 2017 baseline. Note: the demand shares are approximated from the figures provided by Vuuren et al. (2017) in their quantitative appraisal of the SSP1 scenario.

## 3.3 The AUTOLOCK conceptual model: feedback structures and dynamics of automobility

This section is devoted to the investigation of the feedback structure that supports and shapes the system of automobility. The choice of studying this particular transport mode is based on a triad of arguments: (a) the clear dominance of the automobile as the main mode of transport globally (in terms of travel demand), (b) the huge inertia, complexity and stability that the system has historically posed against threats to its dominance and (c) the fact that this dominance and resilience have become an obstacle for modal shifts, or more generally, a transition to sustainable mobility. Therefore, it is worth it to take a closer look at the dynamics that secure the position of automobility in its current status.

As an example of the automobility resilience, the system has "survived" the 1970s oil crisis, the "dieselgate" scandal[8] (The Guardian, 2017), or even the 2008 global financial crisis. Figure 3.3 shows the global production of cars from 1961 to 2015, clearly depicting the effects of the financial crisis, whilst acknowledging that production has kept increasing nevertheless.

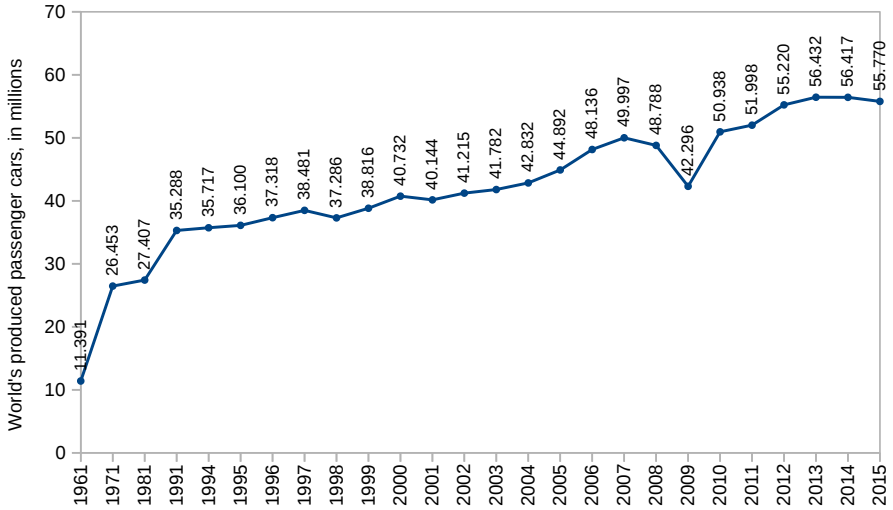



**Figure 3.3** Global passenger car production 1961-2015. Source: own figure; original data from Bureau of Transportation Statistics (2017).

As already mentioned in the Methods chapter, the study of certain feedback structures of

[8] "Dieselgate" refers to the Volkswagen emissions scandal that started in September 2015, when the U.S. Environmental Protection Agency reported that the German automotive industrial group had been faking emission control tests. This caused the $NO_X$ output to be lower in the certification tests than in real-world driving scenarios, thus being able to meet U.S. and European emission standards.

the system, detailed in the following subsections, is carried out through a series of Causal Loop Diagrams (CLD). Because of the resilient nature of the automobility regime, the collection of CLDs that form the overview of the system is referred to as the AUTOLOCK model. Subsection 3.3.1 discusses the stability mechanisms of automobility from an urban planning (land use) perspective. Next, the cultural basis and legitimacy apparatus of automobility is described in Subsection 3.3.2.

**Note:** with regards to notation: (a) CLD variables are denoted by a different font face, such as This Example and (b) causal loop (*reinforcing* or *balancing*) are denoted by the labels assigned in the diagrams, as in **R1**.

### 3.3.1 Urban planning and automobility

Historically, automobility is linked to the development of road infrastructure on one side and on cultural discourses that legitimise the adoption of private mobility on the other (Goodwin, 2012; Gartman, 2004; Sheller, 2012). Figure 3.4 shows the core reinforcing mechanism of automobility, which is founded on the mobility possibilities it supports, through increased Accessibility due to augmented Road capacity. Higher Automobility demand drives higher Congestion, putting pressure for more Road investments. Accessibility, coupled to a cultural background based on ideals of freedom, is seen as a major enabler for climbing up the social ladder, thus increasing Automobile ownership and closing the **R1** reinforcing loop — the *Automobility freedom* loop. With regards to the **R2** reinforcing loop, it accounts for a well-known rebound effect of motorway capacity expansion: induced travel demand (Hymel, Small, and Dender, 2010; Thill and Kim, 2005). Most importantly, the cultural framework, represented by Cultural legitimacy of automobility, ultimately legitimises and supports these feedback structures.

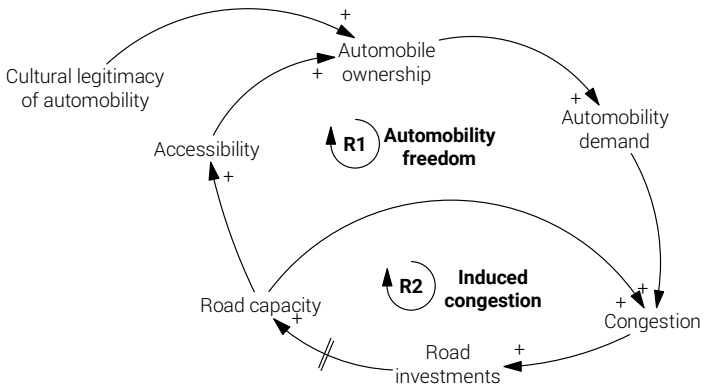



**Figure 3.4** AUTOLOCK socio-spatial perspective: freedom and congestion.

The increased accessibility provided by the ubiquitous construction (and expansion) of roads, coupled with low fuel/vehicle prices stirs the development of suburbs and causes a focus shift from the planning perspective, from integrated areas towards car-based single-use ones: the Single-use urban development variable in Figure 3.5. Automobility demand grows to meet the new requirements derived from the suburban lifestyle, namely the increase in spatial separation of jobs, housing, commercial and recreational areas; in other words, Average travel distance. Due to the low population density found in single-use urban developments, public transport becomes infeasible and expensive to maintain. Thus, the automobile rises as the single viable alternative for the residents of the suburbs, closing the **R3** reinforcing loop of *automobility dependence*. This particular feature of the automobile system is particularly relevant for the focus of the present study. Automobility dependence locks in automobile users, planners, developers, etc. within the system practices space and forces them to adapt their lifestyles to this form of mobility (S. Cullinane and K. Cullinane, 2003; Köhler et al., 2009)[9].

Even though many cities worldwide have begun taking efforts to reduce automobile dependency (and have been doing so for years), it is critical to understand that the existing infrastructure, the huge sunk investments that have been brought into such infrastructure and the overall spatial organisation of residential, commercial and working areas has been built over many decades — the inertia that these developments have is enormous (F. Geels et al., 2012). Not only because of the large amounts of resources that are needed to re-shape roads, cities and suburbs globally, but because the lifestyle that automobility is tied to has become deeply entrenched in cultural frameworks (as discussed in Section 3.2 and Subsection 3.3.2).

Finally, Figure 3.6 presents additional balancing loops that restraint the further growth of mobility: some of them are endogenous, while some others (**B2** and **B3**) are exogenous[10]. For instance, Average travel time is an important factor contributing to the perceived accessibility that automobiles provide. If, due to congestion or longer travel distances, the time spent is excessive, the user might not find it convenient (accessible) to drive around. **B1** captures this phenomenon. When Demand management policies (e.g., road pricing) are introduced, another balancing feedback is produced, creating the **B2** loop (Banister, 2008; Dudley and Chatterjee, 2012).

Furthermore, the use of Mixed-use urban development techniques reduces, with time, the Average travel distance, thus alleviating the pressure on Automobility demand, portrayed in the **B3** balancing loop. However, the mutual exclusivity between mixed and single-use

[9] The concept of *practice space* is used by Köhler et al. (2009) to represent transport alternatives (including automobility) in their modelling and simulation of a sustainable transition.

[10] *Endogenous* refers to dynamics arising from the inner-workings of the system or to actions to support it (single-use planning), while *exogenous* refers to external measures/policies intended to counteract automobility use.

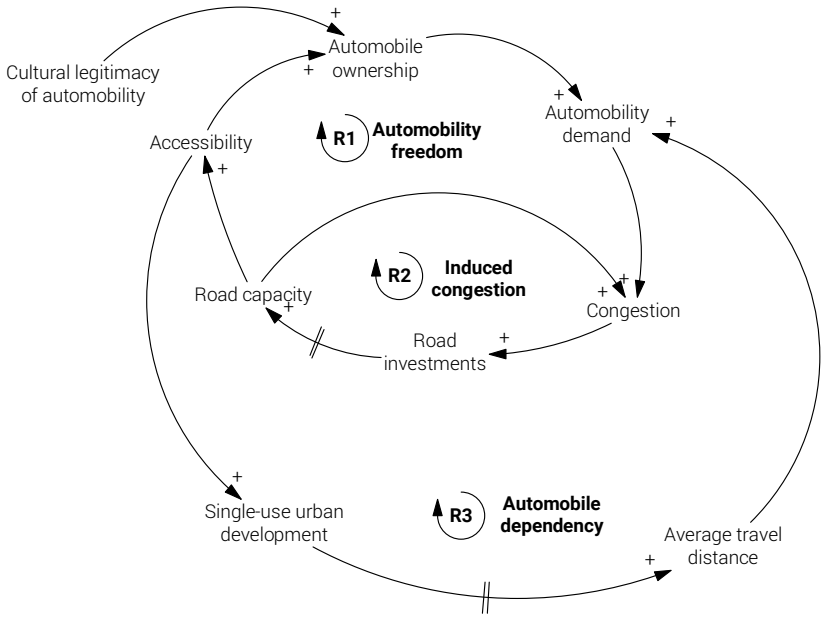



**Figure 3.5** AUTOLOCK socio-spatial perspective: building automobile dependence.

development patterns found in many regulatory frameworks (Hirt, 2007) means that they are in direct competition: if one planning practice increases, the other decreases and vice-versa. This feature is captured by the reinforcing loop **R5**. Finally, in a similar fashion to **B1**, another balancing force opposes the absolute dominance of automobiles: if suburbs grow in size and extension, not only time, but Average travel distance increases, thus reducing the perceived Accessibility, giving rise to **B4**.

### 3.3.2 Cultural legitimacy feedbacks

A highly relevant issue to discuss, with respect to the cultural dimension of automobility, is the legitimacy apparatus that supports it and, at the same time, dis-legitimises other forms of mobility (public transport, cycling, etc.). Due to the limitations in the scope of this study, only this central aspect will be analysed, since the range of practices and discourses that form the body of the automobility culture is huge. Therefore, this subsection is aimed at revealing the dynamics behind the *acceptance* of automobility as a cultural reality.

Figure 3.7 draws from the CLD diagram in the previous section. The core reinforcing mechanism that drives Automobility demand growth (**R1**), is based on the Cultural legitimacy of automobility. However, unlike the CLD model in Subsection 3.3.1, cultural

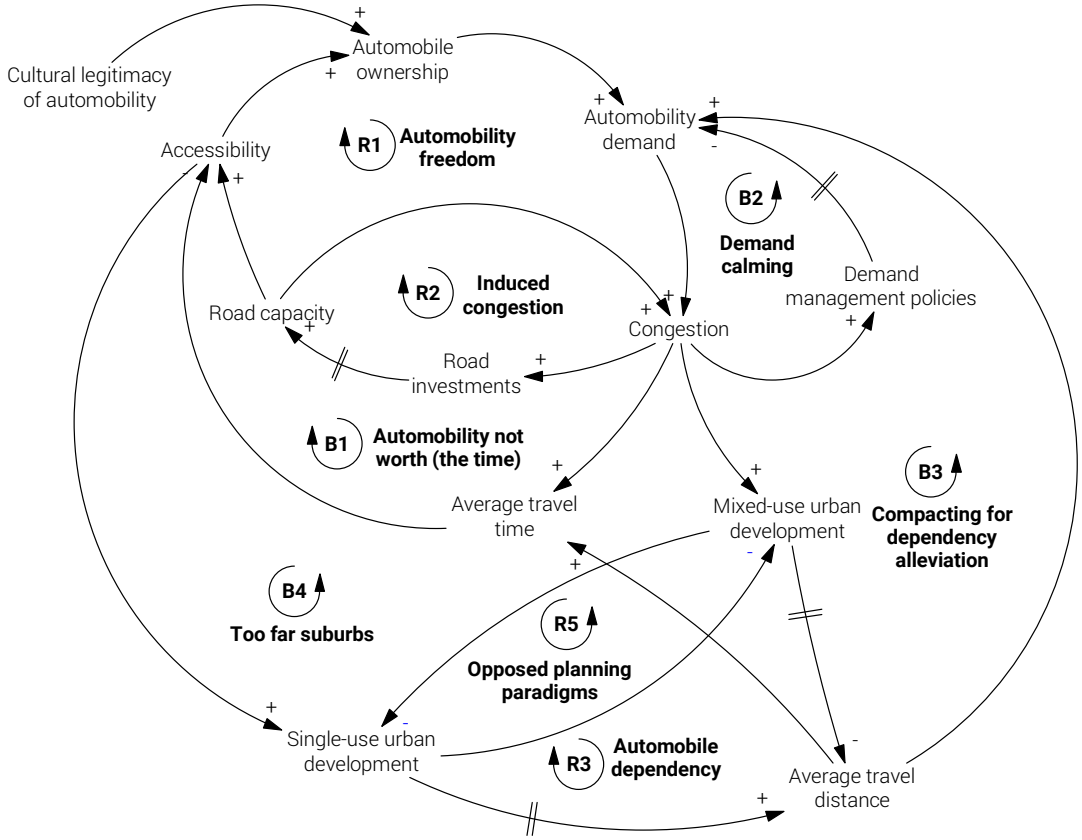



**Figure 3.6** AUTOLOCK socio-spatial perspective: balancing forces.

legitimacy is not an external (supporting) force, but rather an integral part of the *Freedom to move* discourse that sustains **R1**. The Automobility capacity variable is meant as the user's perception of the potential to access more destinations (accessibility) through better, uncongested roads (road capacity). Therefore, Automobility capacity is directly and proportionally linked to cultural legitimacy, since the perception of a higher "degree of freedom" reinforces the belief (the legitimacy) that automobility is the *right* alternative to choose. However, there is a clear precondition that must hold to support this legitimacy dynamic: an framing Discourse on individual freedom as the highest (moral) value in the values hierarchy (Urry, 2004; Böhm et al., 2006; Sheller, 2008).

Secondly, Figure 3.7 shows another reinforcing loop, **R2**, that also contributes to increasing the Cultural legitimacy of automobility. It does so by providing the necessary lifestyle satisfaction (beyond the realisation of *freedom*). Increased Automobility capacity enables the fulfilment of activities that (have) become embedded in the lifestyle: practices such

as commuting, car-based grocery shopping, chauffeuring family members, weekend and holidays car-based tourism, etc. It is then important to understand that a lifestyle is a meaning carrier. Lifestyles are used to express one's identity, a "narrative of the self". Lifestyles are made of behaviours, conducts and practices that are adopted beyond their utility: they shape the individual's identity (Giddens, 1991; Spaargaren and Vliet, 2000). Lifestyle satisfaction then becomes the main mechanism to achieve a Sense of individual identity (RØpke, 1999), closing the **R2** reinforcing loop, labelled as *Seek for identity*.

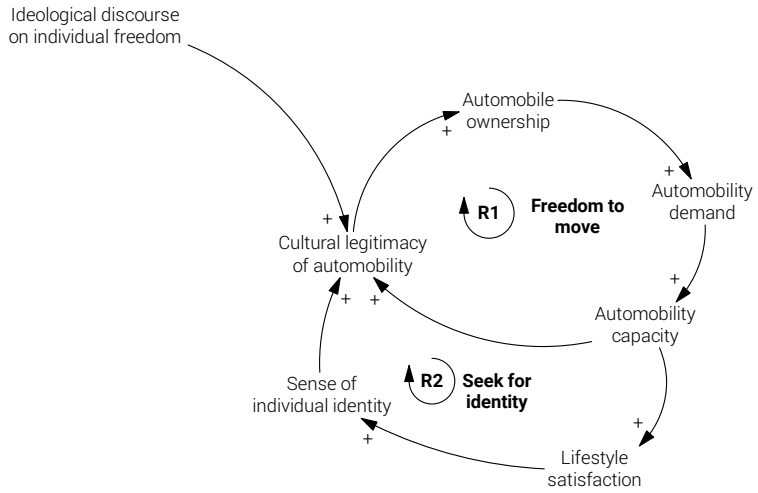



**Figure 3.7** AUTOLOCK cultural legitimacy perspective: identity and freedom.

Figure 3.8 adds an important feature of automobility: cultural homogenisation. Gartman (2004) argues that, similarly to other mass-manufactured products in the capitalist regime, automobiles have become yet another force of cultural homogenisation ((Auto)mobility homogenisation). This effect of the industrialisation of automobiles production, which holds especially during the Fordist era[11], leads to a decreased Sense of individual identity, since the ownership of an automobile no longer distinguishes an individual from another (everyone owns a car). This effectively closes a balancing loop, **B1**, where the loss of individuation power of automobility causes shrinking (or stagnant, at least) auto-ownership and demand.

As a response to the previous effect, the automotive industry has developed a new production pattern: a much wider range of automobile types (e.g., SUVs[12], hybrid cars, minivans, familiar vehicles, sportive cars, etc.) is offered to the users, with the intention to reach to lifestyle niches, that soon become mainstream markets on their own (Gartman,

[11] Fordism refers to the application of manufacturing processes in the industry, following the example of Henry Ford. These techniques consist, in essence, of large-scale and highly mechanised production.
[12] SUV stands for *S*port *U*tility *V*ehicle or *S*uburban *U*tility *V*ehicle.

2004). This response proves to be effective, further accentuating the Subcultural division and, thus, satisfying the need for a Sense of individual identity. This mechanism is labelled in Figure 3.8 as the **R3** reinforcing loop of *Cultural distinction*.

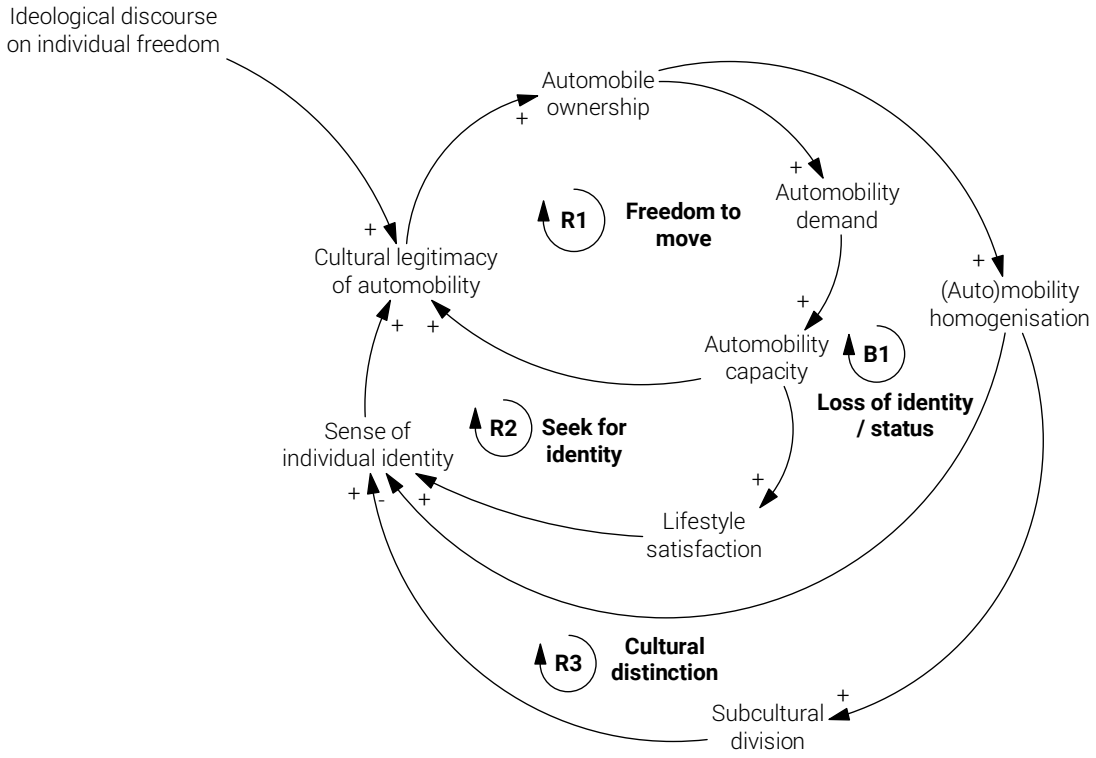



**Figure 3.8** AUTOLOCK cultural legitimacy perspective: homogenisation and subcultural division in (post)modernity.

Figure 3.9 incorporates a *critical theory*[13] approach to the analysis, investigating the origin of the Need for individuation that drives the legitimated institution of automobility as a integral component of the culture. The core of this analysis is the reinforcing loop **R4**, labelled *Capitalism*, in which the concepts of Socio-economic heteronomy[14] and Individual

[13] The *critical theory* refers to the philosophical approach used by the scholars in the Frankfurt School to discuss issues such as the critique of capitalist societies, the modernities or the pursue of social emancipation.

[14] *Heteronomy*, in contrast to *autonomy*, refers to the state in which an individual's actions are driven by forces external to itself. This is, heteronomous are those that are ruled by others. Note that, in the context of this study, the emphasis is put in the socio-economic aspect of heteronomy: the impossibility to conduct a lifestyle due to economic and social constraints (e.g., poverty, class conflicts, dominance/oppression relations, etc.).

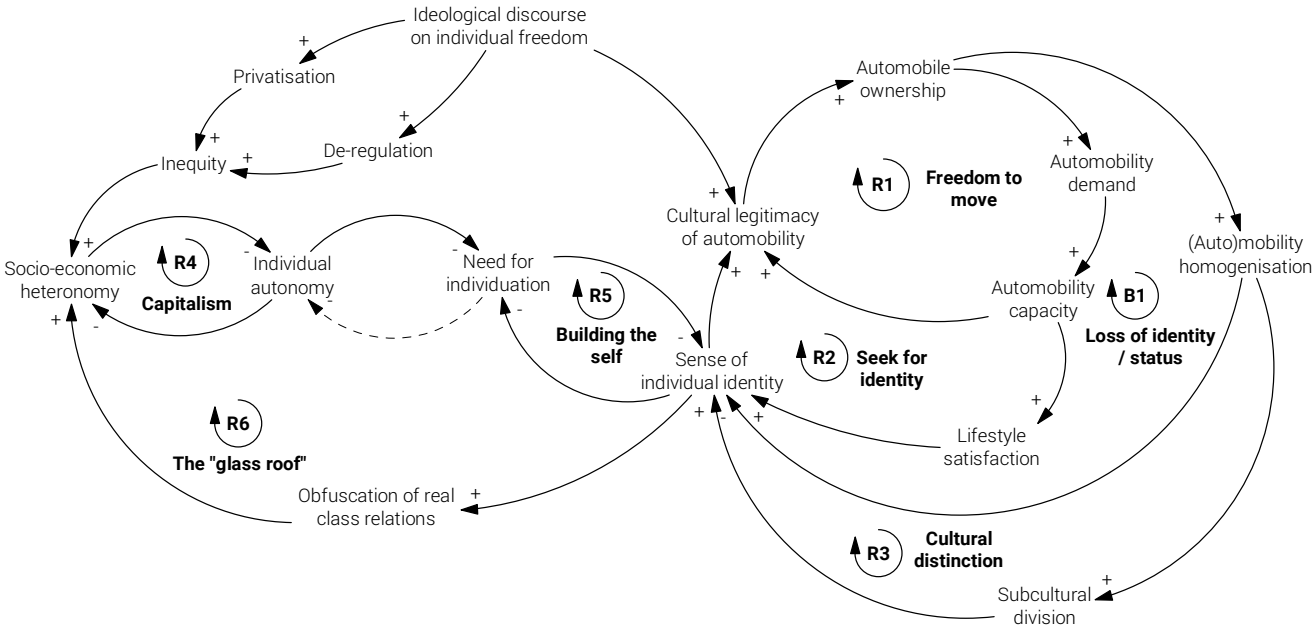



**Figure 3.9** AUTOLOCK cultural legitimacy perspective: class relations in neoliberal capitalism – autonomy and heteronomy.

autonomy[15] are opposed. In the capitalist economy, class relations ultimately dictate the level of (socio-economic) autonomy an individual has. By not owning the production means, workers are highly heteronomous and bound to the forces of the labour market, social safety nets and other supra-individual institutions. In this context, due to the lack of *political* Individual autonomy, identity is sought in *cultural* individualisation (Need for individuation) (Gartman, 2004).

Further deep in the discussion about identity, individuality and autonomy/heteronomy, postmodernist[16] scholars claim that Subcultural division liberates individuals from class struggles. The liberation is due to the fact that identity is expressed within a subculture that is not necessarily superior to any other — i.e., there is no hierarchy, no class (Gartman, 2004). Under the postmodernist perspective, the automobile becomes a liberating product, with its capability to support many lifestyles.

[15] *Autonomy* refers to the ability of an individual to be self-determined and self-governed.

[16] *Postmodernism* is a philosophical movement from the late 20th century, that defends a sceptical approach to rationality and a certain form of relativism. In this particular context, Gartman (2004) is referring to the work of Stuart Hall and Dick Hebdige. These scholars maintain that advanced capitalist societies are diverse in nature, with a fragmented culture and that class identities fell apart due to this (sub)cultural differentiation.

However, the argument held by postmodernist scholars is a highly controversial one. Critical theory provides a very different explanation for the apparent relaxation of class conflicts in the late-capitalism era of mass consumption. The compensatory individuality sought in mass consumption (in automobility, in this study) to alleviate the deprivation of economic autonomy is not liberating. Instead, the mass consumption culture acts by hiding the real class relations: everyone, from all social classes, participates in the same consumption culture (Gartman, 1991; Marcuse, 2013). The boundaries of classes become diffuse in appearance and the (capitalist/automotive) culture becomes legitimised (Gartman, 2004). These dynamics are presented in Figure 3.9 as the **R6** loop (*The "glass roof"*), which represents the hidden class relations that ultimately reinforce Socio-economic heteronomy. Also, the link from the Need for individuation variable to Individual autonomy is *dashed*, to signify the postmodernist "liberating" individuality that subcultures produce, which is actually non-existent according to critical theory.

Finally, a connection is depicted in Figure 3.9 from the overarching Ideological discourse on individual freedom to Socio-economic heteronomy, where (economic) Inequity, preceded by Privatisation and De-regulation, acts as the mediating mechanism. Following Monbiot (2016) and Klein (2008) analyses, the fundamentalist defence of unfettered (individual) freedom, comes at the expense of social/state interventions. The radical market ideology of neoliberalism is based on three tenets: Privatisation, De-regulation and free trade. It is now widely recognised that this ideology has brought huge increases in inequality during the last decades (Milanovic, 2016; Piketty, 2014). Inequality is, precisely, the main source of Socio-economic heteronomy.

## 3.4 Transitions theory integration: SSP1-MOB and AUTOLOCK under the MLP approach

The purpose of this section is to integrate the previous results under a coherent discursive umbrella. The integration discourse should be able to cover: system dynamics analysis, static system descriptions, change accounts, stability patterns and, most importantly, a broad range of social and technical aspects. *Transitions theory* is the chosen framework to achieve this objective. Subsection 3.4.1 provides an assessment of the transition from the current automobility system, as described by the AUTOLOCK conceptual model, to the desired SSP1-MOB vision, under the *multi-level perspective* (MLP) analytical framework.

### 3.4.1 From AUTOLOCK to SSP1-MOB: MLP analysis

The following analysis of the transition using the multi-level perspective does not assess the current situation (represented by the AUTOLOCK model) and the desired future

(described in the SSP1-MOB narrative) separately. Instead, an overview of the transition is given in a prospective fashion. All along the process of this transition, the dominance of regimes, the landscape pressures and the innovations in the niches evolve; this section aims to explain the co-evolution of these elements.

### The 2017 automobility socio-technical regime and the landscape that supports it

In the current mobility system, automobility is, by far, the dominant socio-technical regime. As reviewed within the AUTOLOCK model discussion, automobility has been able to not only dominate mobility, from the travel demand point of view, but has also shaped the lifestyles of generations, driving an adaptation of cultural practices to the spaces and requirements of this form of mobility. The automotive industry, politicians, researchers, planners and the very civil society have embraced this mobility paradigm to the point where alternative, cost-effective and efficient travel modes such as public transport or walking and cycling have been relegated to perform a background and marginal role. Urban landscapes have changed in the last century to accommodate automobiles, with huge road networks being constructed and shifting the focus of urban planning to a car-centric approach. Commuting to work and school, shopping, family visits and recreational activities have all been built around the central role of the automobile.

This pattern of infrastructure development, together with the vested interests shown by the automotive industry and the sunk investments of governments around the globe to support automobility pose an enormous inertia that resists radical change. It is true that technical developments and efficiency increases have been brought to the automobile world: engine improvements, enhanced safety, etc. However, the fundamentals of the system remain. Cars may change in shape and internally, but they serve the same ultimate purpose of personal, private mobility; it is a form of "dynamic stability". The system is configured in such a manner that all the elements that support it are interlocked. The automobility culture/paradigm cannot be understood without the physical infrastructure to drive around, nor without the extensive network of refuelling stations and mechanic workshops, nor without a pervasive imposed notion that automobiles are the best alternative for mobility, because they liberate the individual from the restraints of society.

As revealed in the AUTOLOCK model, the automobility regime is deeply entrenched in the cultural background of our society. Not only through the changes in cultural mobility practices, but as a symbol of the ruling (neo)liberal ideology. Unconstrained individual freedom discourses find in the automobile the perfect mean for liberation, for consumption and for reification from a utility to a meaning that goes beyond that of pure mobility. It is a symbol of status, of positive personal success (in the terms of materialistic capitalism), of the victory of the self over the anonymous mass, of a

unique and distinct identity. The legitimacy of automobility can hardly be contested from environmental or social concerns: culture and ideology prevail.

Therefore, the automobility regime has become resilient to changes and pressures from the landscape and innovation niches so far. It relies on the social and physical complex that supports it on one side (infrastructure, investments and industries), and on the apparent legitimacy of the culture it has helped to shape. A transition to a sustainable form of mobility that dismisses automobility and embraces other travelling modes will have to counter these forces. Moreover, the transition will require efforts from all sorts of agents (stakeholders), ranging from policy makers at the top most spheres to individuals that mould the culture of mobility with their choices and behaviours.

There are many aspects of the discussed automobility regime that rely on trends at the landscape level to be legitimised. A lot has been talked about the liberal ideology and its influence in the development of automobility throughout this thesis. However, there are more influential facets to the ideology than just the ideal (value) of individual freedom. Maximisation of *private property* (capital) is another central tenet of the neoliberal economy that supports the car regime. In contrast, the fact that public transport is not owned by the traveller renders it as a "lower" alternative to opt for. The same applies to walking, where no private nor public property at all is necessary. The fact that cars are private, when embedded in a framework of values that primes private property makes them appealing to the individuals (Zijlstra and Avelino, 2012).

Arguably, another feature that can be attributed to the landscape that supports automobility is the energetic dependence on hydrocarbons. The reliance of the current global energy system on fossil fuels is huge. Their condition as cheap and dense energy carriers causes that, despite minor (or major) crises, fuel prices are low. Low fuel prices drive automobility further ahead, acting as another reinforcing mechanism (Wells, Nieuwenhuis, and Orsato, 2012). Until other energy carriers become available at reasonable prices, internal combustion engines will dominate the technological aspect of the automobility regime, polluting and threatening human and ecological health.

#### Automobility challenged: niches of innovation and landscape pressures

The previous paragraphs paint a picture of automobility that is discouraging, from the sustainability point of view. It seems that automobiles cannot be taken out of the streets, due to the reinforcing mechanisms that stabilise it against all threats. However, this is not the complete picture. Automobility is not completely unchallenged any more. Innovation niches in mobility have emerged. Technology-wise, there have not been true breakthroughs that open the possibility to liberate us from automobiles, but some transport technologies have been rethought into innovative ways to fight for a reduction in car use. For example, municipal bike rental services have emerged in many cities

around the world, offering more than 2 million public use bikes in 2016, doubling the figures of 2015 (Meddin, 2017).

Besides technological options, another type of niches that challenge the dominance of the automobility regime are what Zijlstra and Avelino (2012) call *socio-spatial niches*. *Slow cities*, spatial policies that discourage automobile use in favour of other modes (promotion of bike and bus lanes, restriction of parking spaces, etc.) and sustainable urban planning approaches (new schools of urban planning practices) fall under this niche category. Mixed-use urban development, together with Demand management policies are examples of such niches that the AUTOLOCK model incorporates. Real world examples can be found of sustainable urban planning practices; it is the case of the Spanish city of Pontevedra, in the region of Galicia, where a mere 28% of travel mode share is attributed to automobiles, there have been no fatal accidents in over three years (in a city of 65 000 inhabitants), 80% of the children walk to school and more than 40 km of pedestrian/cycling paths have been built since 1999 (Precedo, 2017).

Some other niches appear in the form of contra-cultures to the established automobile-based lifestyle described in AUTOLOCK — they are not explicit in the model, but they conform the potential balancing forces in the dynamics analysed in Subsection 3.3.2. Alternative mobilities cultures, such as bicycling, or low-mobility lifestyles are an example of these. More important than the actual mobility practices of these contra-cultural movements are the discourses that support them and at that challenge the dominant regime. Anti-consumerism, sustainability advocacy, public health defence, environmentalism and social cohesion fights for livable and equitable cities can be counted among these discourses. An underlying assumption of the SSP1-MOB narrative is that these niche discourses will gain momentum until they are promoted to the landscape level.

Beyond niches, there are some signs that pressure is building up at the landscape level to constrain the dominance of automobility as a regime. $CO_2$ emission caps force governments to increase the pressure for de-carbonising the transport sector. Despite previous efforts by governments to amend this situation through efficiency improvements, the recent Paris agreement to combat climate change may be a beacon of hope to force more stringent regulations on $CO_2$ emissions from this sector. Additionally, the very same dependence on fossil fuels that has kept automobiles on the roads unchallenged for decades may well be a force for change. With oil reserves running low and extraction costs rising (the observed effects of *peak oil*), the steady supply of fuel that automobiles require may be at risk. In a world with ever-decreasing fuel availability, pressure is and will be growing in order to abandon this oil thirsty transport mode. This pressure is exemplified by the introduction of battery electric vehicles (a technological niche, still) capable of long driving ranges at "normal" automobile speeds. However, it must be noted that electric cars are not a solution to automobile regime problems such as congestion, accidents or unsocial spatial organisation (single-use urban developments, separation of

work and living spaces, increased commuting time, etc.).

#### Mobility intermediate futures: landscape and regime reconfigurations in 2050

Down the path of the transition to SSP1-MOB (around the year 2050), the landscape is assumed to change substantially. This is combined with the pressure exerted by technological and cultural niches to challenge the regime of automobility, driving a progressive but certain transition to a more sustainable form of mobility. At the landscape level, (a) sustainability concerns among the population have grown considerably, (b) population itself has grown, but slowly, (c) economic growth has been relatively high, (d) technology has developed rapidly, enabling efficiency increases, (e) material consumption has shrunk and (f) governance systems are effective at the national and international levels (Vuuren et al., 2017). This development pathway trickles down onto several mobility-related trend shifts, ranging from energy/power/fuel system reconfigurations to changes in the urban spatial organisation.

On the side of land use patterns (sometimes considered as part of the landscape of mobility; others an integral part of the system or regime), urban density is assumed to grow, allowing for a shrinkage of travel distances. This alone already puts pressure on the automobility regime, since the use of cars for the daily life is no more an imperative — it is a balancing force that breaks the **R3** *Automobility dependence* reinforcing loop in AUTOLOCK. Moreover, due to the combination of population growth and high concerns for sustainability issues, the urban planning paradigm has moved towards mixed-use developments. While it is not yet a complete transition — (a) it is not the norm yet and (b) already developed (sub)urban areas take a long time and resources to renovate —, it is certainly not a marginal (niche) practice any more: it has surpassed the local/municipal level and has permeated the regional planning levels. This is a second and very important trend that breaks another lock-in mechanism of the automobility regime, because social facilities and living spaces stop being separated far away from each other (implementing the **B3** balancing loop in AUTOLOCK). Automobility starts to not make sense, now that everything is within walking or public transport reach.

The changing urban form is backed by an increasingly extensive public transport network. Railways are being electrified globally, thus reducing operating costs, and high-speed train lines are being built, displacing, once again, the automobile from the long range trips "market" (Vuuren et al., 2017). Intermodal travel, despite not being fully utilised, is facilitated by the provision of integrated travel information through IT services. Bus networks have also grown in size, now that rural area residents shift from car to public transport use. This new distribution of mode shares is the indication of a key aspect of the transition to SSP1-MOB. Even though automobility still dominates in terms of travel demand over any other mode, the aggregated demand attributed to all public transport

modes is on par to that of cars. Instead of a single socio-technical transport system prevailing over others (automobility in 2017), the observed trend in 2050 is that public transport and automobility are now co-existent as full-fledged regimes. The reasons why both can be understood as regimes are: (1) actors within the systems share a common set of practices and rules (particular to each system), (2) they evolve in a form of dynamic stability and (3) they both dominate over radically innovative niches, such as bicycling-only mobilities or other imaginative mobility technologies[17].

Fuel technologies, also in between the landscape and regimes level, have also evolved before 2050. On one hand, fossil fuels still account for a big chunk of the total (global) energy demand — certainly oil, but coal and natural gas too, as dense energy sources for electricity generation —, but bio-fuels are starting to gain share; on the other hand, the power grid has grown in size and has reduced costs, easing the electrification of the transport sector (Vuuren et al., 2017). Cheap and available electricity, coupled with a rise in the share of bio-fuels indicates that the reinforcing dynamics of cheap fuel and oil-dependence within automobility are also starting to be balanced out. The increasing demand for electric vehicles, especially in road and rail due to their perceived cleanliness, accentuates this feedback rupture.

Finally, mobility cultures are in the process of a transition too. There is less support for the automobility regime now, because the reasons that legitimised its dominance are becoming weaker. At the landscape level, the imperative of unfettered individual freedom promoted by the neoliberal ideology has been challenged globally, for two reasons: (1) the realisation that individualist-consumerist behaviours cause deeply negative impacts in the environment (in accordance to the assumed sustainability concerns trend of SSP1/SSP1-MOB) and (2) the economic and social inequality that are generated by the neoliberal policies worldwide. Another landscape trend with respect to culture is the rise in sustainable consumption patterns: self-identity is not provided by materialistic artefacts so much as in 2017, thus stripping car ownership of part of its symbolism.

### Completing the transition to SSP1-MOB in 2100

The world has completed (or advanced in) a series of changes by the year 2100, which can be categorised as landscape developments. The energy system has finally been (mostly) de-carbonised: solar, wind and hydro power are the main sources of electricity generation; bio-fuels dominate over fossil ones and hydrogen fuel cell technology (and infrastructure) has been widely made available for road vehicles. Urban densities are high and cities have become compact nuclei of mixed-use developments: the need for rapid and long-distance

[17] It is worth noting that the discussion of particular niches in the future is somehow futile. Regimes tend to endure and only change over the span of decades, but niches rise and fall rapidly — they are volatile. Besides this, innovative technological niches are hard to predict, because of their uncertain nature.

mobility has greatly been reduced. Single-use planning is a thing of the past and a de-materialised economy also means that lesser transport is needed. Climate change and other sustainability issues have been at the core of national and international policy, because the population has grown highly concerned about it. An enormous pressure from the "bottom", in the form of various socio-technical niches, has caused a cascade of cultural and political changes.

Public transport has the strongest political support ever and its aggregated demand is superior to that of automobiles, positively confirming its position as the dominant socio-technical regime. The rail system has completely been electrified, high-speed trains are common and are heavily used and buses have become electric or fuelled by hydrogen. Intermodal travel is very much facilitated and is commonly used, due to a higher degree of acceptance (especially with regards to the relatively longer travel times) and convenience. Accessibility through public transport is on par with that of the automobile, regarding the public option as more than appealing, from an economic and cultural point of view — it is important to stress the shift towards a sustainability concerned lifestyle that people around the globe has embraced. In this respect, the landscape provides a feature that legitimises public transport over automobility (whenever it is more feasible and convenient): the *common good* is the moral imperative, rather than *individual freedom.*

Automobility has, on the other hand, fallen in terms of demand, but still constitutes a regime, in the sense that the complexity, evolution patterns and interactions between actors in the system follow the same principles of the regime it had been. Therefore, the future of SSP1-MOB has been definitely established as a multi-modal mobility paradigm. Public transport dominates as a regime, but automobility still fills the gaps in accessibility, convenience or economic efficiency that public transit cannot cover. With respect to the environmental sustainability of the automobility system, the main technologies that drives most cars now are sophisticated electric batteries and hydrogen fuel cells — $CO_2$ emissions have therefore been cut and dependence on fossil fuels has dropped considerably. New reinforcing mechanisms have risen, inter-locking automobility with the electricity system, for example, while old ones are broken, such as the inter-dependency of cars and single-use (sub)urban developments.

Finally, the culture of mobility of the SSP1-MOB world has transitioned to a more humanist one. Not only the symbolic nature of automobiles has been completely dismantled (they are regarded as utilities), but integration, management and *reasonable* travel times (vs. minimised times) are the new central focus of mobility. The old legitimacy of the cars regime, based on preceding ideological values, has given way and public transport is now as legit as automobiles. Despite the higher figures of public transport demand, walking and cycling have also re-gained their fundamental role in personal mobility, especially in urban areas. They are used as mediators for faster modes connection (inter-modal travel) and as the basic method to reach shopping, work, school and family locations.

Despite their technical simplicity, the (finally) shared practices and rules — between planners, builders, pedestrians, cyclists and citizens in general — that enable these slow modes, along with the need for the supporting infrastructure, elevate them to the level of a socio-technical regime. This reinforces the notion that mobility has effectively become multi-modal in nature. Furthermore, mobility is now environmentally sustainable and socially human.

## 3.5 Transition-oriented policy recommendations: managing the mobility paradigm shift

This final section of the Results chapter covers the ultimate goal of the thesis: deriving policy recommendations (PR) for a transition to a sustainable mobility future[18]. A transitions oriented approach backs the suggestions, which are categorised into *niche* (Subsection 3.5.1), *regime* (Subsection 3.5.2) and *landscape* level policies (Subsection 3.5.3). Target audiences for the PRs are given too, since some of them require international governance cooperation and some others are suited to local administrations. Finally, the transitions theory MLP approach suggests two general directions that policy makers can follow to induce the required changes for a transition: (a) put pressure on the regimes via legislation, regulation and economic instruments and (b) stimulate socio-technical innovations at the niche level (Kemp, Loorbach, and Rotmans, 2007; F. Geels et al., 2012).

### 3.5.1 Niche level policies

Niche level policies are based on the assumption that forecasting the emergence or success of socio-technical niches to overthrow regimes is difficult or even impossible. However, following the scholarship of *transition management* studies, policies can be put in place to, for example, ensure that already existent niches are guaranteed a safe space to develop (Kemp, Avelino, and Bressers, 2011). To do so, protection could be provided until the socio-technical niches gain enough momentum to compete against the regime (through competition agencies at the national or international level). Local, regional, national or international agents such as governments or private initiatives should also guarantee enough funding, through investment programmes, so that niches can sustain their radical innovation process.

With regards to the financing option, not only direct investments can be granted to specific actors within a niche: research initiatives at universities or institutes or even at private companies should be reinforced, especially those that pose to be promising in

[18] Some of the recommendations are more indeterminate than others, due to the uncertainties and broad spectrum of the policy targets, e.g., niche promotion policies (specific niches are unexpected).

debunking existing regimes. This way, already in-place niches can be further developed and new niches can emerge. Special care should be taken for niches that go beyond technological improvements (such as battery electric vehicles). Initiatives that build counter-cultural movements (contrary to the established unsustainable mobility culture) should be promoted by the authorities. At the same time, these institutional agents should set a common vision for the kind of sustainable mobility they desire (across governance levels) and, most importantly, have the will to follow it and definitively distance themselves from the current regime.

One last comment is worth making with regards to niche-supporting policy: there is a strong need for policy makers to research the niches eligible of support and to understand the mechanisms of innovation that drive them. Furthermore, there is an urgent necessity of policy coordination and of a disassociation from opportunistic and fragmented policy programmes that serve political agendas[19] (Kemp and Rotmans, 2004).

### 3.5.2 Regime level policies

Considering SSP1-MOB as the desired vision for mobility, a two-fold strategy is recommended by this study to policy makers in order to achieve a successful sustainable transition. First of all, it is clear that support for the current automobility regime must be dropped significantly. Secondly, public transport must be increasingly supported as the alternative regime that competes with automobility.

At the local level (municipalities), reducing car usage can be achieved with the introduction of, for example, congestion taxes[20]. Other subtler measures for traffic calming include the design of road networks that impede or obstruct automobile transit[21] and the decision to change urban use planning towards a more mixed use pattern that promotes lower mobility. Furthermore, local authorities should reinforce their commitment with public transport by investing even more in building a safe, reliable and convenient network.

Regional authorities carry the responsibility to manage large scale urban and infrastructural developments. Therefore, it is the most suitable locus for integration efforts of local public transport networks, as well as increased funding and subsidisation of this alternative regime. An integrated public transport network at the large scale is a

[19] *Political* is used here in reference to *politics*, which differs from *policy*. Politics deals with power struggles in government, while policy is the consistent set of actions and methods that orient current and future decisions.

[20] Congestion charges have been successfully applied in London and Stockholm, Gothenburg, Durham, Valletta and Milan, in Europe.

[21] The city of Pontevedra introduced such mechanisms, reaching a record low level of automobility (Precedo, 2017) and the city of Barcelona is experimenting with "super-aisles", where chunks of streets become isolated from regular traffic (only pedestrians, cyclists and neighbours can access the blocks), hindering the convenience of automobility (Ajuntament de Barcelona, 2016).

fundamental requirement to advance in the transition path to SSP1-MOB — regular and high-speed railways are part pf such a network, as are inter-city bus lines, for example. Cheap, long-distance public transport should be a central focus point of regional mobility policy. Moreover, in order to weaken automobility dominance, land use patterns at a broader scale can be adjusted to cut down on suburban sprawl, avoid inter-territorial (between municipalities) single-use areas that encourage car dependency and the like.

Finally, national governments, agencies, and international governance institutions should lead the transition to sustainable mobility by finishing, once and for all, the apparently symbiotic relationship they have with the automotive industry (Wells and Nieuwenhuis, 2012; Sturgeon and Van Biesebroeck, 2009). Economic rescues should not be a political priority, if the regime is to be challenged. Moreover, fuel subsidies and car renewal ("scrappage") programmes should also be left behind. Stringent emission regulations should be issued with increasing pressure in the emission levels themselves, in the compensatory taxes and by shortening the time frames for technological improvement. On the other side, high education curricula of infrastructure engineering or urban planning should include a strong focus on sustainability and sustainable mobility in particular, in order to accelerate the pace of the transition at the theoretical and practical levels.

### 3.5.3 Landscape level policies

The socio-technical landscape level seems difficult to influence through policies because of its definition as a broad social context where beliefs, ideologies, societal values, concerns, macroeconomic trends, infrastructure or media are included. However, some of these aspects can effectively be targeted by policies, perhaps at the national and international level. Carbon taxes are an example of such policies, in that they induce innovation in the automotive industry by indirectly orienting their research efforts to cleaner technologies (Aghion et al., 2016). These type of taxes should be applied at the international level, or at least be coordinated in such spaces. Further examples of policy instruments to address sustainability in transport, beyond automobility, are international aviation taxes, emission trading for airline companies or levies on air-borne emissions (Peeters, Gossling, and Becken, 2006).

Another form of landscape-level policy that complements economic instruments like the ones cited before is betting for an integrated, efficient and reliable (inter)national public transport network. High speed trains, either national or connecting several countries, should be put in place, due to their higher energy, land-use and social "efficiency". Strongly linked to transport infrastructure efforts, the aforementioned electric grid expansion (in size, but also in international integration) and the decarbonisation of the energy system are also landscape developments that would push for sustainable mobility. The policy recommendation in this case is to invest and promote investments in such areas, as well

as passing regulations that force the necessary transition to renewable energy sources onto the private energy sector. Phasing-out fossil fuels is also mandatory for putting pressure on the automobility regime, as well as for transitioning to the energy system that SSP1-MOB relies on — (economic and political) incentives should be put in place for the development of bio-fuel, electric battery and hydrogen fuel cell technologies.

Finally, with regards to the cultural and ideological aspects of the mobility landscape, a lot of work is still ahead in terms of policy. If the dominant neoliberal ideology is not challenged also from the political standpoint, it is unlikely that a fast sustainability transition takes place in the near-mid future. Unless the individualist and *laisez fare* tenets held by market fundamentalists are de-legitimised, through cultural but also policy mechanisms, consumption patterns will not change, industries will keep business as usual and sustainability will not be a concern — most of the pressing issues deal with impacts to the *commons*, that are not recognised by free market fanatics (Kumi, Arhin, and Yeboah, 2014; Cervantes, 2013). Therefore, if sustainability is the truly desired goal for human development, neoliberal policies and all the discourses that underpin them must be left behind in policy schemes.

# Chapter 4

# Discussion

Complementing the results of the previous chapter, a discussion follows, with negative and positive remarks about the general outcome of the thesis. Section 4.1 presents the identified limitations of the study. On the other hand, the strengths and drawbacks of the methodological framework (or research design) are analysed in Section 4.2.

## 4.1 Limitations of the research

Regarding the methods used throughout the thesis, a series of pitfalls have been identified. First and foremost, the development of the SSP1-MOB qualitative narrative, as well as the subsequent backcasting process, could and probably should have been performed on the basis of a participatory process. Even though the normative approach of those sections has a higher saliency for policy and decision makers, the legitimacy of the results might have been compromised, because "divergent values"[1] are incorporated without consultation with stakeholders or any other "democratic" approach (Rounsevell and Metzeger, 2010). However, the scientific credibility of the thesis is well supported by the literature used and, in the particular case of the SSP1-MOB narrative, by being backed by the highly acknowledged scenario framework of the IPCC.

With respect to the AUTOLOCK conceptual model, it is clear that the CLDs developed are not the ultimate depiction of the automobility system. They are not even the *only* possible representation of the aspects they are modelling—again, a participatory approach to their development, such as Group Model Building, would incorporate more points of view, eliciting the most important variables and links in the system (Laurenti, Lazarevic, et al., 2014). Rather, the AUTOLOCK model should be seen as an example of the potential that CLDs have for (a) describing system feedback structures and (b) conveying that information in an understandable way for decision makers and (transition) researchers alike. Many other perspectives could have been taken to model the automobility system,

[1] The thesis' results promote changes in cultural, technological and societal values in order to achieve a transition.

at this highly abstract level. The approach taken in this thesis for each of the AUTOLOCK model components is meant to provide enough basis for a discussion of the dynamic behaviour of the automobility system. Furthermore, the focus on abstract concepts and the loose system boundary (e.g., the inclusion of ideological discourses in the culture legitimation perspective) try to illustrate the difficulty in dealing with such a complex issue.

Another limit of the thesis lies in the breadth of the system perspective used. It is very complex and burdensome to include all the relevant aspects in a discussion of sustainable futures. For example, the fuel/energy discourse that permeates many transport studies is not explored in-depth in this thesis, nor is the technological dimension, in more general terms (new vehicle technologies, efficiency improvements, etc.). However, the constrained time and resources available to conduct this research do not allow for a further expansion of the system boundaries. Anyhow, it was a deliberate decision to shift the focus of this study onto the socio-cultural dimensions of the mobility system, following the hypothesis formulated in the Aim and objectives section.

Finally, the lack of (extensive) quantitative figures in either of the methodological perspectives used throughout the thesis (the backcasting process, the CLD model, etc.) poses a potential limitation to the credibility of the results. Scientific (natural sciences), engineering, economics and planning/policy research communities are used to quantitative evaluations and trust the scientific accuracy of studies when formal modelling has been performed. However, the socio-cultural focus of the thesis and the use of narratives, backcasts and transition perspectives actually brings it closer to social sciences. Furthermore, it is the opinion of the author that providing figures in a normative description of mobility futures, without the use of participatory methods, would render the results as non-credible and liable to huge biases.

## 4.2 Methodological results

Despite some limitations, there are some strong positive outcomes from this study. The methodological framework designed for the thesis manages to combine two seemingly disaligned approaches to futures studies: forecasting (in the form of CLDs) and backcasting. While there are articles in the literature of similar efforts, such as Kok et al. (2011) and Dortmans (2005), the difference lies in the integration method used in this research: the Multi-Level Perspective on sustainable transitions. Figure 4.1 presents a conceptual visualisation of the integration role that transitions theory plays in the thesis. To understand the importance of the contribution of this study, the following paragraphs describe the drawbacks of adhering to a single approach for policy assessment (either forecasting or backcasting). It is argued that the use of the MLP overcomes those limitations, thus becoming a prominent "result" of this thesis.

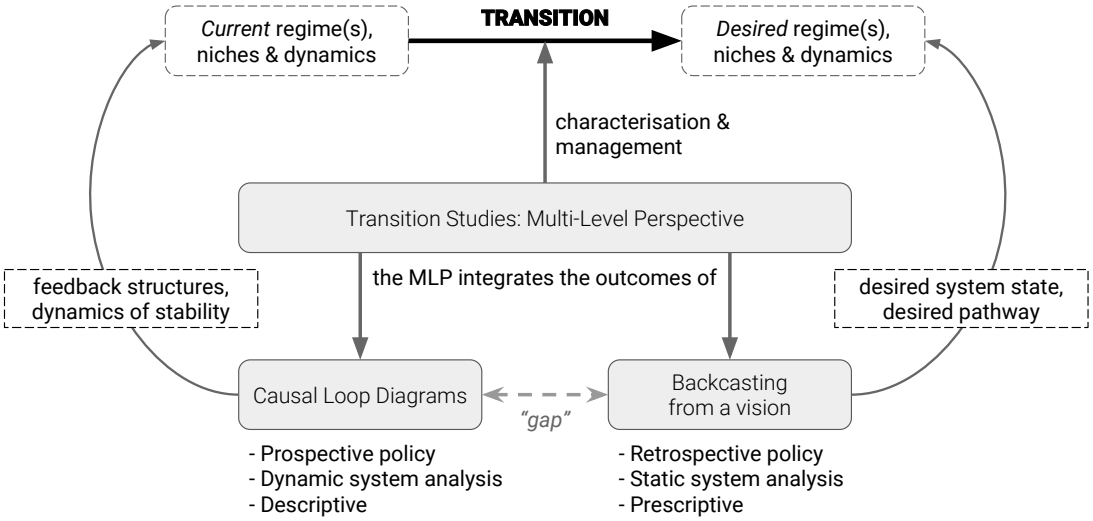



**Figure 4.1** Transition theory can bridge the gap between futures studies and forecasting tools, by translating the insights from each into the same language (discourse).

On one hand, forecasting tools (CLDs and System Dynamics, for example) are commonly used to inform policy makers of the possible development scenarios, but fail to convey normative insights: they are inherently *descriptive* methods. Another weakness of using forecasts as the basis for policy making is that no space is available for radical innovation. This is, predictions based on present system structures cannot take into account structural change or unexpected developments. The policies that emerge from using forecasts are *prospective*. On the other hand, the strength of forecasts and System Dynamics (CLDs) in particular, is the capability to analyse *dynamic*[2] behaviours. Dynamics and feedback structures are very important to policy assessment, because they are sources of policy resistance mechanisms, such as rebound effects.

Backcasting and "desirable" visions methods are, on the contrary, normative in nature, this is, they are *prescriptive* in their analysis (or discussion) of the systems under scope. However, unless explicitly incorporated in the processes, the perspective of the systems is rather *static*. Even though they are used to convey the desired changes (dynamism over time), they do not account for feedback structures nor for dynamic system behaviour. In the context of sustainable transitions, a final feature of backcasting is appealing as a methodology: the *retrospective* approach to policy design. The fact that backcasting processes start from a desired end-state opens the possibility to include radical innovation or, simply, "radical" changes that would be unthinkable from the present system condition.

[2] Again, the dynamism captured by these tools is constrained to the modelled structure of the system.

The use of the MLP in the thesis as a discursive translation tool serves the purpose of overcoming the limitations described above, while benefiting from the strengths of each tool. (1) The focus on co-evolution and dynamism (stability and change) of socio-technical niches, regimes and landscapes fits perfectly the notion of system dynamics captured by CLDs. (2) While not normative per se, the MLP can still accommodate the results of a backcasted pathway to a normative future vision. (3) The context of a "transition" embeds desired future visions and pathways and, therefore, policy design can be made retrospectively, allowing broader possibilities to be included and for policies that support radical innovation. Finally, the multidisciplinary approach of the MLP supports an analysis scope broader than that of the formal models of System Dynamics, similarly to backcasting.

As the concluding remark, the aforementioned use of the MLP approach is, as argued, a significant contribution to sustainability research. It could, to some extent, be regarded as a form of *transition management* (Rotmans, Kemp, and van Asselt, 2001; Kemp, Avelino, and Bressers, 2011), although it differs in some aspects: different emphasis on culture, inclusion of subaltern combined methodologies and, following the transitions governance scheme described by Kemp, Loorbach, and Rotmans (2007), this thesis is situated only at a strategic management level. However, the approach taken can benefit other sustainability studies in the following situations:

(a) A (participatory) process has delivered a desirable vision and/or pathway to a sustainable future, but there are uncertainties with regards to required structural changes or policy resistance mechanisms.

(b) A forecasting study has provided decision makers with a thorough understanding of the current system and its feedback mechanisms but, even at the light of possible scenarios described by the forecast, they are unsure of what normative actions should be taken.

In both cases, a complementary study can be performed and the results can be then harmonised using an MLP approach. This integration framework is, indeed, the most interesting outcome of the thesis.

## 4.3 Further research

The main line of research that stems from the work in this thesis is the investigation of policy analysis frameworks. This is, researching whether transition theory, and the MLP in particular, can help in the design of policies that fit sustainability better than the current paradigm. In this respect, the scholars from the transitions management field have already made progress, but their approach is a little different. Whereas they focus on niche support and long term goals, this thesis also emphasises the ability of the MLP

as an integrative narrative for more "specific" assessment tools.

A straightforward extension of the thesis would be to carry out the backcasting process (and the development of the qualitative narrative that serves as the guideline) in a participatory setting. This way, different policy results might be derived or, at the very least, confirmed and validated by stakeholders and general participants. Democracy is, unfortunately, a forgone aspect of sustainability studies. In the case of the thesis, due to time and resources constraints, but in a more general case, due to technocratic views on what science and research is all about. Lengthier study settings, such as PhD research or government officials could undertake this effort.

The usage of Causal Loop Diagrams in combination with other policy design mechanisms is an interesting contribution that deserves further work as well. Most of the literature on System Dynamics and CLDs deals with narrower scopes and bounded systems than what has been studied here. In particular, they are (almost) never used to model "soft" issue such as cultural frameworks. Despite the difficulty to quantify these aspects, the argument of this thesis is that CLDs could be used to mentally model these very important issues. They definitely serve the purpose of making mental models explicit, especially when developed in workshops or through Group Model Building techniques.

# Chapter 5

# Conclusion

The thesis explores a possible sustainable future of mobility and the transition pathway to it, focusing on the socio-cultural dimensions that shape and drive the way mobility is understood. Goal-driven, transition-oriented policy recommendations are provided as the main result, derived from a combined backcasting and forecasting methodology framework. The successful combination of backcasting and Causal Loop Diagrams is achieved by homogenising the outcomes of each assessment through the logic of the Multi-Level Perspective of transitions theory.

Reinforcing feedback mechanisms and a deeply embedded culture of automobility are behind the enormous inertia and resilience of the current mobility system. If a transition to a sustainable mobility future is to happen, the insights gained from this study point to a necessary shift in cultural trends. The discourses of unrestricted individual freedom, private property and materialistic cultures that legitimise automobility must be challenged. Cultural changes have to be backed by sustainable societal development trends such as fossil fuels phase-out, electrification of mobility, de-carbonisation of the power grid, high levels of sustainability concern, increases in urban density and reductions of mobility demand. Urban planning that supports public transport and hinders automobility development is of utmost importance in order to reduce the negative impacts of today's transport system.

The policy recommendations derived in this research are meant to form a coherent package. They are not understood separately and are designed with the long-term transition goal in mind. Three levels of policy recommendations are provided: niche, regime and landscape measures. The combination of all three levels should break the lock-in mechanisms of today's mobility and narrow the way for the transition to tomorrow's sustainable mobility.

While several limitations are discussed with regards to methodological choices, the overall framework is arguably the most interesting contribution to sustainability and transitions studies. The thesis proves that the Multi-Level Perspective on transitions provides with a narrative capable of integrating results from inherently different approaches to future studies. The framework is generalisable and useful for situations where a normative goal

in the distant future is pursued, while accounting for the reasons behind policy resistance in the current system configuration.

Further research is needed to adapt the methodological framework to quantitative approaches. An appraisal of different scenarios (instead of only one) could also be a future research line, to assess whether or not the framework is still useful for traditional scenario exploration. Finally, participatory processes could and should be incorporated in the future, if the methodology presented in this thesis was to be used in another study.

# Bibliography


Aghion, Philippe et al. (2016). 'Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry'. In: *Journal of Political Economy* 124.1, pp. 1–51. DOI: 10.1086/684581.

Ajuntament de Barcelona (2016). *Omplim de Vida els Carrers – La Implantació de les Superilles a Barcelona. Mesura de Govern.* Ed. by Comissió d'Ecologia, Urbanisme i Mobilitat. Ajuntament de Barcelona. URL: https://bcnroc.ajuntament.barcelona.cat/jspui/bitstream/11703/97356/1/mesuradegovernomplimdevidaelscarrerslaimplantacidelessuperi-160518111846.pdf (visited on 06/01/2017).

Anenberg, Susan C. et al. (2017). 'Impacts and mitigation of excess diesel-related NOx emissions in 11 major vehicle markets'. In: *Nature* 545.7655, pp. 467–471. DOI: 10.1038/nature22086.

Banister, David (2000). *European transport policy and sustainable mobility.* Taylor & Francis. 255 pp. ISBN: 9780415234092.

Banister, David (2008). 'The sustainable mobility paradigm'. In: *Transport Policy* 15.2, pp. 73–80. DOI: 10.1016/j.tranpol.2007.10.005.

Banister, David and Yossi Berechman (2001). 'Transport investment and the promotion of economic growth'. In: *Journal of Transport Geography* 9.3. Mobility and Spatial Dynamics, pp. 209–218. ISSN: 0966-6923. DOI: 10.1016/S0966-6923(01)00013-8.

Böhm, Steffen et al. (2006). 'Part One Conceptualizing Automobility: Introduction: Impossibilities of automobility'. In: *The Sociological Review* 54, pp. 1–16. ISSN: 1467-954X. DOI: 10.1111/j.1467-954X.2006.00634.x.

Börjeson, Lena et al. (2006). 'Scenario types and techniques: Towards a user's guide'. In: *Futures* 38.7, pp. 723–739. DOI: 10.1016/j.futures.2005.12.002.

Bureau of Transportation Statistics (2017). *Table 1-23: World Motor Vehicle Production, Selected Countries (Thousands of vehicles).* European Commission. URL: https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_23.html_mfd (visited on 05/26/2017).

Burns, Lawrence D (2013). 'Sustainable mobility: A vision of our transport future'. In: *Nature* 497.7448, pp. 181–182. ISSN: 0028-0836. DOI: 10.1038/497181a.

Calvin, Katherine et al. (2017). 'The SSP4: A world of deepening inequality'. In: *Global Environmental Change* 42, pp. 284–296. DOI: 10.1016/j.gloenvcha.2016.06.010.

Camagni, Roberto, Maria Cristina Gibelli, and Paolo Rigamonti (2002). 'Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion'. In: *Ecological Economics* 40.2, pp. 199–216. ISSN: 0921-8009. DOI: 10.1016/S0921-8009(01)00254-3.

Carruthers, Robin, Malise Dick, and Anuja Saurkar (2005). *Affordability of Public Transport in Developing Countries. Transport Papers series.* Research rep. TP-3. The World Bank. 27 pp. URL: http://hdl.handle.net/10986/17408 (visited on 05/18/2017).

Castillo, Herb and David E. Pitfield (2010). 'ELASTIC  A methodological framework for identifying and selecting sustainable transport indicators'. In: *Transportation Research Part D: Transport and Environment* 15.4, pp. 179–188. DOI: 10.1016/j.trd.2009.09.002.

Cazzola, Pierpaolo, Marine Gorner, and Renske Schuitmaker (2016). *Railway Handbook 2016. Energy Consumption and CO2 Emissions*. Focus on Sustainability Targets. English. Tech. rep. International Energy Agency (IEA). 120 pp. URL: http://www.uic.org/IMG/pdf/iea-uic_railway_handbook_2016.pdf (visited on 05/17/2017).

Cervantes, Juan (2013). 'Ideology, Neoliberalism and Sustainable Development'. In: *HUMAN GEOGRAPHIES  Journal of Studies and Research in Human Geography* 7.2, pp. 25–34. DOI: 10.5719/hgeo.2013.72.25.

Chapman, Lee (2007). 'Transport and climate change: a review'. In: *Journal of Transport Geography* 15.5, pp. 354–367. ISSN: 0966-6923. DOI: 10.1016/j.jtrangeo.2006.11.008.

Clémençon, Raymond (2016). 'The Two Sides of the Paris Climate Agreement'. In: *The Journal of Environment & Development* 25.1, pp. 3–24. DOI: 10.1177/1070496516631362.

Cox, Wendell (2017). *Demographia World Urban Areas 13th Annual Edition: 2017:04*. Ed. by Demographia. Demographia. URL: http://www.demographia.com/db-worldua.pdf (visited on 05/17/2017).

Creutzig, Felix (2015). 'Evolving Narratives of Low-Carbon Futures in Transportation'. In: *Transport Reviews* 36.3, pp. 341–360. DOI: 10.1080/01441647.2015.1079277.

Cullinane, Sharon and Kevin Cullinane (2003). 'Car dependence in a public transport dominated city: evidence from Hong Kong'. In: *Transportation Research Part D: Transport and Environment* 8.2, pp. 129–138. DOI: 10.1016/S1361-9209(02)00037-8.

UN-DESA (2015). *World Population Prospects: The 2015 Revision – Key Findings and Advance Tables*. English. Department of Economic and Social Affairs of the United Nations Secretariat. URL: https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf (visited on 05/09/2017).

Dortmans, Peter J. (2005). 'Forecasting, backcasting, migration landscapes and strategic planning maps'. In: *Futures* 37.4, pp. 273–285. ISSN: 0016-3287. DOI: 10.1016/j.futures.2004.07.003.

Dreborg, Karl H (1996). 'Essence of backcasting'. In: *Futures* 28.9, pp. 813–828. ISSN: 0016-3287. DOI: 10.1016/S0016-3287(96)00044-4.

Dudley, Geoff and Kiron Chatterjee (2012). 'The Dynamics of Regime Strength and Instability. Policy Challenges to the Dominance of the Private Car in the United Kingdom'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transition. Routledge, Taylor & Francis Ltd. Chap. 4. ISBN: 9780415885058.

Eurostat (2017a). *Eurostat Online Database - Transport*. European Commission. URL: http://ec.europa.eu/eurostat/web/transport/data/database (visited on 05/19/2017).

Eurostat (2017b). *Statistics Explained – Railway safety statistics*. European Commission. URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Railway_safety_statistics (visited on 05/19/2017).

Forouzanfar, Mohammad H et al. (2016). 'Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 19902015: a systematic analysis for the Global Burden of Disease Study 2015'. In: *The Lancet* 388.10053, pp. 1659–1724. DOI: 10.1016/s0140-6736(16)31679-8.

Forrester, Jay W (1972). 'Counterintuitive Behavior of Social Systems'. In: *Technological Forecasting and Social Change* 3.2, pp. 1–22.

Freudendal-Pedersen, Malene (2009). *Mobility in Daily Life: Between Freedom and Unfreedom*. Transport and Society. Ashgate. ISBN: 9780754674900.

Fricko, Oliver et al. (2017). 'The marker quantification of the Shared Socioeconomic Pathway 2: A middle-of-the-road scenario for the 21st century'. In: *Global Environmental Change* 42, pp. 251–267. DOI: 10.1016/j.gloenvcha.2016.06.004.

Fujimori, Shinichiro et al. (2017). 'SSP3: AIM implementation of Shared Socioeconomic Pathways'. In: *Global Environmental Change* 42, pp. 268–283. DOI: 10.1016/j.gloenvcha.2016.06.009.

Gartman, David (1991). 'Culture as Class Symbolization or Mass Reification? A Critique of Bourdieu's Distinction'. In: *American Journal of Sociology* 97.2, pp. 421–447. ISSN: 00029602, 15375390.

Gartman, David (2004). 'Three Ages of the Automobile'. In: *Theory, Culture & Society* 21.4-5, pp. 169–195. DOI: 10.1177/0263276404046066.

Geels, Frank (2001). 'Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study'. In: *Nelson and Winter Conference*, pp. 1–39.

Geels, Frank (2005). 'The Dynamics of Transitions in Socio-technical Systems: A Multi-level Analysis of the Transition Pathway from Horse-drawn Carriages to Automobiles (1860–1930)'. In: *Technology Analysis & Strategic Management* 17.4, pp. 445–476. ISSN: 0953-7325. DOI: 10.1080/09537320500357319. URL: http://filer.sustrans.dk/23/3.%20Geels%202005%20automobile%20transition%20TASM.pdf.

Geels, Frank (2011). 'The multi-level perspective on sustainability transitions: Responses to seven criticisms'. In: *Environmental Innovation and Societal Transitions* 1.1, pp. 24–40. ISSN: 2210-4224. DOI: 10.1016/j.eist.2011.02.002.

Geels, Frank W. and René Kemp (2012). 'The Multi-Level Perspective as a New Perspective for Studying Socio-Technical Transitions'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transition. Routledge, Taylor & Francis Ltd. Chap. 3. ISBN: 9780415885058.

Geels, Frank et al. (2012). *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. ISBN: 9780415885058.

Ghosh, Asish (2015). *Dynamic Systems for Everyone*. Springer Nature. DOI: 10.1007/978-3-319-10735-6.

Giddens, Anthony (1991). *Modernity and Self-Identity: Self and Society in the Late Modern Age*. Stanford University Press. 264 pp. ISBN: 9780804719445.

Goodwin, Phil (2012). 'Providing Road Capacity for Automobility: The Continuing Transition'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transitions. Routledge, Taylor & Francis Ltd. Chap. 7, pp. 140–159. ISBN: 978-0-415-88505-8.

Gudmundsson, Henrik and Claus Hedegaard SØrensen (2013). 'Some useLittle influence? On the roles of indicators in European sustainable transport policy'. In: *Ecological Indicators* 35, pp. 43–51. DOI: 10.1016/j.ecolind.2012.08.015.

Haghshenas, Hossein and Manouchehr Vaziri (2012). 'Urban sustainable transportation indicators for global comparison'. In: *Ecological Indicators* 15.1, pp. 115–121. DOI: 10.1016/j.ecolind.2011.09.010.

Hirt, Sonia (2007). 'The Devil Is in the Definitions. Contrasting American and German Approaches to Zoning'. In: *Journal of the American Planning Association* 73.4, pp. 436–450. DOI: 10.1080/01944360708978524.

Hjorth, Peder and Ali Bagheri (2006). 'Navigating towards sustainable development: A system dynamics approach'. In: *Futures* 38.1, pp. 74–92. ISSN: 0016-3287. DOI: 10.1016/j.futures.2005.04.005.

Höjer, Mattias and Lars-Göran Mattsson (2000). 'Determinism and backcasting in future studies'. In: *Futures* 32.7, pp. 613–634. ISSN: 0016-3287. DOI: 10.1016/S0016-3287(00)00012-4.

HØyer, Karl G. (2000). 'Sustainable Tourism or Sustainable Mobility? The Norwegian Case'. In: *Journal of Sustainable Tourism* 8.2, pp. 147–160. DOI: 10.1080/09669580008667354.

Hymel, Kent M., Kenneth A. Small, and Kurt Van Dender (2010). 'Induced demand and rebound effects in road transport'. In: *Transportation Research Part B: Methodological* 44.10, pp. 1220–1241. DOI: 10.1016/j.trb.2010.02.007.

IEA (2017). *Statistics (web portal)*. International Energy Agency. URL: https://www.iea.org/statistics/ (visited on 05/17/2017).

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [core writing team R.K. Pachauri and L.A. Meyer (eds.)] Research rep. Geneva, Switzerland: Intergovernmental Panel on Climate Change. 151 pp.

Jiang, Leiwen and Brian C. O'Neill (2017). 'Global urbanization projections for the Shared Socioeconomic Pathways'. In: *Global Environmental Change* 42, pp. 193–199. DOI: 10.1016/j.gloenvcha.2015.03.008.

Kauppila, Jari (2012). *OECD Countries Spend 1% of GDP on Road and Rail Infrastructure on Average. Infrastructure Investment*. Tech. rep. International Transport Forum (ITF-OECD). 7 pp. URL: https://www.itf-oecd.org/sites/default/files/docs/2012-06.pdf (visited on 05/17/2017).

KC, Samir and Wolfgang Lutz (2017). 'The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100'. In: *Global Environmental Change* 42, pp. 181–192. DOI: 10.1016/j.gloenvcha.2014.06.004.

Kemp, René, Flor Avelino, and Nann Bressers (2011). 'Transition Management as a Model for Sustainable Mobility'. In: *European Transport/Transporti Europei* 47, pp. 25–46.

Kemp, René, Derk Albert Loorbach, and Jan Rotmans (2007). 'Transition management as a model for managing processes of co-evolution towards sustainable development'. In: *International Journal of Sustainable Development and World Ecology* 14.1, pp. 78–91. ISSN: 1350-4509. URL: http://www.scopus.com/inward/record.url?eid=2-s2.0-34247274634%7B%5C&%7DpartnerID=tZOtx3y1%7B%5C%%7D5Cnhttp://www.scopus.com/inward/record.url?eid=2-s2.0-34247274634%7B%5C&%7DpartnerID=40%7B%5C&%7Dmd5=4718dc8eeb02dd1e8bb5edcc7314c459.

Kemp, René and Jan Rotmans (2004). 'Managing the Transition to Sustainable Mobility'. In: *System innovation and the transition to sustainability: theory, evidence and policy*. Ed. by Boelie Elzen, Frank W Geels, and Kenneth Green. Edward Elgar. Chap. 7, pp. 137–167. ISBN: 9781845423421.

Kerr, Richard A (2011). 'Peak oil production may already be here'. In: *Science* 331.6024, pp. 1510–1511.

Klein, Naomi (2008). *The shock doctrine: The rise of disaster capitalism*. Macmillan. 720 pp. ISBN: 9780312427993.

Köhler, Jonathan et al. (2009). 'A transitions model for sustainable mobility'. In: *Ecological Economics* 68.12, pp. 2985–2995. ISSN: 0921-8009. DOI: 10.1016/j.ecolecon.2009.06.027.

Kok, Kasper et al. (2011). 'Combining participative backcasting and exploratory scenario development: Experiences from the {SCENES} project'. In: *Technological Forecasting and*

*Social Change* 78.5. Backcasting for Sustainability, pp. 835–851. ISSN: 0040-1625. DOI: 10.1016/j.techfore.2011.01.004.

Korzhenevych, Artem et al. (2014). 'Update of the Handbook on External Costs of Transport'. In: *Final Report* 1. Ref: ED 57769 - Issue Number 1, p. 139. URL: http://ec.europa.eu/transport/themes/sustainable/studies/doc/2014-handbook-external-costs-transport.pdf.

Kriegler, Elmar et al. (2017). 'Fossil-fueled development (SSP5): An energy and resource intensive scenario for the 21st century'. In: *Global Environmental Change* 42, pp. 297–315. DOI: 10.1016/j.gloenvcha.2016.05.015.

Kumi, Emmanuel, Albert A. Arhin, and Thomas Yeboah (2014). 'Can post-2015 sustainable development goals survive neoliberalism? A critical examination of the sustainable development–neoliberalism nexus in developing countries'. In: *Environment, Development and Sustainability* 16.3, pp. 539–554. ISSN: 1573-2975. DOI: 10.1007/s10668-013-9492-7.

Laurenti, Rafael, David Lazarevic, et al. (2014). 'Group Model-Building to identify potential sources of environmental impacts outside the scope of LCA studies'. In: *Journal of Cleaner Production* 72.May, pp. 96–109. ISSN: 0959-6526. DOI: 10.1016/j.jclepro.2014.03.001.

Laurenti, Rafael, Rajib Sinha, et al. (2015). 'Towards Addressing Unintended Environmental Consequences: A Planning Framework'. In: *Sustainable Development* 24.1, pp. 1–17. DOI: 10.1002/sd.1601.

Litman, Todd (2007). 'Developing Indicators for Comprehensive and Sustainable Transport Planning'. In: *Transportation Research Record: Journal of the Transportation Research Board* 2017, pp. 10–15. DOI: 10.3141/2017-02.

Lyons, Glenn (2012). 'Visions for the Future and the Need for a Social Science Perspective in Transport Studies'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transitions. Routledge, Taylor & Francis Ltd. Chap. 2, pp. 29–48. ISBN: 978-0-415-88505-8.

Marcuse, Herbert (2013). *One-Dimensional Man: Studies in the Ideology of Advanced Industrial Society*. Routledge Classics. Taylor & Francis. ISBN: 9781134438808.

Marshall, S. (2001). 'The challenge of sustainable transport'. In: *Planning for a Sustainable Future*. Ed. by Susan Batty Antonia Layard Simin Davoudi. Spon Press. ISBN: 9780415234085.

Mayer, Heike and Paul L. Knox (2006). 'Slow Cities: Sustainable Places in a Fast World'. In: *Journal of Urban Affairs* 28.4, pp. 321–334. DOI: 10.1111/j.1467-9906.2006.00298.x.

McDowall, William and Malcolm Eames (2006). 'Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature'. In: *Energy Policy* 34.11, pp. 1236–1250. DOI: 10.1016/j.enpol.2005.12.006.

Meadows, Donella H. (1972). *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books. ISBN: 9780856440083.

Meddin, Russell (2017). *The Bike-sharing World at the End of 2016*. MetroBike LLC. URL: http://bike-sharing.blogspot.se/2017/01/the-bike-sharing-world-at-end-of-2016.html (visited on 06/01/2017).

Milanovic, Branko (2016). *Global Inequality*. Harvard University Press. 299 pp. ISBN: 9780674737136. URL: http://www.ebook.de/de/product/25237275/branko_milanovic_global_inequality.html.

Monbiot, George (2016). *Neoliberalism the ideology at the root of all our problems*. URL: https://www.theguardian.com/books/2016/apr/15/neoliberalism-ideology-problem-george-monbiot (visited on 05/29/2017).

Moriarty, Patrick and Damon Honnery (2008). 'Low-mobility: The future of transport'. In: *Futures* 40.10, pp. 865–872. DOI: 10.1016/j.futures.2008.07.021.

Muñiz, Ivan and Anna Galindo (2005). 'Urban form and the ecological footprint of commuting. The case of Barcelona'. In: *Ecological Economics* 55.4, pp. 499–514. ISSN: 0921-8009. DOI: 10.1016/j.ecolecon.2004.12.008.

O'Neill, Brian C. et al. (2017). 'The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century'. In: *Global Environmental Change* 42, pp. 169–180. DOI: 10.1016/j.gloenvcha.2015.01.004.

Peeters, Paul, Stefan Gossling, and Susanne Becken (2006). 'Innovation towards tourism sustainability: climate change and aviation'. In: *International journal of innovation and sustainable development* 1.3, pp. 184–200. DOI: 10.1504/IJISD.2006.01242.

Piketty, Thomas (2014). *Capital in the Twenty-First Century*. Harvard University Press. ISBN: 9780674430006. URL: http://www.ebook.de/de/product/21683807/thomas_piketty_capital_in_the_twenty_first_century.html.

Precedo, José (2017). 'Pontevedra, el sueño de la ciudad (casi) sin coches'. In: *elDiario*. Monográfico 16. Ed. by Daniel Sánchez, pp. 22–27. ISSN: 2255-3932.

Riley, Paul et al. (2010). *Intermodal Passenger Transport in Europe: Passenger Intermodality from A to Z*. Research rep. LINK Consortium – European Commission – DG MOVE.

RØpke, Inge (1999). 'The dynamics of willingness to consume'. In: *Ecological Economics* 28.3, pp. 399–420. DOI: 10.1016/S0921-8009(98)00107-4.

Rotmans, Jan, René Kemp, and Marjolein van Asselt (2001). 'More evolution than revolution: transition management in public policy'. In: *Foresight* 3.1, pp. 15–31. DOI: 10.1108/14636680110803003.

Rounsevell, Mark D. A. and Marc J. Metzeger (2010). 'Developing qualitative scenario storylines for environmental change assessment'. In: *WIREs Climate Change* 1, pp. 606–619. DOI: 10.1002/wcc.63.

Sheller, Mimi (2008). 'Mobility, Freedom and Public Space'. In: Sager, Tore. *The Ethics of Mobilities: Rethinking Place, Exclusion, Freedom and Environment*. Ed. by Sigurd Bergmann. Transport and Society. Routledge, Taylor & Francis Ltd. ISBN: 9781138253421.

Sheller, Mimi (2012). 'The Emergence of New Cultures of Mobility – Stability, Openings and Prospects'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transitions. Routledge, Taylor & Francis Ltd. Chap. 9, pp. 180–202. ISBN: 978-0-415-88505-8.

Shiau, Tzay-An and Jung-Shan Liu (2013). 'Developing an indicator system for local governments to evaluate transport sustainability strategies'. In: *Ecological Indicators* 34, pp. 361–371. DOI: 10.1016/j.ecolind.2013.06.001.

Spaargaren, Gert and Bas van Vliet (2000). 'Lifestyles, consumption and the environment: The ecological modernization of domestic consumption'. In: *Environmental Politics* 9.1, pp. 50–76. eprint: http://rsa.tandfonline.com/doi/pdf/10.1080/09644010008414512.

Sterman, John D (2000). *Business Dynamics*. McGraw-Hill Higher Education. ISBN: 0-07-231135-5.

Sturgeon, Timothy and Johannes Van Biesebroeck (2009). 'Crisis and Protection in the Automotive Industry: A Global Value Chain Perspective'. In: *World Bank Policy Research*. (Visited on 06/03/2017).

The Guardian (2017). *Volkswagen reveals record car sales amid emissions scandal*. Ed. by Agence France-Presse. URL: https://www.theguardian.com/business/2017/jan/11/volkswagen-reveals-record-car-sales-amid-emissions-scandal (visited on 05/26/2017).

Thill, Jean-Claude and Marim Kim (2005). 'Trip making, induced travel demand, and accessibility'. In: *Journal of Geographical Systems* 7.2, pp. 229–248. DOI: 10.1007/s10109-005-0158-3.

Urry, John (2004). 'The 'System' of Automobility'. In: *Theory, Culture & Society* 21.4-5, pp. 25–39. DOI: 10.1177/0263276404046059.

Verhoef, Erik T. and Peter Nijkamp (2002). 'Externalities in urban sustainability: Environmental versus localization-type agglomeration externalities in a general spatial equilibrium model of a single-sector monocentric industrial city'. In: *Ecological Economics* 40.2, pp. 157–179. ISSN: 0921-8009. DOI: 10.1016/S0921-8009(01)00253-1.

Vimercati, Luigi (2011). 'Traffic related air pollution and respiratory morbidity'. In: *Lung India* 28.4, p. 238. DOI: 10.4103/0970-2113.85682.

Vuuren, Detlef P. van et al. (2017). 'Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm'. In: *Global Environmental Change* 42, pp. 237–250. DOI: 10.1016/j.gloenvcha.2016.05.008.

Wells, Peter and Paul Nieuwenhuis (2012). 'Transition failure: Understanding continuity in the automotive industry'. In: *Technological Forecasting and Social Change* 79.9, pp. 1681–1692. ISSN: 0040-1625. DOI: http://dx.doi.org/10.1016/j.techfore.2012.06.008.

Wells, Peter, Paul Nieuwenhuis, and Renato J. Orsato (2012). 'The Nature and Causes of Inertia in the Automobility Industry – Regime Stability and Non-Change'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transition. Routledge, Taylor & Francis Ltd. Chap. 6. ISBN: 9780415885058.

WHO (2006). *Air quality guidelines. Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. Tech. rep. WHO Regional Office for Europe. URL: http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide.

WHO (2017). *Global Health Observatory data repository (web portal)*. World Health Organization. URL: http://www.who.int/gho/en/ (visited on 05/18/2017).

Li-Zeng, Mao, Zhu Hong-Ge, and Duan Li-Ren (2012). 'The Social Cost of Traffic Congestion and Countermeasures in Beijing'. In: *Sustainable Transportation Systems*. Proceedings, pp. 68–76. DOI: 10.1061/9780784412299.0010.

Zijlstra, Toon and Flor Avelino (2012). 'A Socio-Spatial Perspective on the Car Regime'. In: *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Ed. by Frank W. Geels et al. Routledge Studies in Sustainability Transition. Routledge, Taylor & Francis Ltd. Chap. 8. ISBN: 9780415885058.