Adaptive Mobility

A new policy and research agenda on mobility in horizontal metropolises

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Introduction

SETTING A NEW RESEARCH AGENDA FOR A MORE SUSTAINABLE MOBILITY AND LOGISTICS IN FLANDERS

Luuk Boelens
Dirk Lauwers
Frank Witlox

Flanders is a densely populated region in the northern, Dutch-speaking part of Belgium, Europe. The region has a population of approximately 6.4 million inhabitants (not counting Brussels) in an area of 13,597 km^2 and is divided in 308 municipalities. There are three major cities with a high employment attraction: Brussels (1,160,000 inhabitants in the Brussels-Capital-Region, which has its own government, legislation and administration) is the center of service and government jobs; Antwerp (512,000 inhabitants) is characterized by its port activities (e.g. chemical industry and petrochemicals); and Ghent (248,000 inhabitants) mainly offers jobs in industry, research, education, and development. Additionally, there are 11 other large cities with a central function in their region with regard to employment, health care, education, culture, and entertainment (Dewulf et al. 2015).

Developing a sustainable urban mobility and logistics policy implies that governments have to focus on creating high-quality, livable cities with acceptable standards of access to goods and activities. Such sustainable urban development aims to shorten distances between locations of activities so that more sustainable transport modes other than the car and/or truck will be used resulting in a reduced use of energy and other resources and a reduction of emissions including carbon dioxide (Banister, 2008, 2010). The core common feature of such sustainability in European cities thus primarily depends on a reduction of motorized vehicles (whether cars or trucks) use. This involves a change in people's way of life, a shift in their mindset, and looking for a shift in governance and policy-making towards more sustainable mobility and logistics solutions (Van Acker et al. 2015). This policy shift is also closely related to such topics of smart architecture, green built-up land use and environment, climate change, safety issues, and health issues.

The need for a psychological and institutional turn

As such, the quest for sustainable and resilient mobility remains one of the most important issues within the Flemish administration, media and public domain. Not a day passes when sustainable mobility is not questioned in the media. Examples are abundant: the criticism about the new Flanders Mobility Plan, the Oosterweel-link (completion of the Antwerp 'ring road', attracting more traffic to the urban highways in this city), Brussels ring road (separating international and urban highway traffic but also extending the road capacity), extensions of public transport lines (such as GEN-Brussels), Uplace (large shopping centre planned in the fringe of the Brussels agglomeration close to an already congested Brussels highway interchange), Mobility planning of Antwerp and Ghent (discussion if a more or a less car oriented accessibility should be planned for)……. For the one part this media coverage and therefore ongoing discussion within Flemish public planning is not remarkable. For Flanders is one of the car-densest regions in Europe, as it is characterised as a region with one of the most diffuse infrastructure ever (UU/TNO 2012, Boelens 2013, Lauwers and De Mol, 2013). Unlike its neighbouring countries and regions (the Netherlands or the North-Rhine-Westphalia in Germany), Flemish civil engineers upgraded existing roads and planned new infrastructures next to the existing ones, instead of creating a stand-alone new and consistent network. Although in the 1980s an infrastructure programme called 'Doortochten' started with projects aiming at downgrading the function of local and regional roads and since the approval of the 'Ruimtelijk Structuurplan Vlaanderen' (the Flemish spatial policy plan) a binding categorisation system aiming at rebalancing accessibility and liveability has been introduced, the dense road network is still very permeable for car traffic. As a result, the whole of Flanders appears to be well accessible by car, and consequently its environmental impact is felt everywhere.

Moreover, this infrastructural feature was flanked by a rebuilding policy soon after the Second World War, to subsidize individual family housing together with a liberal spatial planning policy, instead of taking those issues as state-affairs in their own hands (Boelens and Taverne, 2012). The result is suburban sprawl, characterized as a horizontal metropolis or 'citta diffusa' ('nevelstad' in Dutch, Vigano 2012). In this respect mobility and especially car-mobility has turned out to become a love-hate affair for the majority of the Flemish people. On the one hand, they love their car and the dispersed infrastructure network, while it serves the accessibility of the citta diffusa. On the other hand, they hate it, not only due to the daily traffic jams, but also since the environmental impact of ongoing and dispersed mobility has in the meantime generated major consequences in most urbanised areas, where the car traffic – but also its harmful emissions – accumulate. Thus, at the one side there is a quest for additional infrastructure, in order to guarantee accessibility and diminish traffic jams; on the other hand it is highly contested while it further affects health and well-being. Therefore, there is a growing and ongoing policy focus on minimizing the (social-environmental) impact of the expanding mobility, by covering up main highways, public transport or parking places, or by inducing new technologies in the transport and traffic market, in order to make these more sufficient and/or sustainable. Upgrading of biking infrastructures and public transport services since the beginning of 21st century have led to an absolute growth of these modes, but only at the same pace as car traffic. So the relative position of biking, public transport and car travel in the modal split in the Flanders region has been quite stable for some decades.

Although these incentives contribute to sustainable mobility on the short run, the impression is that each of these policies start at the wrong end of the story. They just minimize the (social-environmental) impact of growing mobility, rather than represent a real endeavour for socio-spatial resilient transport-travel-traffic planning (Vanoutrive and Boussauw, 2014). It is focussed on the hardware of the issue (infrastructure, vehicles, public transport means etc.) and hardly on the software (preventing or inducing a more sustainable use, preventing inefficient or avoidable travel, diminished energy-use and thus its environmental impact) or the orgware of infrastructure and mobility planning (organization of space and mobility, efficient situational and adaptive shared mobility, focussed on the specific demand at hand etc.). There is a real need to refocus more on these last two domains, instead of an ongoing expansion planning, serving the needs of a growing mobility. According to the BREVER-law (Hupkes 1977)[1] this is in fact a self-reinforcing development, – in Anglo-Saxon literature often referred to as 'the fundamental law of road congestion' (Downs 1962) – for which more and more empirical evidence has been documented (Cervero, 2003; Duranton and Turner, 2011). Scholars are increasingly convinced that it would be more resilient on the long run to refocus on the existing requirements and means of mobility (Dijst and Gimmler, 2016). In fact, that would need a change on the internal drives, specific motives, interests etc. of the mobility users and actors themselves; in fact a radical turn from a pure civil engineering approach, towards an integrated approach of sustainable mobility, including also psychological, sociological and/or institutional aspects. Despite the fact that we have an increasing number of telematics and technological resources at our disposal (e.g. smart phones, automatic vehicle control, satellites, computerized flow control, etc.), this endeavour is however not so easy to implement. Since our network society has become much more complex, volatile and contingent and since new actors, organizations and technological means have appeared on the scene, the future mobility flows will become much more non-linear, criss-cross, fuzzy, and thus unpredictable and hardly controllable top-down (Allen 1997, Boelens and De Roo, 2014). We have to become smarter than smart, and dig into this complexity ourselves, in order to come up with new tactics and strategies enhancing sustainable or resilient mobility in fuzzy, changing circumstances.

1 in Dutch 'wet van Behoud van REistijd en VERplaatsingen', meaning 'law of constant travel time and trips' stating that through recent history and in different economic and cultural conditions daily travel time budgets are constant, regardless of the transport modes available or the average speed of these modes

Three lines of thought

With this in mind, the current book sketches a new, future research and policy agenda. It departs from existing, preliminary attempts of research in this direction; and tries to further materialize this into a resilient agenda for the future. These preliminary attempt starts from a different view about the interaction between society, space and mobility; driven by radical transitions (disruptions) from the traditional to more complex, a-linear approaches. This transition is characterized by three major challenges (or lines of thought):

- From generic towards situational approaches of the demand side of the travel market;
- From hard and stable to smart adaptive approaches within the transport and traffic market;
- From top-down strategies towards structural couplings and coevolution in the mobility market.

The first line of thought (SOCIETY AND SPACE) deals with situational travel behaviour in respect to changing settings of accessibility, lifestyles, and their interaction with society, health and space.

The second line of thought (TECHNOLOGY AND INDIVIDUAL TRAVEL) deals with the ongoing use of new technological means, including shared mobility and interactive design to facilitate these increasing individual demands;
The third line of thought (GOVERNANCE AND COLLECTIVITY) deals with adaptive, actor-relational approaches of mobility, in changing settings of formal and informal initiatives in mobility planning.

This book is structured along the three above-mentioned lines of thought.

Contributions

The first contribution, in the first line of thought, of *Koos Fransen*, *Greet Deruyter* and *Philippe De Maeyer* is focused on the complex matter of accessibility. Although accessibility is regularly related to the socio-economic opportunities to access important destinations beyond their immediate surroundings, they show that the current debates often fall short to the question of how the complexities of the existing and evolving society's travel behaviour are incorporated into the decision process of actions that lead to a gain in mobility. Social disadvantages, related to these particular mobility-needs, have a strong link with the transport disadvantages, because of the specific transport system's characteristics. If both aspects are not fine-tuned to each other, transport poverty originates, which in turn results in the inability to access social networks, services and vital commodities. Therefore they conclude that in order to combat social exclusion, there is a growing policy attention needed to define where and when transport poverty materializes.

In the same way, also *Veronique Van Acker* pleads for a growing policy attention towards a more life-style adaptive approach of mobility planning. Nevertheless she shows that what are regularly called lifestyles in mobility research rather refers to stage-of-life or household composition, which refers only to general objective socio-economic characteristics. She therefore tries to provide a more sophisticated overview of the 'lifestyle' concept in terms of definitions and measurement methods towards a so-called sociographic lifestyle approach focussing on a behavioural orientation – values, attitudes and preferences – and a latent factor motivating behaviour patterns. In addition, she tries to add some evidence on this issue using data on attitudes and leisure activities from a sample of highly educated respondents in Flanders, Belgium. Here she concludes that the influence of lifestyles becomes more interesting when considering the interaction with residential location choices and car ownership decisions in a path analysis. This path analysis gives more profound insights into which type of people (in terms of lifestyles) is associated with urban residential choices (i.e., residing in high density neighbourhoods close by a regional city center) and car ownership decisions.

In that respect the third contribution of *Jonas De Vos, Ben Derudder* and *Frank Witlox* focuses on the reciprocal interaction of travel patterns in their surroundings. Since existing literature predominately focusses on the one-dimensional impact of the built environment (as for instance the distinction between compact or suburban environments) on daily travel patterns, they suggest that this interaction is more complex and reciprocal adaptive. The link between residential location and travel behaviour is also affected by travel-related attitudes. As land use preferences are partly shaped by these attitudes, people self-select themselves in a neighbourhood where they can easily travel with their preferred travel mode. This could be called a path dependency of the respective lifestyles, in Van Acker's idea of thought. But additionally De Vos, Derudder and Witlox also stipulate that these preferences are subject to how people perceive their travel; travel mode choice plays an important role in how satisfied we are with our trips. People using public transport – especially the bus – are least satisfied with their trips while walking and cycling results in the experience of positive feelings during the trip and a positive evaluation of the trip. Since travel satisfaction is affected by travel mode choice and is also related with travel-related attitudes and the residential location, it is important to include these adaptive approaches and travel satisfaction within policies with regard to the interaction between residential location and mobility.

Here the contribution of *Veerle Van Holle* and *Lieze Mertens* comes in. They discuss those ideas of travel behaviour and travel satisfaction from a Public Health Perspective (PHP). After introducing health benefits and measurement methods, and the influencing factors of active transport, they make a distinction between macro-incentives (i.e. accessibility of destinations) and micro-incentives (i.e. specific street characteristics such as quality of infrastructure). For four different age groups they show how these macro- and micro-incentives could influence travel behaviour and travel satisfaction in reference to public health results in specific Flemish cases. And although it is difficult to provide 'one fits all' advice on how the physical environment should be designed to promote active transport, they suggest that accessibility of destinations are key factors in this respect. As such the circle is round again, and we have to turn back to the first contribution, stipulating that we need a multifaceted policy from various (lifestyle) perspectives to induce sustainable transport for tomorrow.

The second part of this book is focussed on how new technological measures and/or telematic means could help in this respect.

In a first contribution *Sidharta Gautama*, *Nico Van de Weghe* and *Philippe De Maeyer* show how movement of people can be observed and organized using modern ICT tools in a smart city environment. Current technological advances allow within certain limits to observe aspects of multimodal mobility behaviour. Camera networks, city sensors and smartphone applications all deliver different insights in the complex interplay of transport modes in a city. However, and although more an more advances are made in this domain they stress that we have to move beyond simply collecting mobility data into big data repositories, and explore how ICT can be used to set up the dialogue between citizen and policy maker. It helps in bringing forward purpose of travel and the preferences and dislikes of the mobility consumer with respect to current and future policy.

In that respect also *Sabine Wittevrongel* and *Joris Walraevens* stress that those new means have to be applied in the shared-vehicle paradigm in order to enhance its performance as a good alternative for 'vehicles as property'. The main performance measure of those shared systems is the availability of vehicles when and where users need them. To get good performance, fleet-size should be large enough and operation management such as relocation of vehicles could be necessary. This obviously comes at a cost. In this chapter Wittevrongel and Walraevens therefore review queuing models for different types of shared mobility systems. These queuing models are essential to improve the performance of shared-mobility systems, to capture the influence of different parameters and of operational choices on this performance and, on a more strategic level, to compare different forms of shared mobility.

Additionally the third contribution of *Rodrigo Rezende Amaral, El-Houssaine Aghezzaf, Birger Raa* and *Ehsan Yadollahi* in this line of thought focuses on how these new technological means could also help to improve urban logistics and mobility. The challenge here is how to optimize logistics and transport activities in urban areas, while taking traffic congestion and air pollution into account, with a view of reducing the number of vehicles on the city's road network through the rationalization of their operations. The logistical activities and mobility aspects involved in this process include, in addition to transport, handling and storage of goods, the management of inventory and related pickup and delivery operations. They show how this could be done and how smart city logistics could be viewed as a first step towards a clean, safe, mobile and economically and environmentally sustainable city.

Nevertheless, and although these new technological means are a necessary prerequisite for a smarter and possible more sustainable mobility in and around cities, the third line of thought in this book stresses that these new means are not sufficient. Additional institutional, organizational measures are necessary in order to make these new technologies work efficiently and adaptive situational in an ongoing and ever more complex networked society.

In their contribution *Enrica Papa* and *Dirk Lauwers* therefore stress that we have to become smarter than smart. In order to enhance sustainable mobility planning, we should move beyond technology, and integrate technologies, systems, infrastructures, and capabilities, with the real interests and ambitions of the customers and actors involved. The new technology means should evolve toward a means and an end. Here there is a need to commit 'citizens' and not just 'users' to a *smarter* mobility paradigm. The open and active involvement of people and stakeholders would be far more effective. Thus, broad coalitions should be formed to include specialists, researchers, academics, practitioners, policy makers entrepreneurs and activists in the related areas of technology, transport, land use, urban affairs, environment, public health, ecology, engineering, green modes and public transport. Accordingly, we should start with the situational human capital itself, and facilitate a willingness to change and an acceptance of collective responsibility with regard to sustainable mobility. Papa and Lauwers stress that a central aspect over here is a bottom up approach, with active involvement from every sector of the community: civic, public business, and knowledge institutions. Main actions over here include for instance:

- creating the conditions of a continuous process of learning and innovation;
- broad coalitions: specialists, researchers, academics, practitioners, businesses, policy makers and activists in the related areas of technology, transport, land use, urban affairs, environment, public health, ecology, engineering, green modes and public transport;
- integrating smartness, local context, citizens, sustainability in real-life testing and experiential environments (Mobility Living Labs);
- developing prospective areas for Public-Private-People (PPP) Partnership for innovative sustainable transport and mobility solutions in urban areas;
- interactive and participatory processes to commit people in their role as “citizens” and not just as “mobility users” within the development and implementation of innovative technology products and services in the city

In the final contribution *Luuk Boelens* confronts these challenges with the recent decree of the Flemish government with regard to complex infrastructure planning. Also based on international literature with regard to complex decision making, he shows that this decree doesn’t deal so much with the ongoing complexity of real life settings itself, but rather tries to reduce that kind complexity in a layered, linear system of decision making and a one-government-fits-all-concept. Therefore this decree only serves the streamlining of the internal affairs of the Flemish Administration – which is for all that matter even disputed in itself (see Beyers 2014, SERV 2014) – and not the adaptation of mobility planning to the changing and infinitely complex decision circumstances in real life itself. Next to the fact that this legislation starts at the wrong end of the problem (fixing the impact and avoiding complexity whatsoever), he therefore expects no real contributions of this decree to a more efficient and smarter mobility planning, let alone a more resilient or sustainable one. Instead he stresses that mobility planning has to become more situational in order to develop focussed mobility measures with regard to specific life styles, healthy accessibilities, reciprocal interaction between environment and travel modes, the introduction of new technological means over here, within for instance participatory living mobility labs as mentioned before, etc. Here he distinguishes several degrees of complexity, depending on the object of mobility planning and the actors involved: fixed, dynamic, open and fuzzy. In fact each of these situations asks for a specific governance of these challenges of sustainable mobility: smart, procedural, adaptive, collaborative, co-evolutionary. Although each of these planning approaches is still in their infant phase, there is an ongoing need to further elaborate them. Only in this way mobility planning could become more involved with the major challenges mentioned before, as that it could induce a more overall conditional vision in this respect.

Towards a more sustainable policy and research agenda

What would this all mean for a future policy and research agenda on sustainable mobility?
The first line of thought (SOCIETY AND SPACE) seems to drive towards an urgent need for a better understanding of 'soft' factors such as personal attitudes and lifestyles. Such soft factors must be questioned in relation to transport and mobility in the first place (e.g., how do people perceive car versus public transport, do people prefer multimodality or not). But also other themes that are related with transport and mobility such as residential and workplace location, health, climate awareness, subjective well-being and happiness? Without this, the attention for the software of transport can never reach a comparable level as the dominant hardware of transport. Future research should therefore focus on how attitudes and lifestyles are formed and change throughout the life course of individuals and households. This refers to the impact of past and future life events on current attitudes and behaviors, but also to the extent to which attitudes and behaviors are shared across different generations, peer groups, places and cultures.

The second line of thought (TECHNOLOGY AND INDIVIDUAL TRAVEL) drives towards a better understanding and policy processing of the ongoing use of new technological means that pervades daily life and allows us to construct connected mobility and interactive design to facilitate increasing individual demands. The availability of smart city sensors, internet of things and big data processing are not a technological goal as such, but have increasingly become a supporting means to better understand the individual and collective mobility needs and to set up a dialogue between mobility stakeholders and the consumer. Design of this technology transcends pure engineering and requires a multidisciplinary approach that combines among others information processing, user-centric design and participatory governance.

The third line of thought (GOVERNANCE AND COLLECTIVITY) drives towards a better understanding of the complexity of decision making and the adaptive, collaborative or co-evolutionary 'governance' of complex mobility situations. The coming decades will bring disruptive changes in the mobility system, based on the introduction of new technologies (making vehicles, infrastructure as well as users more connected), but also based on the emergence of new business models and actors (especially of new types of providers and brokers). Combined with the new mobility cultures following broader megatrends in society, this will bring new challenges to the mobility governance in different situations. There is no one-size-fits-all solution anymore, but there is a need for specific and situational approaches. Further research on possible mobility scenarios (from 'mobility as a service' to 'individual mobility luxury') and how they relate to mobility paradigms (sustainable mobility, place-making) will have to clarify adequate policy and governance approaches to meet the challenges for the mobility as well as for the spatial disruptions they might cause.

However, one could also question the 'sustainable' adjective of mobility itself: would in fact 'no-mobility' become the best sustainable, safe and robust mobility whatsoever? Therefore, this book also includes a fictive dialogue between two 'ironic' mobility experts. That dialogue starts with a discussion on the dialogue as a genre of scientific writing itself. It subsequently reflects on the concept of sustainable mobility and illustrates that there is no such thing as a homogeneous sustainable mobility discourse. The 'ironic experts' argue that sustainable mobility primarily deals with questions of justice and goodness and establishes a link to social justice-inspired work. Nevertheless, and after some thoughts on irony, they also conclude with a twofold role of transport studies. Firstly, researchers are in the position to make the normative nature of discussions on mobility more visible, and to reflect on the principles underlying transport policy. Secondly, they are able to make a profound analysis of the current transport system and its genesis. It puts our work as mobile experts and planners profoundly into perspective, although there evolves also a growing need to analyse and study mobility to its very psychological, technological and spatial core.

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Society and Space

CONCEPTS, REFLECTIONS AND APPLICATIONS OF SOCIAL EQUITY

Koos Fransen
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Philippe De Maeyer

APPROACHES TO ACCESSIBILITY TO PRIMARY GOODS AND SERVICES IN THE REGION OF FLANDERS, BELGIUM

Introduction

Mobility presents a variety of opportunities as it allows users to access locations and services, and to meet people beyond their immediate surroundings. While the concept of mobility primarily focuses on the ease of moving, accessibility delineates the actual potential to participate in out-of-home activities. As a result, accessibility is a complex concept with a multitude of foci. This complexity is presented in the first section, which explains the general concept of accessibility, how it is defined and how it is related to the notion of transport-related exclusion. This section also gives an overview of the body of literature on the measures to determine area-based as well as personal accessibility levels and points out the important contrast between the simple, easy-to-interpret methods, adopted by policy makers and the complex methods preferred by experts.

The second section clarifies how the dichotomous relationship between the urban and rural environment is reflected in transport policy that emphasizes on (especially car-based) mobility rather than on accessibility. Furthermore, the environmental and economic points of view are highlighted and the common policy strategies focused on sustainability are illustrated. Subsequently, the shortcomings in the way in which the contemporary debates concerning mobility, sustainability and the social implications of transport planning are conducted, are criticized. Finally, the last part of this section is dedicated to an extensive discussion on the ability of transport policies to, on the one hand, generate spatially as well as temporally uneven accessibility effects that give preference to certain population groups above others, and on the other hand, their ability to strive for a more equitable distribution of transport services amongst the population.

The third section proposes two methodologies for measuring transport-related social exclusion implemented in a literature-based case study in Flanders. These studies comprise the following topics: measuring transport gaps by relating the social to the transport disadvantage and measuring modal disparities by comparing accessibility by private and public transport. The former investigates in which areas the provision of the public transport system is not tailored to specific public transport needs. The latter examines the disparity in access by private and public transport in order to highlight the car dependency. Both case studies incorporate the temporal variability in provision through the private and public transport network, as the time-of-day strongly influences accessibility levels.

The complex concepts of accessibility

Defining accessibility: a widely applied yet slippery notion
Although the concept of accessibility is deeply rooted in the research domains of transport geography and planning (Neutens, 2015), the definition of accessibility greatly depends on the context, ranging from social equity studies to transport and economic expansion issues. The difficulty of finding an operational definition of accessibility is well stipulated by Gould, who says: "Accessibility […] is a slippery notion […] one of those common terms that everyone uses until faced with the problem of defining and measuring it" (Gould, 1969, p.64). According to Hanson (1995), accessibility is "the number of opportunities, also called activity sites, available within a certain distance or travel time" (Hanson, 1995, p. 4). Ingram (1971) uses the following definition: "Accessibility may loosely be defined as the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction (for example, time and/or distance)" (Ingram, 1971, p. 101). A third example is to be found in Morris et al. (1979): "Accessibility has generally been defined as some measure of spatial separation of human activities. Essentially it denotes the ease with which activities may be reached from a given location using a particular transportation system" (Morris et al., 1979, p. 91). In essence, accessibility refers to the relative ease by which the locations of activities – such as work, shopping or health care – can be reached from a certain location and by using a given transport system. On the one hand, it varies across space, because it is affected by where the activities or services (supply) and the people (demand) are located. On the other hand, accessibility also varies over time, because both supply and demand are time-dependent (Luo & Wang, 2003; Neutens, 2015). In sum, it can be seen as the opportunities of individuals or groups to participate in a desired activity at a desired location and at a chosen time.
In fact, accessibility is a multi-faceted concept that involves five dimensions: affordability, acceptability, accommodation, availability and geographic accessibility. These dimensions can be classified in two classes: spatial (geographic accessibility and availability) and non–spatial (affordability, acceptability and accommodation) (Penchansky & Thomas, 1981). In the spatial class, geographic accessibility can be defined as the relationship between the locations of supply and demand, taking into account the distance and the clients' transportation resources and time budget. For example, if there are no pharmacies located within walking distance of a bus stop, they can only be accessed by car-owners or people who live nearby. Availability is the second spatial dimension and concerns the relationship between the volume and type of existing services and the clients' volume and type of needs. Geographic accessibility and availability are often considered as one, and grouped under the denominators 'spatial accessibility' or 'accessibility'. In the non-spatial class, affordability is seen as the relationship between the cost of a service and the clients' income or ability to pay. Acceptability refers to the relationship between the clients attitudes about personal and practice characteristics of existing providers including sex, age, location, education, religion, etc. as well as the provider's attitude about personal characteristics of the client. A common example is found in shopping

behavior. A store can be attractive for one person because the goods are low priced and of good quality, while another person can have issues with the store's hygienic condition and, as such, prefers to pay more for the same quality in another shop with higher hygienic standards. Finally, the term accommodation is understood as the relationship between the manner in which the supply resources are organized and the clients' ability to accommodate to these factors, such as the office hours of a service, and the clients' perception of their suitability. For example, the confidence that someone has to be able to get good medical care when needed. The non-spatial factors influencing the overall accessibility are often highly correlated. For example, neighborhoods with low educational attainment tend to have high unemployment rates and low income levels (not considering complex mechanisms such as upwards mobility or social and cultural capital) (Dai & Wang, 2011; Penchansky & Thomas, 1981).

Another dichotomous classification of access to services is the potential access versus the revealed (realized) access. Revealed accessibility focuses on the actual use of the service, whereas potential accessibility signifies the probable entry into the service, but does not ensure the automatic utilization of the offered services (Khan, 1992; Luo & Wang, 2003). The ability to participate in out-of-home activities is closely related to people's well-being. An example of where potential access will influence policy is the issue of the ageing of the population. To face the ageing population in Flanders in the future, it is necessary to take action at the present. Based on demographic statistics, it is possible to calculate the number of elderly people in need of a stay in a retirement home in the short and medium term. The dimensions of the services (in the example, number of available rooms in homes for the elderly) can then be adjusted in response to the potential user dimensions. This means that potential access is offered to potential users. Potential access thus means probable entry into the retirement home system. However, it does not signify the automatic occupancy of the total number of rooms made available. The actual utilization is susceptible to a lot of factors (barriers or facilitators) depending on both the service and the users, such as the quality of the rooms, the cost, other services that may expand (i.e. home based care), the retirement benefits, the family situation, etc. When the facilitators are preponderant to the barriers, the service will be utilized and realized access is achieved (Khan, 1992; Luo & Wang, 2003). While the concept of potential access is likely to be used in planning processes, the concept of realized access is often applied to evaluate existing systems.

The degree of fairness of access to these opportunities, however, is a highly complex matter. Van Wee and Geurs (2011) highlight three primary ethical theories that form the guiding principles for transportation equity: utilitarianism, egalitarianism and sufficientarianism. The utilitarianism approach states that an equitable distribution is achieved when the net benefits outweigh the costs and, therefore, is often applied to analyze and evaluate transport projects and plans (Rock et al., 2014). In other words, justice is done when the total amount of utility is maximized (Geurs & van Wee, 2004). Consequently, the distribution of these benefits is not taken into consideration. An egalitarian approach answers this shortcoming by introducing a sense of fairness by broadly stating that all people are to be treated equally. Nevertheless, this general view on justice does not consider specific needs and does not fully answer the question of who gains the benefits and who bears the costs. Sufficientarianism focuses on the degree that people can meet their particular needs sufficiently and states that priority should be given to improve the well-being below a certain threshold (Rock et al., 2014). This would, however, imply that small benefits for someone below this threshold are prioritized above benefits for larger groups, even though this choice would bring more people below that threshold. In addition, determining this threshold has proven to be a difficult task and seems practically impossible to justify. Martens et al. (2014) delineate prioritarianism as an expansion to sufficientarianism, as it states that benefits matter more the worse off the person is to whom these benefits accrue. Contrary to sufficientarianism, the concern is not absolute: large gains for well-off people can outweigh small gains for worse-off. The prioritarian approach has become an important focus of transport-related social equity studies.

Modeling accessibility: from place-based to sophisticated people-based measures

Modeling accessibility has a long history with a trend towards increasingly sophisticated measurements. More detailed accessibility analysis enables to better determine who has the strongest claim when resources are scarce and, therefore, further unravels the key role transport may play in ensuring an equitable distribution of opportunities. Based on their complexity, methods for measuring accessibility can be categorized in at least four groups. The first group consists of methods in which accessibility is measured at the level of spatial boundaries, mainly administrative districts. 'Provider to population ratio' (PPR) is the most popular method in this category and is derived from dividing the number of facilities (supply) by the number of inhabitants (potential demand) located within a zone of a particular zoning system. An important limitation of these container-based metrics is the assumption that facilities outside the predefined areal unit are inaccessible and that those within the unit are equally accessible to all people within that areal unit. As the same level of accessibility is allocated to all inhabitants of a zone, these methods do not factor in the difficulties related to the spatial distribution of both supply and demand within that zone and ignore competition between suppliers and consumers (Huff, 1963, 1964). However, these methods are often used in spatial policy decision making because such metrics are easy to calculate, do not always require GIS (Geographical Information Systems) tools and are intuitive and readily understood by policy makers (McGrail & Humphreys, 2009; Neutens, 2015). An example of PPRS used in Belgium can be found in IMPULSEO[2], a system that awards financial assistance to physicians settling in shortage areas based on the calculation of the PPR per physician zone. Nevertheless, research shows that this only offers a very crude representation of accessibility to primary health care, because physician zones cover too large geographic areas (Dewulf et al., 2013).

Methods belonging to the second group are slightly more complicated than PPRS,

[2] Koninklijk besluit tot oprichting van een Impulsfonds voor de huisartsengeneeskunde en tot vaststelling van de werkingsregels ervan, B.S., March 30, 2012

however they also produce easily interpretable values, and are easy to understand and to implement using popular off-the-shelf GIS software. Well known methods are 'travel impedance[3] to nearest provider', also called 'closest facility' function (CF) and 'average travel impedance to provider'. The advantage over PPRS is that services in other zones are also considered, however, in the CF, the competition between services is still not accounted for. Therefore, the measure is primarily useful in rural areas characterized by a low availability of services. The average-travel-impedance-to-provider method is more suitable for analysis in urban environments, as it considers all the services or a predefined maximum number of the closest services in the research area. This method introduces the competition between services into the calculations. Taking into account the demand side, however, requires more advanced models. Variations to these basic principles are applied in different case studies (Apparicio et al., 2007; Apparicio et al., 2008).

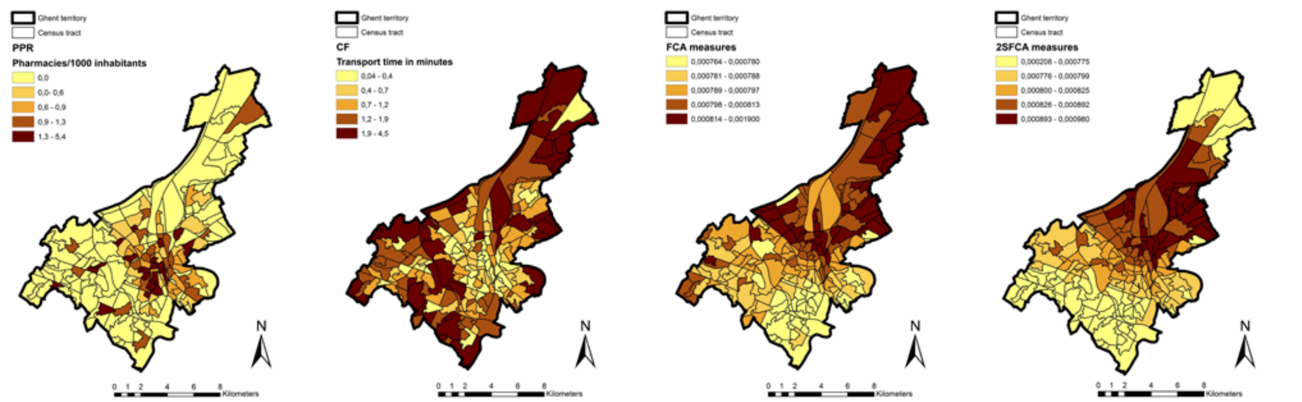
The third category comprises the more complex gravity-based and cumulative-opportunity measures that partly overcome the limitations of the methods described above. They rely on three elements: the demand or population location, the service locations such as shops, physicians, or schools, and an impedance function (travel impedance) to reduce the number of opportunities in function of the distance or effort that needs to be overcome (Delamater, 2013). They deliver a combined indicator of accessibility and availability and can provide accessibility measures for both urban and rural areas. Gravity models attempt to represent the potential interaction between any population point and all service points within a cut-off value, discounting the potential with a mode-dependent impedance decay function. To be successful, these functions need to be fine-tuned for each new study to reflect the true impedance at that point in time and space. Cumulative-opportunity measures on the other hand, integrate the impedance by excluding opportunities beyond a cut-off value. The simple gravity-based model has two main problems. First, the calculated values are not intuitive for policy makers, who prefer to think of spatial accessibility in terms of PPRS or simple distances. Second, it only models supply. There is no adjustment for demand or for the competition between services (Luo & Wang, 2003). Over the years, several enhanced methods were developed based on the gravity model. Some of these sub-types are extensively documented in literature.

The floating catchment area (FCA) family of metrics is a widely applied method and is based on gravity models. FCA metrics incorporate the interaction among supply, potential demand, and travel cost in their characterization of spatial accessibility. These metrics allow the containers to "float" as travel buffers or catchments and are based on the travel impedance from the facility and/or population locations. They also offer detailed variations within large administrative entities. Therefore, they offer a more realistic approach of accessibility than the traditional container-based regional availability measures (first category). The shape and size of the catchment area depend on the density of, and the location in the transportation network. Unlike general gravity models, the FCA metrics provide an output in a highly interpretable

[3] Travel impedance or travel cost can be expressed as a distance, a time, or an amount of money and is often used to define the size of the catchment area of a population or a service. Numerous accessibility measures use the concept of catchment areas of which the size is defined by the threshold travel impedance or the maximum cost a person is willing to spend on one trip. As a consequence, the distance is often not introduced directly in the accessibility calculations. Instead, given a certain maximum time limit, a transport mode, a transportation network and speed limitations inherent to the transport mode or to the network (speed limitations), the threshold travel distance will be calculated and then used as input for the network calculations.

supply to population ratio (e.g., number of physicians per person) and was amongst others applied to calculate accessibility to primary health care (Luo, 2004; Luo & Wang, 2003). A disadvantage of the FCA method is that it does not account for the competition between services in case of overlap between service areas. This limitation is overcome by the two-step floating catchment area (2SFCA), which is a favored method for the assessment of accessibility to health care (McGrail & Humphreys, 2014). The 2SFCA was subject to further modifications, some of them tailor made solutions to a specific accessibility issue. The best known are the enhanced 2SFCA (E2SFCA) and the kernel density 2SFCA (KD2SFCA), which improve the calculations by introducing travel impedance decay functions in function of the distance to the center of the catchment area, meaning that locations near the center are more accessible than locations situated at the edges (Dai & Wang, 2011). Another example is the three-step floating catchment area (3SFCA) which also takes into account the potential competition between services to avoid an overestimation of the demand when several services are accessible from one location (Bell et al., 2013; Wan et al., 2012).

The importance of selecting the most suitable method for a given accessibility issue is illustrated by Figure 1. This figure shows the results for some of the measures described in the previous paragraphs for the accessibility assessment of pharmacies in Ghent, Belgium. It is clear that the conclusions drawn from an accessibility study strongly depend on the type of measures used.



PPR calculation: The best accessibility is situated in the city center, Gentbrugge and Ledeberg.

CF calculation: Low transport times indicate a high accessibility in the city center, Gentbrugge and Ledeberg. The figure shows more variation in areas with low accessibility.

FCA calculation: The catchment area is 15 minutes. The figure shows a high accessibility in the north.

2SFCA calculation: The catchment area is 15 minutes. The figure shows a high accessibility north of the city center, except for the most northern part.

FIGURE 1

Comparison between the results of the PPR, CF, FCA and 2SFCA method for the assessment of the car accessibility to pharmacies in Ghent, Belgium

While the first three categories are predominately place-based measures, the fourth category consists of person-based measures or a combination of both. Place-based accessibility measures are particularly suited to examine changes in the proximity of services to the homes or workplaces of individuals or modifications of the transport network. All these measures tend to use the home or workplace as a static substitute for an individual. They ignore the many trips that originate from the work location (such as noon errands and childcare), other anchor points, and the multi-linked trips. Furthermore, they do not take into account accessibility limitations as a result of social inequalities caused by language, gender, financial situation, mobility, etc. or individual-based needs (Miller, 2007; Neutens, 2015). Moreover, these accessibility indicators ignore the fact that accessibility is time-dependent and that both supply and demand fluctuate over time, e.g. day and night rhythm, daily routines, travel time, public transport schedules and traffic congestions (Delafontaine et al., 2011; Neutens et al., 2010). When temporal changes are made to the service provision (e.g. by changing opening hours), spatio-temporal accessibility levels will fluctuate, which may lead to the exclusion of certain groups within the population from participating in specific activities (Casas, 2007). In fact, the actual accessibility levels will constantly fluctuate during daily or weekly cycles. These fluctuations derive in part from variations in operating hours of services and facilities as well as from the individuals' commitments or fixed activities that bind them to particular places at specific times of the day, e.g. workplace, childcare, shopping, sleeping (Schwanen & de Jong, 2008; Zandvliet & Dijst, 2006). Today's lifestyle implies that using information about the distribution of the stationary, night-time population across street addresses or zones and the implicit assumption that (adult) members of that population can access services at any time of the day, as the basis for the evaluation of changes in service provision have become increasingly problematic (Neutens et al., 2010).
People-based measures rely on the characteristics of the transportation system as well as on detailed observations of an individual's activity schedule (Neutens et al., 2010). A very recognizable situation in which spatio-time accessibility measures (STAMS) can be used to improve the individual accessibility is comprehensively narrated by Schwanen and de Jong (2008) in the article "Exploring the juggling of responsibilities with space-time accessibility analysis". In this article the story of a highly educated mother who has to reconcile fixed employment times, chauffeuring her son to childcare, and a lengthy commute via congested highways is used to explain the benefits STAMS have over the traditional space-based measures. The case study shows how STAMS allow analysts to evaluate if, and to what extent, individuals can actually benefit from proximity to services. Nonetheless, the number of empirical studies of space-time accessibility that explicitly consider the effects of open hours on opportunities is limited to date.

Recently, researchers have succeeded in introducing not only spatially related parameters, but increasingly also temporal and person-based parameters into the calculation of accessibility measures, thanks to the increased computational power of GIS and the availability of individuals activity and travel data. Instead of a measure of potential accessibility, it is now possible to determine revealed or realized accessibility for different groups of people. This leads to more accurate and realistic assessments of changes, variations or gaps in accessibility, but also implies more complex methods and results that are difficult to interpret, which is probably the main reason why most policy decisions are still based on the simple and intuitively interpretable, yet not adequately accurate PPR methods. Although policy makers have historically paid little attention to the exploration of these complex analysis methods, there has been a shift within the planning and transport fields towards a focus on measures that aspire to attain a just and equitable distribution of opportunities.

A reflection on the social aspect of transport planning

Shaping mobility: the locational paradox

Both the living environment and the location have an impact on an inhabitant's mobility. Additionally, they are strongly influenced by and at the same time have an impact on the transport mode choice. As a result, deciding on a city, town or village to settle in is one of a household's most important life choices: in between jobs, but close to friends and family; lots of child-friendly space for the kids to play outside, yet not too far from shops and services that offer the daily required commodities. Urban environments are generally known for their high built density and their elevated number of and variation in facilities within walking or biking distance. Cities bear enormous potential in making use of their efficient layout and the proximity of amenities to maximize accessibility. Consequently, they have risen as pre-eminent spaces for initiatives to counteract the overall car dominance with more sustainable

FIGURE 2

Projects Fietsschool Leuven (left, source: Mobiel 21) and Leefstraat Ghent (right, source: Lab van Troje)

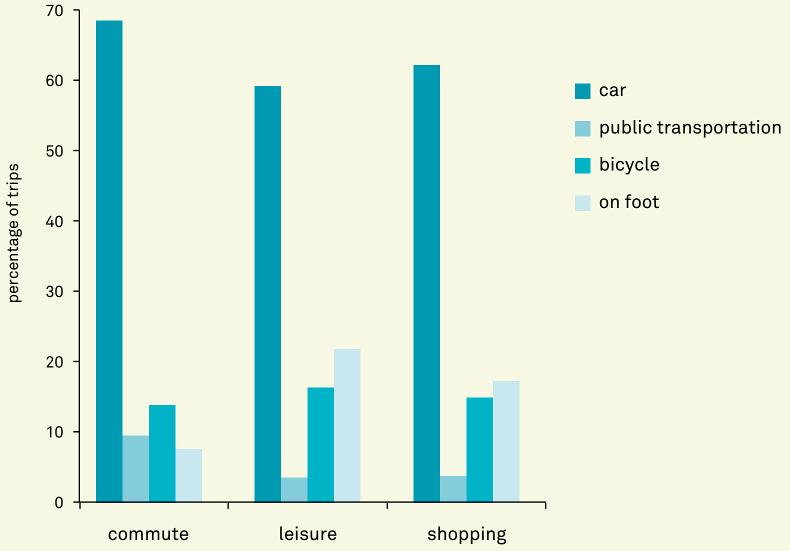
alternatives. In 2015, both Ghent and Brussels have reimagined their mobility plan to focus on phasing out cars and creating breathing space for cycling and walking. Car-free streets, hindrance of car flow between different neighborhoods and stronger restrictions in maximum drive speeds are becoming fixed values in city's mobility policies. Recent ambitions are no longer only policy-based, more often citizen initiatives and organized movements arise that aim to improve the quality of life of the street, neighborhood or city they live in. Cycling School Leuven ('Fietsschool Leuven'), for example, annually teaches over 100 adults to safely ride a bike in the city of Leuven, in the ambition to provide a satisfactory substitute to car transportation. In Ghent, volunteers of the Lab van Troje-network aid the residents of dozens of streets to temporarily convert them to car-free zones with space for greenery, cohabitation and encounters (Figure 2).

Another example is the project Elderly as Public Transport Ambassadors ('Ouderen als Openbaar vervoer-ambassadeurs') in the regions of Flanders and Brussels, where elderly people provide information to other elderly people on how to use the public transport system, in order to overcome barriers such as the complex time schedules or purchase of tickets. This type of qualitative investments contribute to putting a halt to the great migration from the city centers to suburban and rural areas that peaked in the second half of the 20th century as a result of the increased wealth and the use of the automobile.

Paradoxically to the apparent advantages of living in a city, suburban and rural areas remain the most favorable living location for households willing to trade in proximity and vivacity for tranquility and spaciousness, at the cost of car ownership and longer commute. The outer city neighborhoods and suburbs combine the vicinity of the city center's goods and services with the peace and quiet of living outside the city core. As the city's scale remains small, commutes, leisure trips and social visits are characterized by short distances, which are often still possible to bypass by bike (the emergence of the electrical bike has even further increased the radius by bike) or on foot. The accessibility to daily needs such as employment, health care or education remains relatively high, even for households with a lower mobility. However, as the distance to the city center increases, so does the transport dependency. Facilities are more distributed and thus harder to reach, and the range of options rapidly diminishes. Additionally, public transport stops that commonly radiate peripherally from the city center, become a rare characteristic in the rural fabric. Road layouts are no longer focused on pedestrians' and cyclists' safety, as sidewalks and bike lanes make way for car-oriented infrastructures that ameliorate the efficiency of travel by car. These transitions culminate in the most remote areas, frequently distinguished by ribbon development along the roads connecting city centers.

In general, mobility rather than accessibility has been the focus of transport policy since the popularization of the car (Martens et al., 2012). Due to its typical spatial structure characterized by sprawl and ribbon development, Flanders is known for its strong car dependency. Almost 70% of the commutes and around 60% of the leisure

FIGURE 3
Transport mode choice for different travel types in Flanders (De Vos, 2015)

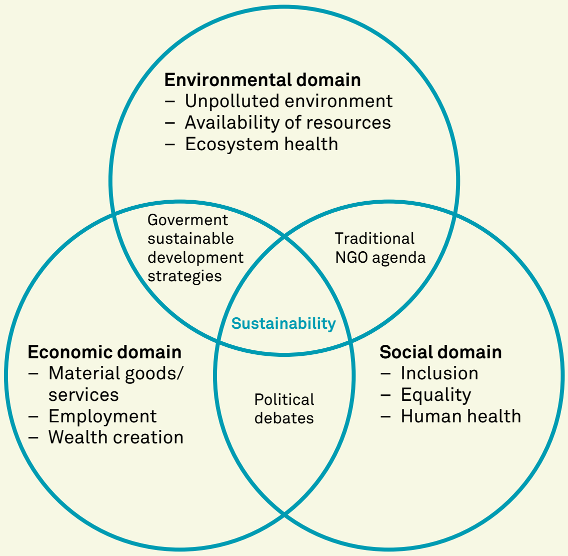


[4] Rurban as a combination of urban and rural space, distinctive for the Flemish countryside. This transition zone is considered as an important social, institutional and spatial challenge (Vanempten, 2010).

and shopping trips in Flanders are made by car (Figure 3). In the Netherlands for example, the modal share of car use lies below 50% for all type of trips and bicycle use is considerably higher (De Vos, 2015). Improving the accessibility by increasing the number of facilities in these areas is often not efficient, as insufficient inhabitants are located in the additional catchment areas. As a result, the best way to facilitate better access is by increasing the mobility, which in the Flemish rurban[4] landscape is usually realized by more travel by car. Providing adequate public transport in even more remote areas has proven to be difficult. This has largely been to the detriment of inhabitants without access to a car and disadvantaged groups (Martens et al., 2012). It remains a challenge to maximize mobility while at the same time trying to replace the dominance of private motorized transportation by alternatives that currently do not provide a comparably qualitative solution. In recent years, several projects arose in rural areas that focus on car sharing or communal taxies, yet they do not always provide solutions for people living in poverty or individuals without an adequate social network.

From an environmental and economic point of view, the dichotomy between urban and rural mobility is believed to be reflected in the degree of sustainability. Longer commutes are generally considered disadvantageous because of the externalities related to motorized transportation. These outcomes are intensified by the preference of private motorized transport over more sustainable alternative transportation modes. The increased mobility leads to a considerable strain on the environment in the form of pollution, whereas congestions or the high number of traffic accidents have an important financial impact. In Flanders, for example, fine particles diminish average life expectancy with three years (Van Zeebroeck & Nawrot, 2008). In addition, possible future problems have become the subject of debate, as global warming or exhaustion of fuel resources are considered to endanger future generations. To prevent these externalities from manifesting, policies often strive to minimize the environmental and economic effect of the growing mobility in order to enhance sustainability.

FIGURE 4
The domains of sustainable development (Reeves, 2005)



Towards equitable accessibility: transport as a social issue

As illustrated, common policy strategies focused on sustainability strive to compensate the effects related to an augmented mobility. Figure 4 indicates the functionality of governmental sustainable development strategies in the cross-section of the economic and environmental domain. There is a strong interaction between both domains, as measures aimed at increasing the economic benefits can have an inversely proportional impact on our environment. For example, making goods and services better accessible by introducing more road capacity simultaneously increases the number of cars on the road and thus the overall emission of CO_2 and fine dust. Discussions on these types of topics are a fundamental component of the daily debates, especially as it is often the economic domain fueled by political opinions that prevails. Independent on their outcome, these discussions frequently start from the recognition that the overall mobility, and more specifically car use, is increasing, and policy should aim at counteracting the economic and environmental externalities related to growth. In this respect, the debate on the realization of the shopping and recreational complex Uplace in Machelen is exemplary, in the sense that figures on the uplift of trips by automobile have played an important role for the opposition to object to the project (Boussauw & Lauwers, 2015). As of today, public as well as political support is waning rapidly as the project is considered not only an economic mishap but also a significant trigger for traffic congestion and pollution. These debates, however, fall short to the question of how the complexities of the existing and evolving society's travel behavior are incorporated into the decision process of actions that lead to this gain in mobility. Consequently, this growth should not be compensated after the decision process, but it should be countered by including a more sustainable provision to the population's complex mobility needs into the decision process. Boussauw and Vanoutrive (2015) rightfully indicate that the development of a transport system which is overall less environmentally harmful does not automatically contribute to a more just and socially substantiated configuration. This line of reasoning rises beyond the classic vision on mobility, as the social domain of sustainability is incorporated into the equation.

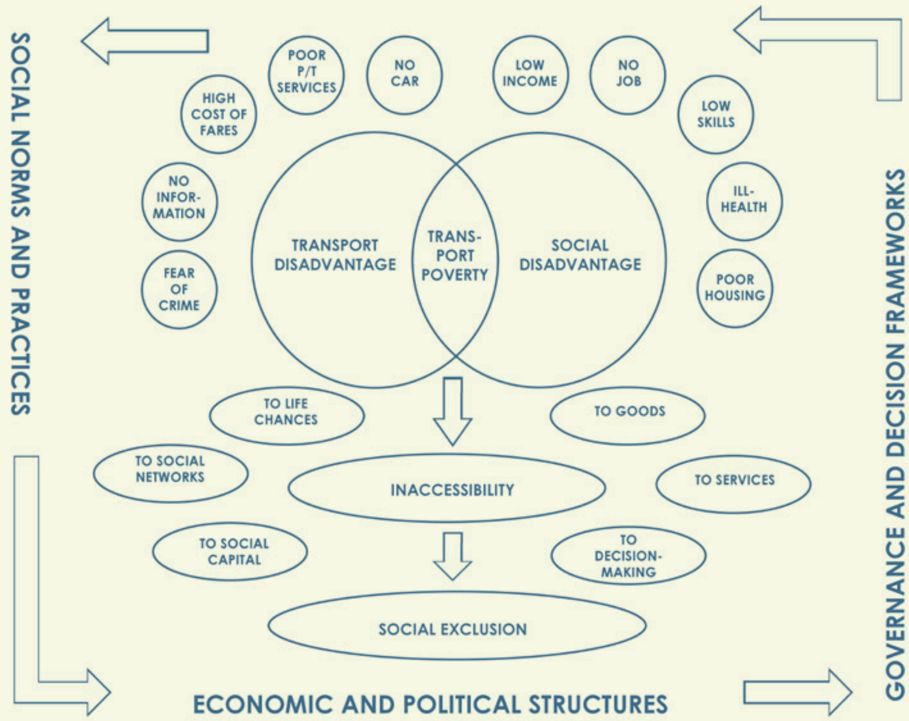
Reeves' view on sustainability also highlights the importance of exploring the social domain alongside the traditionally well-studied economic and environmental outcomes. The past two decades have witnessed a growing academic as well as policy interest in the social implications of transport planning (Boussauw & Vanoutrive, 2015; Bulkeley & Betsill, 2005; Lucas, 2012). In addition to locational substrata, a lack of mobility and, consequently, the inability to access primary needs is unmistakably related to an individual's socio-economic and demographic status. Inhabitants without a privately owned vehicle do not have access to the luxuriously dense Flemish road network, whereas low-income households might struggle to allocate a sufficient portion of their budgets for daily public transport fares. There is a wide recognition that transport policies have the ability to generate spatially as well as temporally uneven accessibility effects that give preference to certain population groups above others (Grengs, 2015). For example, increasing the road capacity is not beneficial in enabling less privileged population segments without privately owned motorized vehicles to participate in everyday activities. A more complicated illustration is the way in which improving the public transport frequencies does not necessarily benefit wheelchair users' mobility if the extra buses, trams or trains are not wheelchair accessible.

Nonetheless, policies simultaneously have the ability to strive for a more equitable distribution of transport services amongst the population. The region of Flanders, for example, has adopted a clear-cut stance towards combatting social disadvantages, as it is one of the only regions in the world where the right to basic provision of public transport is granted by law in the decree 'Personenvervoer'[5]. This right is defined as the right to basic mobility ('Basismobiliteit'[6]) and is formulated as having spatial access to a minimum level of public transport service irrespective of the location of residence. However, as this decree defines maximum distances to transport stops and minimum frequencies at these stops, it answers to social disparities in access to the public transit system (accessibility of the transit stops) rather than by that transit system (accessibility of the facilities through the transit system). It does not determine what places or services a person could reach at a given time and, as such, describes mobility rather than accessibility. Furthermore, a gain in mobility does not necessarily lead to a higher accessibility if people are unable to satisfy their primary daily needs. Recently, understanding the ways in which inadequate or lack of mobility can contribute to social disadvantage and isolation has been brought to the forefront of the transport policy agenda (Fransen, et al., 2015a). The right to basic mobility as constructed in 2001 by the Flemish government, for instance, is currently reformulated as the right to basic accessibility ('Basisbereikbaarheid'). Hence, this revision will additionally aim to guaranty access to specific location types.

5 Decreet betreffende de Organisatie van het Personenvervoer over de Weg, B.S., August 21, 2001

6 Besluit van de Vlaamse Regering betreffende de Basismobiliteit in het Vlaamse Gewest, B.S., January 23, 2003

FIGURE 5
Transport poverty as the interaction between social and transport disadvantage (Lucas, 2012)



From transport disadvantage to social exclusion

Policy concerns related to social discrepancies in mobility and accessibility have appeared and grown parallel with a wider policy interest in the causes and effects of social exclusion. Understanding the underlying factors that lead to these incitements, however, is not an easy task. The number of factors influencing both supply and demand is on the increase, as the present-day society is becoming more complex. The topic of social exclusion originated in the United Kingdom, where the Social Exclusion Unit (SEU) drafted a report on the interactions between transport and social disadvantage in the late 1990s. Since the publication of the report, researchers from around the world have built up empirical evidence of examples of transport problems that have led to various forms of social exclusion. Studies on this relationship have been conducted in Europe (Priya & Uteng, 2009), North America (Paez et al., 2010), Latin America (Delmelle & Casas, 2012), Australia (Delbosc & Currie, 2011) and Africa (Porter et al., 2012). Revealing the main drivers for social exclusion commences with the relationship between transport disadvantage and social disadvantage (Figure 5). Herein, the former corresponds with the degree of service by a transport system while the latter relates to area-based populations most in need of transport. Theoretically, transport poverty occurs on the cross-section of transport disadvantage and social disadvantage.

Nonetheless, it is difficult to determine when a person is to be considered transport poor (Fransen et al., 2015a). By definition (Lucas, 2012, p. 106), this has to do with the inability to access a 'normal' range of activity locations, but the exact meaning of such a 'normal range' remains absent, apart from it being the range of activities that is available to the majority of people in society (Levitas et al., 2007). The necessity of being able to reach certain opportunities unmistakably varies for each individual and in different societies. Having access to health care, for example, is more important to the elderly than to students, whereas the opposite may be true for education. Generally, inaccessibility takes place when the provision is not regulated to the need. Pinpointing the threshold when this discrepancy actually occurs is challenging as this depends on whether inaccessibility is conceptualized on normative or relative terms. Normative terms coincide with expectations about the minimum required level of accessibility while relative terms refer to a particular standard expressed by the accessibility level of other individuals in the same society (Paez, Scott, & Morency, 2012). Eventually, inaccessibility results in exclusion from goods, services and social contacts, which relates to social exclusion and personal isolation.

A number of projects conducted under the umbrella domain of transport-related social exclusion try to pinpoint when and where disparities between the transport and social disadvantages take place and subsequently aim to provide solutions to these gaps. For instance, the project Job within reach ('Job binnen bereik'), conducted by Mobiel 21 and Nazka Mapps aims to promote job locations (such as ports or business parks) that are hard to reach for job applicants without a privately owned vehicle. An online map application demonstrates the possibility of using alternative travel modes while at the same time promoting these locations as an appealing workplace. The first such application was commissioned by the Cycling School of Antwerp, to help people with low access to the job market to find their way to the jobs in the Port of Antwerp. There is also a wide range of academic studies that used GIS to explore the connection between social disadvantage, transport needs and transport provision. Combining both practical and theoretical research on social exclusion and transport poverty bears a large potential, as it enables researchers to cooperate with policy makers and analysts in order to pinpoint issues as accurately as possible.

Empirical evidence and case studies

Public transport deficiencies

The first section indicated the complexity of the concepts of mobility and accessibility. As our society is growing more multifaceted, so do the models that aim to simulate societal behavior in the most accurate way. Recent endeavors focus on personal mobility, changes over time and underlying, often unexplored relationships between the different actors (e.g. competition, trip chaining, etc.). On the contrary, the resulting accessibility levels are becoming harder to understand for non-professionals. This can lead to two important side effects: on the one hand, the results of our current models are hard to interpret and thus confined to 'experts', while on the other hand, results are harder to verify, and these 'experts' can project their (subjective or distorted) interpretation on the general public. Nevertheless, there is a need for more precise measures of accessibility, as they enable to incorporate indicators on the individual level. In an ideal situation, accessibility measures would take into consideration every personal aspect of an individual in order to determine the accessibility on the most detailed level possible. The second section underlined the importance of examining the population's specific mobility needs, in order to help shape justice and equity in access to the primary amenities that are deemed necessary in the society that we live in. Herein, social disadvantages related to these particular mobility needs have a strong link with the transport disadvantages that occur because of the specific transport system's characteristics. If both aspects are not accustomed to each other, transport gaps come into existence that in turn result in the inability to access social networks, services and vital commodities. Defining where and when transport poverty materializes is a necessary step in supporting policies aimed at combatting social exclusion.

Within the internationally embedded body of literature on the social domain of transportation, much attention has been devoted to the degree of quality of alternative transport modes to car use. Various studies have examined active travel modes such as biking or walking, not only from a planning point of view (Saelens et al., 2003), but also in the domains of health care (Dewulf et al., 2012), and movement and sport science (Van Holle et al., 2012). These topics have been widely examined because of their strong correlation with benefits for physical health, and their positive impact on the quality of life in as well as livability of cities. However, these studies are mainly conducted for urban settings because they are primarily related to the built environment. In addition, not everyone is capable of active travel modes: elderly people are less likely to ride a bike or walk for longer distances, and wheelchair users are strongly dependent on public transport for greater distances. Research that focuses more on the inclusive aspect of mobility is often situated in the domain of public transport and more specifically, targets on designating individuals and areas that suffer from public transport deficiencies. People without access to private transportation are strongly disadvantaged in reaching opportunities in an auto-oriented spatial structure (Kawabata, 2009). Furthermore, improving the provision of public transport has played an important role in countering the financial, environmental and societal externalities related to car-oriented development (Glaeser et al., 2008; Lucas, 2006). From an academic point of view, two main strands of studies aimed at assessing the quality of public transport arise. A first group quantifies socio-spatial deficits in public transport by constructing and comparing two indices: one that expresses public transport needs (social disadvantages) and another that represents public transport provision (transport disadvantages). The difference between both indices is termed the 'transport gap', which acts as a proxy for an area's vulnerability to developing transport poverty (Fransen et al., 2015a). Considering accessibility by public transport is a first step, yet it does not fully consider the broader picture. An important question remains: How does access through public transport relate to the access by car? A second strategy seeks to determine the discrepancy between accessibility by private (car) and public transport, which is a measure for the degree of automobile orientation (Golub & Martens, 2014). The travel time-based ratio of accessibility compared for both transport modes is an indicator of the probability a person will choose the car as primary transport mode, as the time budget strongly affects an individual's travel mode choice. This choice is also influenced by the degree of freedom and ease associated with car use, in the sense that users are not bound to time tables, intermodal connections or service quality.

Case study: transport poverty in Flanders

This paragraph is based on the literature review and results for an ongoing study on transport poverty in Flanders, conducted by the Department of Geography, Ghent University (Fransen et al., 2015a). As illustrated, transport poverty is an important trigger for social exclusion and threatens an equitable distribution of access through the considered transport system. There are two main actors that shape this transport poverty: the particular needs for transportation and the actual transport system. Both actors and their relationship have been internationally studied. The first studies in this strand of research mainly focused on social disparities in access to the public transport system rather than by the public transport system. For example, Wu and Hine (2003) examined the impact of changes in the bus network for different social groups in Northern Ireland. In their study, they determine accessibility levels based on walking times to and waiting times at the bus stops. Similarly, Currie (2010) combines the access to the transit stop with the number of bus, tram or train arrivals per week for the city of Melbourne, Australia. While such indicators provide understandings in the identification of socio-spatial differences in access to the public transport system, they do not examine whether the system brings people to preferred locations within an acceptable travel time at the desired time of day[7]. Moreover, these indicators disregard the fact that local availability of goods and services can compensate an inadequate proximity to public transport provision. Several studies have answered these limitations by calculating end-to-end travel times by public transport. Delmelle and Casas (2012), for example, developed a multimodal approach that accounted for the travel time to as well as by the transit system, in order to assess the equity of the development of a Bus Rapid Transit (BRT) system in Cali, Colombia. However, these types of accessibility measures are static because they describe what is reachable by public transit from a specific origin at a single temporal section. They do not consider the time-based variability in accessibility levels at multiple origins, which is driven by variations in operating frequencies across the diurnal cycle and between weekdays and weekends. The most recent studies contribute to the research outlined above by additionally drawing on the latest field of modelling time-continuous, schedule-based public transport. The study by Farber et al. (2014) attempts to analyze public transit access to supermarkets in Cincinnati, Ohio, by calculating travel times at different times of the day. These types of studies indicate how schedule-dependent, public transportation can be factored into measures of accessibility analysis.

For public transport, there are several socio-demographic variables that shape the population's needs, ranging from physical and spatial to socio-economic factors. For the study area of Flanders, these indicators were determined based on previous studies (Currie, 2010; Jaramillo et al., 2012; Kamruzzaman & Hine, 2011) and in

7 These are also the considerations that at the present day fuel the debate on the efficiency of the concept of basic mobility (*Basismobiliteit*) and the transition to the more specific concept of basic accessibility (*Basisbereikbaarheid*), as is explained in the previous section.

consultation with mobility experts as well as professionals in the social domain. They provide the most relevant information about the relative size of the socio-demographic groups that tend to depend largely on public transportation. However, supplementary and more precise indicators can further detail specific needs (e.g. information on disabilities, data on a personal level, etc.). Car ownership and income are considered to be strongly related to transport poverty, as well as the percentage of unemployment. Low degrees of car ownership and income (often characterized by a strong correlation) and high levels of unemployment are indicators for an elevated dependency on alternative modes of transportation. Additionally, age-related indicators such as the percentage of elderly and children play an important role in identifying the need for transport, as these groups seldom have access to privatized motorized vehicles or even active travel modes such as a bicycle. Amenities within walking or biking distance should also be incorporated in order to formulate the need for public transport accurately. For Flanders, the rural and suburban areas are mainly characterized by high public transport needs, because of their specific socio-demographics (e.g. higher number of elderly) and lower density of facilities. However, comparison of the calculated values to the population density indicates that the highest needs coincide with less densely populated areas (Figure 6). On the contrary, city centers and coastal areas have low public transport needs, primarily due to the high number of facilities within walking or biking distance.

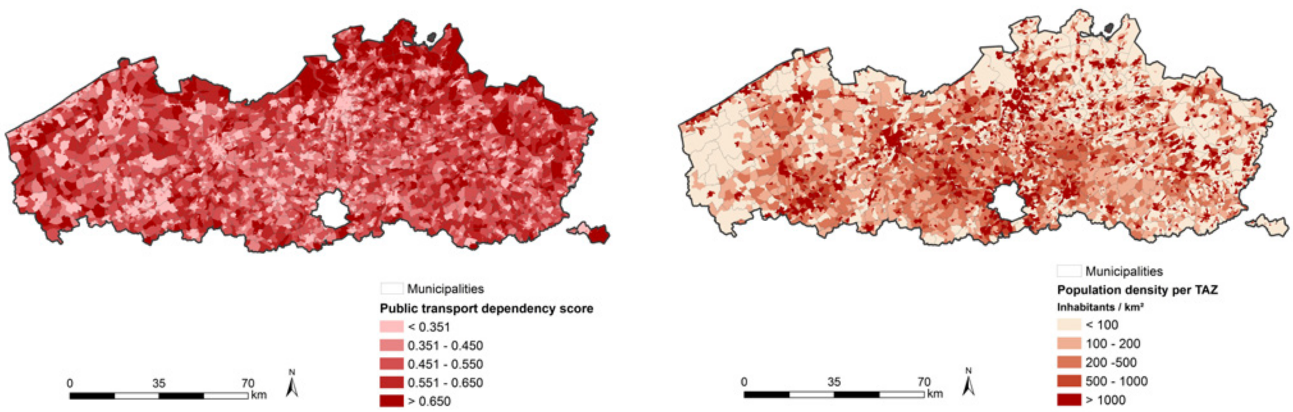
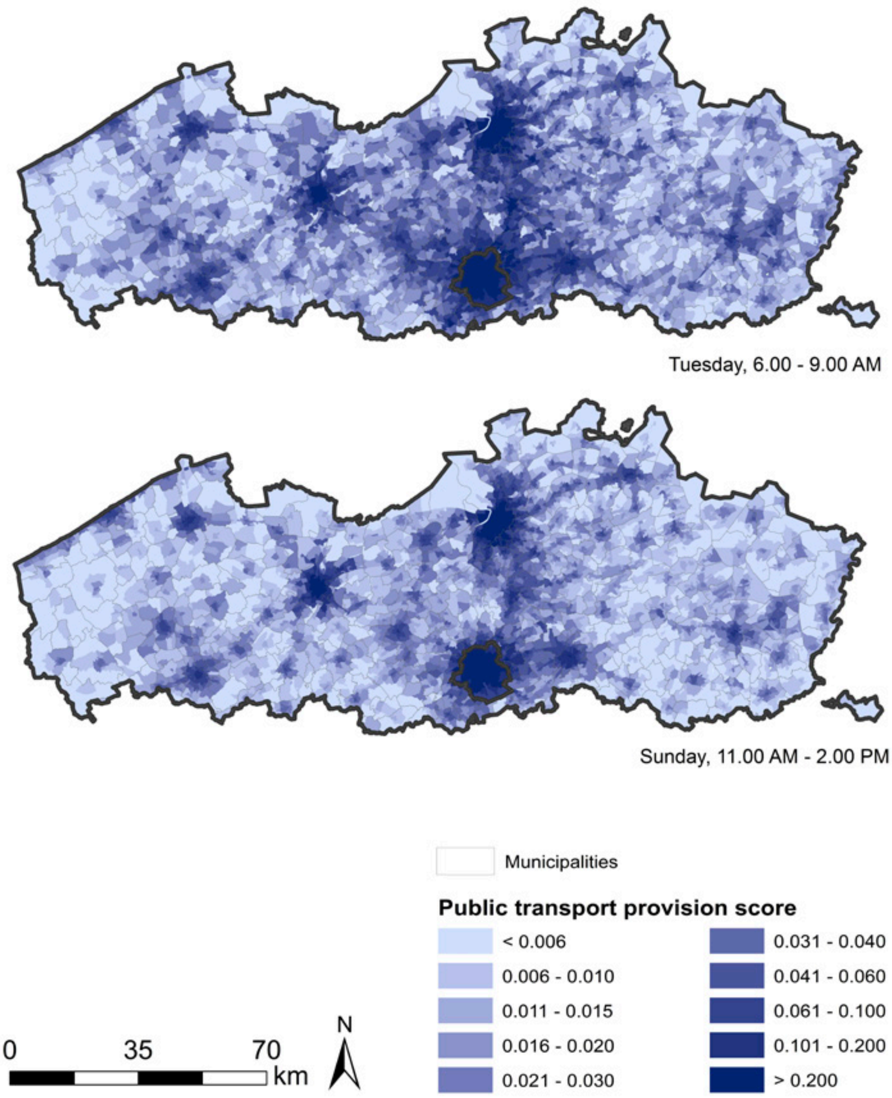


FIGURE 6
Indices of Public Transport Needs per traffic analysis zone or TAZ (a) and population density per TAZ (b) for Flanders (Fransen et al., 2015a)

The provision of public transport is complex as it is dependent on the time schedules of different types of transit systems. Recent accomplishments have indicated the benefits of integrating time schedules for bus, tram, metro and train as well as a pedestrian network into a single multimodal network (Farber et al., 2014; Hadas, 2013; Ma & Jan-Knaap, 2014). As a result, this network accounts for all components of a public transport trip: the walking time from the origin to the public transport stop through the pedestrian network, the waiting time at the public transport stop (including the time to enter or exit the vehicle), the actual travel time through the transit network (including transfers) using timetable information and the walking time from the public transport stop to the destination through the pedestrian network. The resulting network can be applied to calculate travel times to various types of destinations at different times of the day and days of the week. In Flanders, a high provision of primary facilities corresponds with areas with a good availability of public transit. This is the case for cities and along the railway tracks and bus lines running peripherally from the larger city centers. The region of Brussels is characterized by the highest values, as the city of Brussels serves as the most important public transport hub. Due to lower transit frequencies, the provision noticeably declines during off-peak hours, especially for the suburban areas (Figure 7).

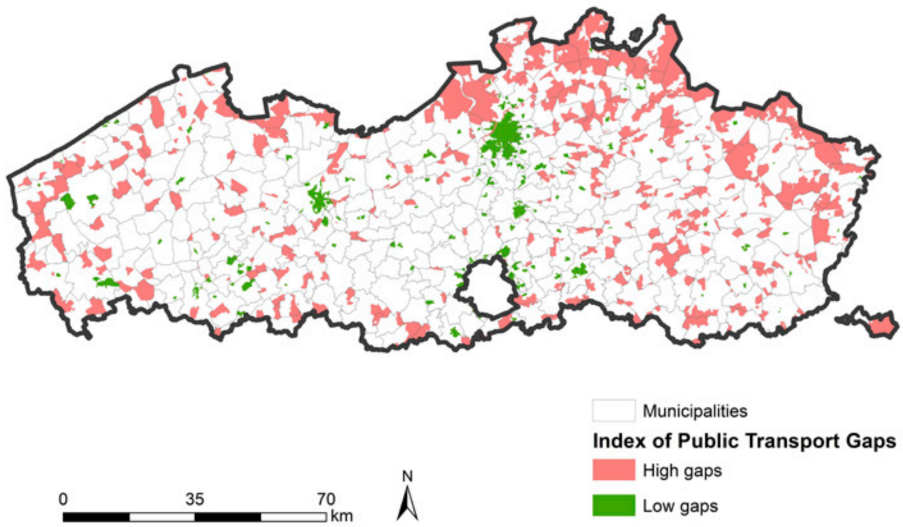
Eventually, the relative values of the public transport needs and provision are compared to determine the mismatch between both indicators (Figure 8). Low values designate areas where the provision surpasses the need, which is interesting from an economic stance as service can be restricted. Additionally, from an urban policy point of view they indicate the ability to intensify the use of the transport network and, as such, accommodate more need in these areas. Low values are mostly apparent

FIGURE 7
Public transport provision per traffic analysis zone for Flanders and Brussels, for various temporal sections (Fransen et al., 2015a)



in the larger city centers. The past years, several public transport companies have conducted studies to determine if and where cutbacks in service would be beneficial. It is important that possible actions are thought through, since diminishing service in public transport dependent neighborhoods would further strengthen its inhabitants' social exclusion (Fransen et al., 2015b). Higher values pinpoint areas with an overall high need for and under provision of public transport and thus assign areas in need of considerable attention in transport planning. Higher transport gaps are primarily found in the rural and suburban areas. However, the detailed scale of analysis allows to additionally highlight urban areas with high transport gaps (e.g. the city ports in Antwerp and Ghent). Furthermore, this measure offers transit agencies, policy makers or academics the possibility to examine specific transit gaps for a certain type of need in respect to the appropriately related type of provision (e.g. elderly access to physicians or access of the unemployed population to jobs).

FIGURE 8
Public transport gaps per traffic analysis zone in Flanders (Fransen et al., 2015a)



Case study: modal disparities in Flanders
This paragraph is based on the literature review and results for an ongoing study on modal disparities in job accessibility in Flanders, conducted by the Department of Geography, Ghent University (Fransen et al., 2015b). The previous case study allowed to identify public transport gaps, which proved an important tool for both policy makers and transport companies in better adjusting the provision to society's specific needs. However, this public transport provision (more precisely bus, tram and train use), is also related to car availability and dependency since both transport means compete with each other. From the viewpoint of a fair distribution of opportunities, persons with access to the dominant mode of transport (private motorized transport) will face few accessibility problems in the current society. Persons without access to a car, however, will experience insufficient levels of accessibility depending on the access provided by alternative transport modes (Martens et al, 2014). Several studies have examined the relationship between motorized private and public

transport in order to better understand travelers' attitude towards transport in general and, more specifically, perceptions of public transport service quality. Beirão and Sarsfield Cabral (2007) performed a qualitative study of travel attitudes and behaviors for public transport and car users in Porto, Portugal. A more practical example is found for Flanders, where the public transport company De Lijn aims at upgrading the public transport travel experience by providing free Wi-Fi connection on trams in several major cities.

Apart from the perception of the transport mode, the actual efficiency of the transit system also plays an important role in travel mode choice. As mentioned, comparing car-based and transit-based accessibility is an indicator of the degree of car-orientation of a certain area. Increasing the attractiveness of public transport (e.g. lower fares, improved wheelchair accessibility, etc.) benefits the ability of this means of transport to compete with private motorized transportation. On the contrary, if policies aim at facilitating car use (making it faster and cheaper), this transport mode is more likely to act as the primary mode choice. A study on the transport gaps in the Tel Aviv metropolitan area by Benenson et al. (2011) underlined the importance of adequate policy responses by estimating accessibility to employment and other land uses. Studying the modal disparity in accessibility is a key indicator to assess urban policy and urban form. Different studies have also examined the spatial disparity as an interesting framework for assessing the impact and distribution of benefits generated by transport developments. Golub and Martens (2014) assessed the rate of transport poverty for the San Francisco Bay Area by measuring the differences between public transit and automobile access for the situation before and after two proposed transportation investment programs. A major limitation in the current studies on modal disparity is that its temporal variability has received little attention. Time measures, however, are more sensitive since they incorporate constraints related to a demographic, social, economic and cultural context (Miller, 2007). The previous case study showed that the transport provision fluctuates over time, since transit is often characterized by time-specific, schedule-based travel times. The frequency and service hours can make necessary, fixed activities unreachable by public transport, which in turn adversely affects an equitable distribution of primary needs (Tribby & Zandbergen, 2012). Additionally, car-based travel is also influenced by the time of day, as congestion is stronger during peak hours.

In combination with a time-dependent, multimodal network to assess travel through public transport, a routable and time-variable network for travel by car is an important requisite in determining car accessibility on a detailed level. Historical data on travel speeds (often extracted from car GPS data) allows users to adapt the commonly applied network datasets that solely focus on the maximum travel speed for each road segment. Average travel speeds on different times of the day are linked to the road network and the dataset becomes time-dependent. As a result, travel times are based on actual average travel speeds instead of theoretical speeds, leading to distinct lower average values during peak hours. These time-dependent networks allow for the calculation and, subsequently, comparison of accessibility

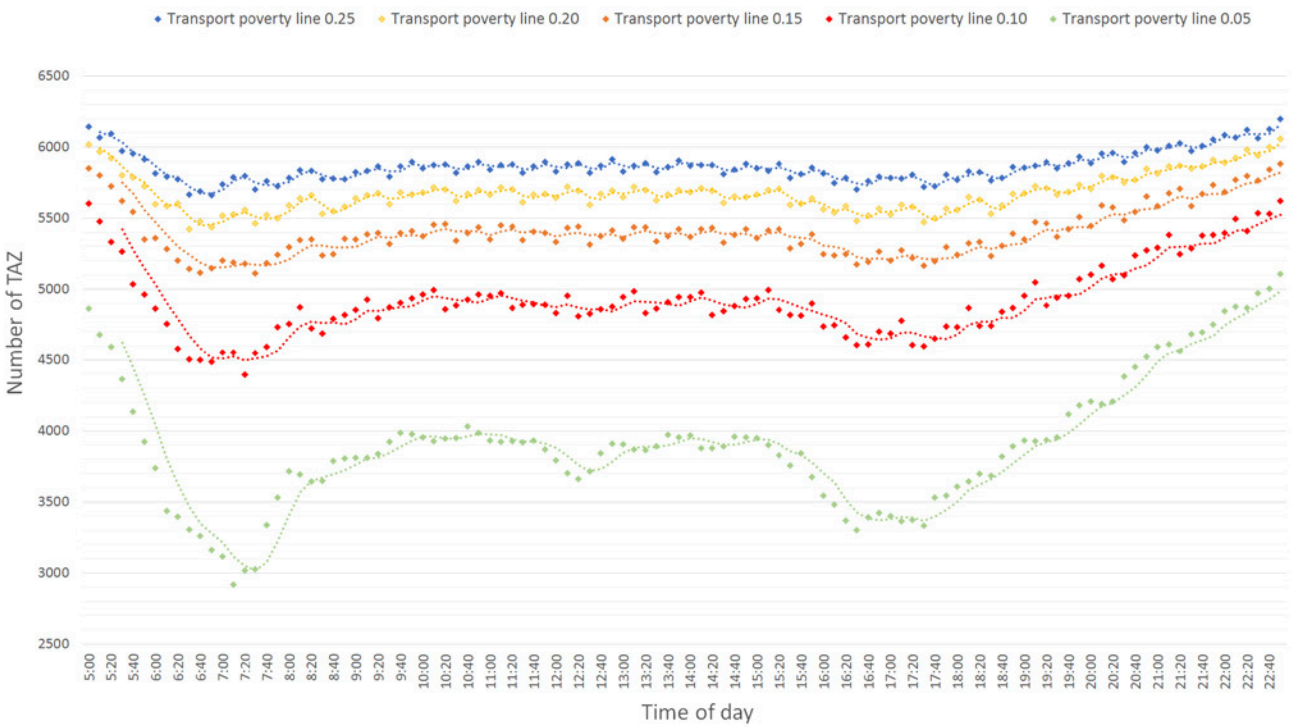


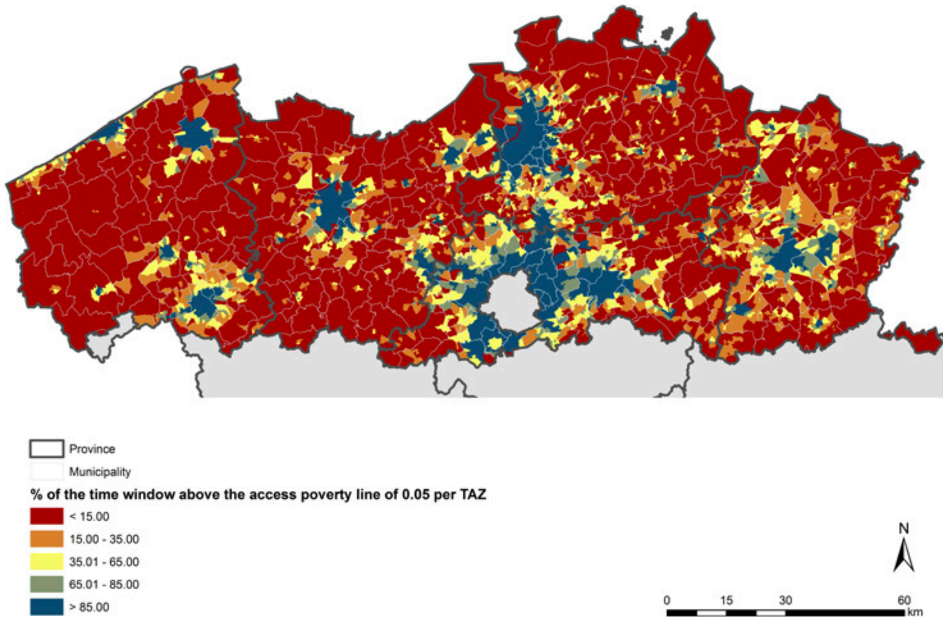
FIGURE 9
Fluctuations in the number of traffic analysis zones in Flanders under the access poverty line during the day

rates by both transport modes. An accessibility rate bordering 1.00 equals a more equal modal distribution. If this value exceeds 1.00, more opportunities are reachable through public transport than by car and vice versa. The maximum accepted gap in car and public transport accessibility is defined by the public transport poverty line[8], which is an explicit normative standard. For example, an access poverty line of 0.25 indicates that inhabitants who are not able to reach a number of opportunities by public transport equal to or higher than ¼ of the opportunities accessible by car are pinpointed as access impoverished. Figure 9 shows that for the strictest access poverty line of 0.25, on average almost 90% of the traffic analysis zones in Flanders is considered transport poor. For less strict values (0.15 and lower), the temporal fluctuations throughout the day become apparent. The number of public transport impoverished zones declines during peak hours, mainly due to congestion in and around city centers and higher transit frequencies. On the contrary, this number rises strongly in the early morning and late evening when public transport becomes more scarce and higher driving speeds can be reached by car. However, close to 60% of the traffic analysis zones have average values below the transport poverty line of 0.05. Policy makers should decide on the acceptable maximum gap for relative public transport access.

It is important to understand where the fluctuations are situated geographically, since this enables to determine areas with a relative high or low public transport provision on a detailed level. Figure 10 indicates the percentage of the day a zone has values above the chosen transport poverty line of 0.05. Zones with low percentages are considered as access impoverished, and this does not change strongly throughout the day. These zones are mainly located in a rural environment, characterized by

8 Also referred to as access poverty line.

FIGURE 10
Percentage of the day the traffic analysis zones in Flanders are considered as access impoverished



a sparsely distributed transit system and a lower number of facilities in the direct vicinity. Similarly, zones with high percentages have adequate relative access through public transport for almost every time of the day. This is mostly the case for the larger urban centers, such as Ghent, Antwerp or the metropolitan area of Brussels. Values in between indicate a strong temporal variability of the relative access through public transport for this traffic analysis zone (TAZ), with higher values during peak hours and lower values during off-peak hours. Areas with a strong temporal variability are predominantly located around the zones with an overall high value peripheral from the larger city centers and in the smaller town centers. When comparing the access impoverishment to the dominant job types, a strong division is apparent. Jobs in agriculture, industry, construction and retail are mainly located in areas with a low relative job access through public transport, while jobs in services, administration, education or health care are primarily situated in areas with a high relative access to jobs.

The province of Vlaams-Brabant has the highest values, as it is located around the region of Brussels, which is a major public transport hub (especially train) and the main provider of jobs for the region of Flanders. As a result, temporal fluctuations in accessibility rates are more apparent, even for the more strict access poverty lines (Figure 11). For the access poverty line of 0.05, the rate of traffic analysis zones considered as access impoverished drop below 30% during peak hours. Performing the accessibility level on a detailed level of analysis allows researchers to determine intraregional difference. For the city of Ghent, located in the province of East-Flanders, for example, a strong disparity occurs between the city center and the port area in the north (Figure 12). These differences on the microscale are of utmost importance, as the port area is an important concentration of job opportunities that are hard to reach by public transport. As a result, a transportational

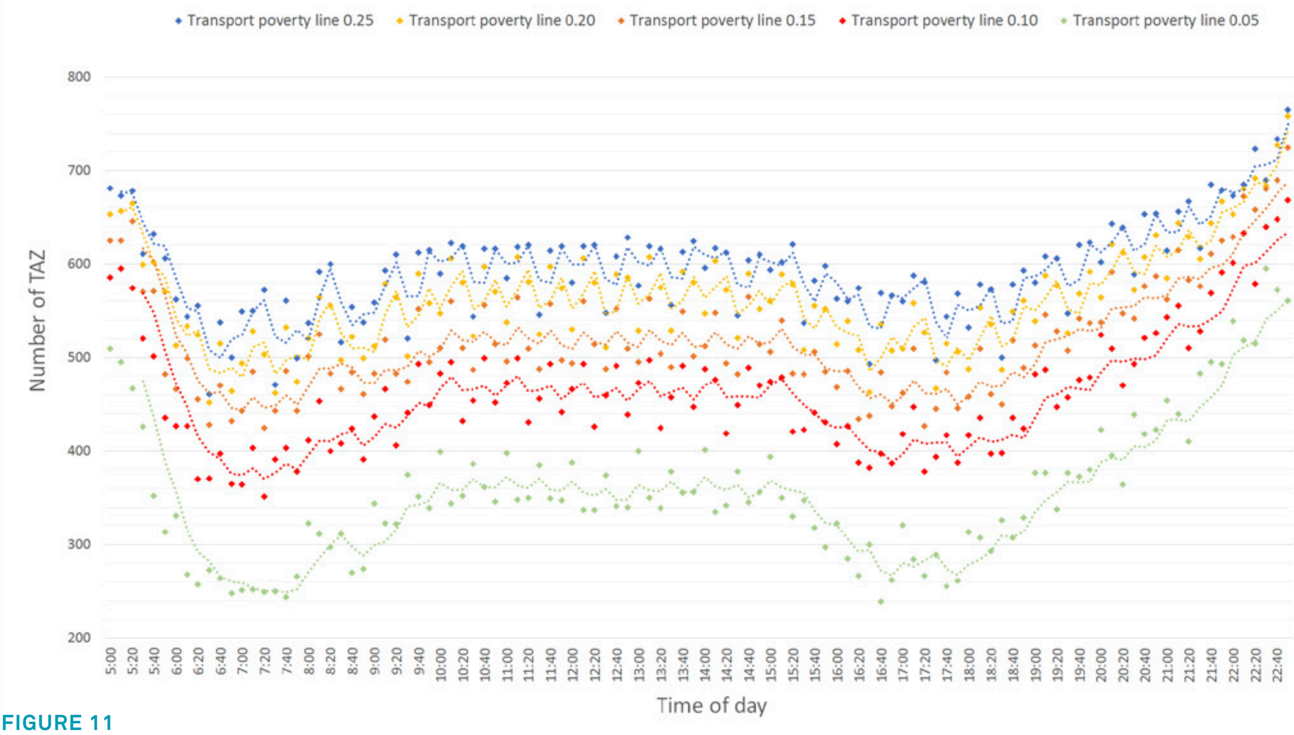


FIGURE 11

Fluctuations in the number of traffic analysis zones in the province of Vlaams-Brabant under the access poverty line during the day

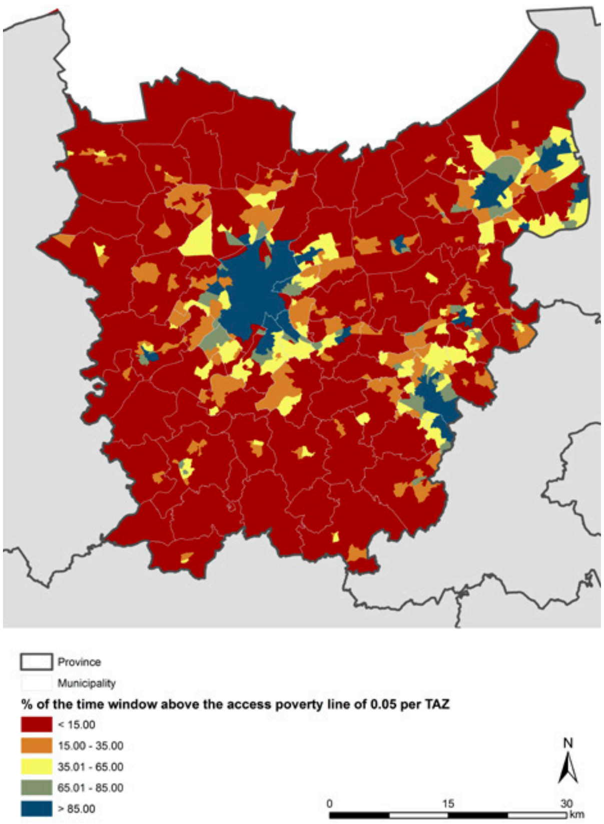


FIGURE 12

Percentage of the day the traffic analysis zones in the province of East-Flanders are considered as access impoverished (Fransen, Neutens, De Maeyer, et al., 2015)

mismatch between certain population segments dependent on public transport and possible adequate job opportunities is generated. Because of their detail of analysis, these accessibility measures provide policy support for decision-making on the local, supralocal and regional level.

Conclusion

The presented case studies provide an example of how academically based methodologies have the ability to provide policy support in the broad topic of transport-related social equity issues. They are an important first step to further unraveling the intricacy of the concept of fairness in transport. Nevertheless, as yet, they do not fully succeed in incorporating all the complexities of the modern day society. An important limitation is the fact that different people have different views on how equity in accessibility is established. Especially in the political arena, this may lead to difficulties in translating theoretical concepts and methodologies to a practical implementation. For example, the debate on redefining the concept of basic mobility to basic accessibility provides several important hurdles for policy as well as all other actors to take. 'What services or goods should be considered as necessary?', 'When are destinations to be regarded as accessible?' or 'How are specific needs incorporated in the concept of basic accessibility?' are questions that arise within this contemporary debate.

Whether or not all factors at a personal level can be included, more detailed measures construct a theoretical framework that allows policy makers to substantiate policy decisions and investigate the implications of these decisions. Depicting the transport gaps in Flanders, for example, enables highlighting the areas most in need of injections in the transport system. From a prioritarian point of view, the gaps are compared to the population density in order to better prioritize the available resources. In addition, comparison to various socio-demographic variables allows for policy makers to think about possible alternative solutions: transport gaps for a larger number of young families can be answered by providing subsidies for bicycle purchase, while elderly people living in areas with poor transport provision may benefit more from a system of communal taxis.
Policy makers should be aware that a supply of public transport matching the actual demand is a conditio sine qua non for countering the car-dominance. For example, portraying the modal disparity between private and public transport accessibility aids policy in pinpointing areas where public transport provision is lagging far behind in comparison to the provision through privatized motorized vehicles. However, a change in attitude towards car ownership is equally important and probably harder to realize as the 'average Fleming' is very attached to the individual freedom associated with car ownership. Hence, stronger efforts should be made to sensitize citizens to the negative effects on the overall quality of life and the possible uneven accessibility effects associated with the present-day dependence on individual motorized transport.

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CAR USE AS A LIFE STYLE?

Veronique Van Acker

INTEGRATING LIFESTYLES INTO TRAVEL BEHAVIOUR

Introduction

>> What makes that somebody drives a Volkswagen Golf and another person drives a Mercedes-Benz S-class? Differences in income one might think of, or the associated differences in social class. But prosperity increased during last decennia, so that income is no longer such a strict limiting choice factor as it used to be before. People of the same income group or social class not necessarily have to make similar choices; they have more freedom to make individual choices and to develop a personal 'lifestyle'.

This concept of 'lifestyle' can potentially become a new buzzword in travel behaviour research. A swift search for articles with 'lifestyle' in its title by research area on the ISI Web-of-Science indicates that lifestyle studies in transport remain limited compared to other research areas such as psychology, health sciences, marketing and sociology. , But the number of lifestyle articles in transportation increases. The first empirical lifestyle studies in transport date back to late 1980s – early 1990s, and where mainly in accident analysis. The influence of lifestyle factors such as sleep, stress and exercise in accidental injuries was compared to other factors such as substance use (e.g., Gregersen and Berg, 1994). These studies thus narrowed down the meaning of the 'lifestyle' concept to factors related to the physical well being of drivers. Especially since the early 2000s transport researchers have become more interested in the 'lifestyle' concept and apply it in a much broader way than the previous accident analyses. It is now used in reference to mobility and residential attitudes (e.g., Choo and Mokhtarian, 2004) but also to actual mobility and residential choices and activities (e.g., Krizek and Waddell, 2002; Lin et al., 2009). It illustrates that the increased interest also goes together with a blurring of our understanding of the 'lifestyle' concept. Various researchers claim to study lifestyles but apply the concept with different meanings and measure it in different ways.

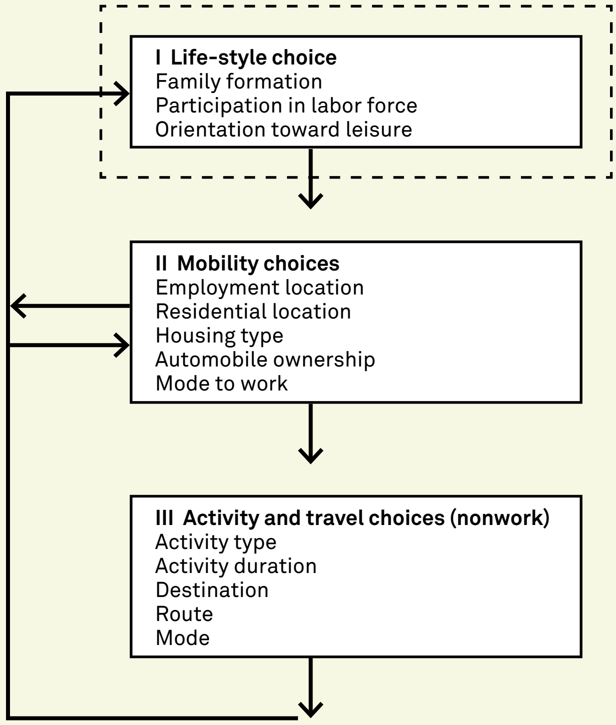
One of the reasons for this interest in 'lifestyles' is that it highlights the importance of including 'subjective' factors in addition to the traditionally used 'objective' factors such as price and costs in explaining travel behaviour. The 'lifestyle' concept is nowadays considered to be relevant in explaining why different travel patterns still exist within socio-economic homogenous population groups living in neighbourhoods with similar spatial characteristics (van Wee, 2002; Mokhtarian and Cao, 2008). Consequently, the 'lifestyle' concept adds a behavioural component to travel models that used to be dominated by engineering and economics traditions (Talvitie, 1997; Krizek and Waddell, 2002; Krizek, 2006). Such a behavioural component is highly needed considering the current debate of 'peak car' for example (Delbosc and Currie, 2013; Van Dender and Clever, 2013). Many developed countries noticed a decline in car use, a trend described by the term 'peak car'. The economic crisis of 2008 is often suggested as a possible explanation because a long-held assumption is that transport demand grows with income. So from this perspective, it would make sense that car use declines after the economic crisis. But 'peak car' occurred already around the turn of the millennium and thus long before the economic crisis. Moreover, it still continues despite the recent economic uptake. The size and structure of 'objective' economic determinants of transport demand might therefore be changing, and other more 'subjective' factors such as personal lifestyles might become more important today. This will have far-reaching implications for both science and practice. Long-held 'objective' and economic assumptions of transport demand have to be questioned, which will result in different ways of forecasting future mobility demand and decision-making on infrastructure investments. In order to highlight the importance of including 'subjective' factors in these discussions, this chapter will discuss the usefulness of the 'lifestyle' concept in explaining travel behaviour.

One of the first explicit references to the issue of 'lifestyle' in travel behaviour was work by Salomon, based on his PhD thesis in 1980 (Salomon, 1980). Alongside Salomon, the work by Kitamura (1988; 2009) was also very influential in bringing this idea of lifestyles into travel behaviour research. Applications of lifestyle in travel behaviour research are mainly in activity-based travel modelling studies. By using the concept of 'lifestyle', activity-based studies seek to make a significant progress toward a more behavioural framework for simulating household travel behaviour. Within this behavioural approach to travel behaviour, daily travel patterns are often considered within a hierarchical decision structure (e.g., Ben-Akiva, 1973; Salomon & Ben-Akiva, 1983). This hierarchy ranges from short-term decisions on daily activities and travel (such as activity type, activity duration, destination, route and mode), to mediate-term decisions on vehicle ownership, residential and workplace location, and long-term decisions on lifestyles (such as family formation, participation in labour force and orientation toward leisure). It is assumed that within each time block decisions are made jointly, but decisions in the lower block are made conditional on those in the upper block (see Figure 13).

Since then, many researchers claim to study lifestyles in relation to travel behaviour but – as already mentioned above – actually use very different definitions and approaches. Research findings are therefore difficult to compare and generalizations are almost impossible. This chapter attempts to provide a structured overview of definitions (Section 2) and measurement methods (Section 3) in the first place. Then, it illustrates how the use of different measurement methods leads to different conclusions. Section 4 presents an example in which lifestyles are introduced to explain modal choices for leisure trips in Flanders, Belgium. This example uses two different viewpoints and measurement methods of 'lifestyles". Finally, Section 5 summarizes some important conclusions.

FIGURE 13
The 'lifestyle' concept as part of an extended choice hierarchy (Salomon & Ben-Akiva, 1983)

***Note:* The dotted box corresponds to the social, cultural and political environment**



Defining the 'Lifestyle' Concept

Despite its frequent and colloquial use, no formally stated agreed definition of the 'lifestyle' concept exists. Moreover, it is elaborated pragmatically rather than theoretically. Especially marketing studies (e.g., Mitchell, 1983) use the 'lifestyle' concept in order to retrieve market sectors. These studies generally cluster analyse numerous data. Each cluster is then referred to as another lifestyle. Because results are data-dependent without a sound theoretical basis, each study 'finds' new lifestyles. Among others Sobel (1983) criticizes this pragmatic approach. Nevertheless, scholars such as Weber (1922), Bourdieu (1979), Ganzeboom (1988) and Schulze (1992) have made theoretical contributions to the 'lifestyle', especially in sociology. Social structure used to be explained in terms of social class measured by differences in education, profession and income. Such indicators clearly emphasize participation in labour force, which seems adequate when describing the structure of an industrial society preoccupied with production. However, it has various disadvantages especially in modern societies, which are more focussed on consumption rather than on production (Richter, 2002). Social class structure was believed to be very stable throughout the years. However, in modern society changes can be noticed with respect to the use of free time, cultural behaviour and participation in society. For example, it no longer holds that employees and entrepreneurs vote conservative parties while workers vote socialist parties. During last decennia, prosperity increased resulting in increasing individualization and decreasing social control. Consequently, the social burden to behave uniformly according to social class membership disappeared, and traditional relations between behaviour and social class membership have broken down. Social structure is thus not as stable as it once was (Hradil, 1987) and there is less uniformity of behaviour within social classes (Ferge, 1972; Bootsma et al., 1993). Individuals nowadays not only behave according to their social class, but also to their personal lifestyles based on their values and interests in life. Consequently, a cultural dimension needs to be added to the discussion on social structure.

Weber's Wirtschaft und Gesellschaft (1922) was one of the first sociological studies that contributed to the theoretical debate on lifestyles. Criticising Marx' class theory in which a person's behaviour is determined by his or her economic position (i.e., the possession of production means), Weber emphasized the importance of a cultural/symbolic and a political dimension. He argued that behaviour is not always based on what a person produces (i.e., economic dimension) but also on what he or she consumes (i.e., cultural/symbolic dimension). Through these consumption patterns, a person has a particular social status. According to Weber, social status refers to a group of people that share the same prestige and who clarifies this prestige. Lifestyle is thus considered as a pattern of observable and expressive behaviours. Weber conceptualized lifestyles (or 'Lebensstil' in his work) through 'Lebensführung' (translated as life conduct) and 'Lebenschancen' (translated as life chances). 'Lebensführung' refers to choice and self-direction in a person's behaviour and 'Lebenschancen' refers to structural conditions that constrain these choices (e.g., economic conditions such as income and property but also social elements such as rights, norms and social relationships). Consequently, Weber recognized that people have choices in the lifestyles they adopt, but the actual realization of these choices is influenced by their life chances. Or in other words, lifestyle is the result of the interplay between choice and structure (Cockerham et al., 1993).

Following Weber, Bourdieu (1979) considered lifestyle as a pattern of behaviours indicating the social position of the individual. His work La Distinction is based on the analysis of consumption patterns in France. He combined socio-demographic data (e.g., education, profession, income) with information from thirty surveys on preferences and behaviours associated with lifestyle related subjects such as purchasing behaviour, holidays, car type, culinary preferences, fashion, cultural activities and taste. Based on this information, each individual occupies a position in a two-dimensional social space which is defined by the composition and the volume of capital. Within this two-dimensional space, traditional socio-demographic variables define the 'space of social position', whereas specific patterns of behaviour define the 'space of lifestyles'. Based on this, two hierarchies can be distinguished. One category reaches from the traditional lower status groups to the economic elites who pursue material welfare and obtain rather traditional aesthetic and moral beliefs. Another category reaches from the same lower status groups to cultural elites (see Figure 14). Doing so, Bourdieu's conceptualization of 'lifestyle' still contains a hierarchical aspect with 'lower' ranked lifestyles with less variety associated with lower status groups and 'higher' ranked lifestyles with much more variety associated with higher status group. Ganzeboom (1988) builds on the work of Bourdieu in order to analyse lifestyles in

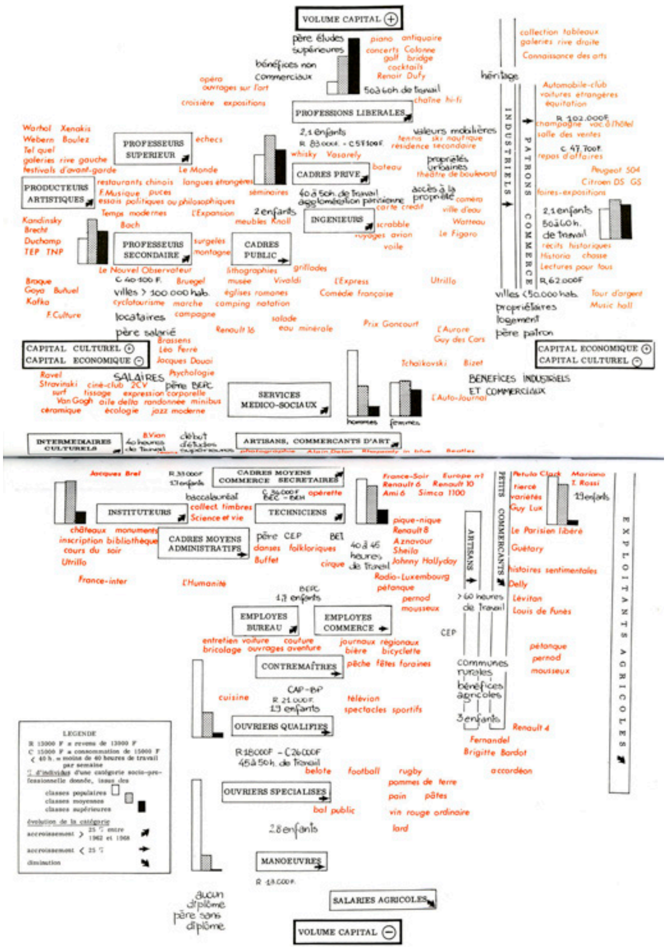


FIGURE 14
'Space of social position' and 'space of lifestyle' (Bourdieu, 1984)

the Netherlands. In his work, lifestyle is related (but not considered a synonym!) to the individual's socio-economic characteristics and also influenced by intermediate variables referring to opportunities and constraints offered by time budget, income, cognitive skills and status. Ganzeboom argues that lifestyles must not be considered as unambiguous types but rather as a continuum determined by three dimensions: a stage of life-dimension, an economic dimension, and a cultural dimension. The first dimension originates from Bourdieu's 'space of social positions' which is based on traditional socio-economic variables. The latter two dimensions are clearly inspired by Bourdieu's 'space of lifestyle', but Ganzeboom considers economic and cultural capital as two separate dimensions instead of opposite extremes of one dimension. Doing so, he no longer considers a hierarchy of lifestyles like Bourdieu but rather considers each lifestyle type as another equally important niche. Schulze's Erlebnisgesellschaft (experience society) (1992) is another example of this postmodern approach. Moreover, he added a spatial dimension to the discussion on lifestyles. He observed that leisure consumption often occurs outside the home in specific places that attract a congenial group sharing similar lifestyles (e.g. cafes, shopping centres, football stadiums). Schulze refers to these specific sites as 'scenes': combinations of a congenial lifestyle group sharing similar leisure consumption behaviour. These scenes gain importance in a postmodern society at the expense of traditional urban living and working environments (van der Wouden and Kulberg, 2002).

Without any intention of providing a comprehensive overview, this section illustrated how the theoretical discussion on lifestyle has evolved throughout the years. Two opposing views are apparent: Weber and Bourdieu who considered social class as an important determinant of lifestyles and thus a clear hierarchy of lifestyles, in contrast to Ganzeboom and Schulz who considered lifestyles as niches that are no longer in line with social classes in a postmodern society where old social structures are flattened (Tomlinson, 1998). Nevertheless, they all agree on the communicative character of lifestyles and, therefore, a basic definition of the 'lifestyle' concept should at least refer to: *"The way by which the individual indicates his or her social position through specific patterns of behaviour, mainly in consumption and leisure behaviours."*

Measuring the 'Lifestyle' concept

Defining the 'lifestyle' concept is one thing, measuring it is another one. Some empirical studies in travel behaviour research (e.g., Cooper et al., 2001; Hildebrand, 2003) analyse what they would call lifestyles, but in fact combine various objective socio-economic and demographic characteristics of the individual and the household. Such studies are characterized by a socio-economic and demographic approach and rather measure stage of life or household composition than lifestyles. Statistical techniques such as cluster and factor analysis are frequently used to determine stage of life groups like youngsters, households with young children, single-parent families and the elderly. The advantage of this approach is that data on socio-economics and demographics are widely available. However, the theoretical discussion above illustrates that such characteristics do not necessarily reflect how people want to socially represent themselves towards other people. It is therefore questionable whether a socio-economic and demographic approach can be considered appropriate to measure lifestyles.

The theoretical discussion in Section 2 ended with a basic definition of lifestyles as behavioural patterns, mainly in consumption and leisure, through which an individual elucidates his or her social position towards others. From this perspective, it makes sense to use data such as consumption behaviours, activity patterns and time-use. Lifestyle studies based on this type of data are using a mechanistic lifestyle approach. This approach considers the simplest content of the lifestyle concept: lifestyles as a way of living or as "a condition of existence and a manner of being" (Cathelat, 1993, p. 97). The available data on (consumer) behaviours is often combined with socio-demographic data. The empirical analyses in Bourdieu's La Distinction can be considered as a good example. His two-dimensional social space is based on a correspondence analysis of socio-demographic data combined with information on consumption behaviour. The proximity of characteristics within this two-dimensional social space implies that these characteristics are often combined with one another.

But according to others, lifestyle includes more than observable patterns of behaviour. We behave in a particular way because we think in a particular way. Behaviour is thus related to personal thoughts, attitudes and preferences. No surprise that some lifestyle studies focus on such underlying opinions and motivations, including beliefs, interests and attitudes (Ganzeboom, 1988), and use a sociographic lifestyle approach. Sociographic lifestyles studies aim at monitoring changes and trends in society by the analysis of changing individual and shared opinions and attitudes.

This contradiction between lifestyles as behaviours or as attitudes may confound our understanding of the 'lifestyle' concept. For that reason, Munters (1992) distinguished lifestyles from lifestyle expressions. He considered lifestyles as the individual's opinions and motivations, or orientations. Frequently studied lifestyle orientations relate to fields such as family-life, work-life, leisure, consumption and housing (Bootsma et al., 1993). Consequently, lifestyles are internal to the individual and are thus unobservable. A lifestyle, then, manifests itself in observable patterns of behaviour, or lifestyle expressions which is in line with the previously mentioned basic definition of lifestyles. In this way, observable patterns of behaviour (lifestyle expressions) are explained by underlying opinions and orientations (lifestyles).

Two broad perspectives thus exist (for a more detailed overview, see, e.g., Van Acker, 2015): (1) lifestyles as a behavioural typology of activity and time use patterns (in accordance with a mechanistic lifestyle approach and 'lifestyle expressions' by Munters), and (2) lifestyles as a behavioural orientation – values, attitudes and preferences – and a latent factor motivating behaviour patterns (in accordance with a sociographic lifestyle approach and 'lifestyles' sensu stricto by Munters).

Using the Lifestyle concept in travel behaviour research: an example

The theoretical overview indicated different dimensions of 'lifestyle', let only to measure as well. Two broad perspectives can however be detected: (1) lifestyles as a behavioural typology of activity and time use patterns, and (2) lifestyles as a behavioural orientation – values, attitudes and preferences – and a latent factor motivating behaviour patterns. There is little evaluation of which of the many formal classification systems are more useful in travel behaviour research. This chapter therefore tries to add some evidence on this issue using data on attitudes and leisure activities from a sample of highly educated respondents in Flanders, Belgium.
This section first describes the dataset used, then explores the sociographic and mechanistic approach of lifestyles, and eventually illustrates the interaction between lifestyles, residential location, car ownership and car use.

Data on lifestyles
Since most travel surveys lack information on lifestyles, an Internet survey on lifestyle and travel behaviour was organized between May 2007 and October 2007 in

Flanders, Belgium. In total, 2,363 respondents completed the survey, of which after data-cleaning 1,878 were retained for further analyses. Despite all efforts to obtain a well-balance sample, highly-educated respondents are overrepresented: 66% has a degree of higher education or university education (for more detailed information on sample characteristics, see Van Acker et al., 2011). Some studies suggest car use is higher among highly-educated people (e.g., Kockelman, 1997), but this analysis attempts to illustrate that this is not necessarily the case due to the influence of personal lifestyles.

Respondents were asked what kind of leisure activities they perform on a monthly basis. The focus is on leisure because of the assumption that personal characteristics such as lifestyles are of greater importance for optional or discretionary trips than for routine or recurrent trips. Recurrent trips like commuting are also determined by non-personal characteristics (e.g., work schedule, workplace location), contrary to discretionary trips where transport choices are less restrictive by such non-personal characteristics. Doing so, the analysis in this paper focuses on leisure activities in which respondents actively participate such as practicing sports or playing theatre (and not passively watching sports or a theatre play). More than 1,000 respondents (N = 1,009) indicated to have performed such active leisure activities in the past month, and almost one third of these respondents (29.8%) use their cars for this type of activities.

The Internet survey included questions on attitudes toward family-life, work-life and leisure, and holiday and leisure behaviour. Consequently, the survey allows us to illustrate the use of a sociographic and mechanistic lifestyle approach (see subsequent sections 4.2 and 4.3). In each approach, the relevant information was factor analysed using a principal axis factoring complemented with a promax rotation. Number of factors were always determined based on interpretability of the factors combined with interpretation of the scree-plot and eigenvalues larger than one.

A sociographic lifestyle approach

Respondents had to indicate to what extent they agreed with statements such as “A career is important to me” or “I enjoy outside leisure activities”. A factor analysis of the statements related to family-work balance extracted four factors: friends-oriented, family-oriented, job-oriented, career-oriented (see Figure 15). A similar analysis of the statements related to leisure time extracted two factors: outdoor leisure activities, and home leisure activities (see Figure 16).

Statement	Friends-oriented	Family-oriented	Job-oriented	Career-oriented
A career is important to me				0.442
A succesful marriage or relationship is important to me		0.547		
An interesting and exciting job is important to me			0.433	
Friendship is important to me	0.738			
Having and raising children is important to me		0.682		
Others' opinion is important to me				
Regular contact with friends is important to me	0.723			
The kind of job is not important as log as I earn enough			−0.446	
30.9% variance explained				

FIGURE 15

Pattern matrix for sociographic lifestyle factors related to family-work balance

***Note:* factor loadings between -0.200 and 0.200 are not reported**

FIGURE 16

Pattern matrix for sociographic lifestyle factors related to family-work balance

***Note:* factor loadings between -0.200 and 0.200 are not reported**

Statement	Outdoor leisure activities	Home leisure activities
I enjoy leisure activities at home		0.742
I enjoy outside leisure activities	0.737	
Meeting people during outside leisure activities is important to me	0.293	
Sufficient time for leisure activities at home is important to me		0.797
Sufficient time for outside leisure activities is important to me	0.871	
51.5% variance explained		

A mechanistic lifestyle approach

Respondents were also asked to indicate how they spent their holidays, on what subjects they had recently read and how they spent their weekends. For example, respondents had to mark what aspects are important on a holiday (having 13 possible choices), on what types of subjects they generally read a book or magazine (having 29 possible choices), and what recreational activities they like to do (having 20 possible choices). This resulted in 136 binary variables representing a diverse set of activities. These binary variables were constructed in such a way that the three dimensions of lifestyles (economic, cultural, and stage-of-life – referring to Ganzeboom, 1988) were reflected in the possible choices. For example, important holiday aspects ranged from 'inexpensive holiday' to 'luxury stay' (referring to the economic dimension), literary interests ranged from 'comic books and cartoons' to 'art and architecture' (referring to the cultural dimension), and recreational activities ranged from 'going out to party' to 'visiting family' (referring to the stage-of-life dimension). Such questions clearly refer to aspects of lifestyle expressions (behaviours) instead of the underlying orientations (lifestyle sensu stricto).

Factor analysis was, then, used in order to reduce the considerable amount of information found in the observed indicators to a feasible number of lifestyle factors. Because of the large number of candidate variables, it made sense to initially factor analyse each group of leisure aspect (36.4% explained variance for holidays, 36.4% variance explained for literary interests and 23.7% explained variance for recreational activities) separately rather than all together. Many of the retrieved factors reflected the three-lifestyle dimensions (a more detailed description of these factors is reported in Van Acker et al., 2011).

FIGURE 17

Second-order pattern matrix for mechanistic lifestyle factors

***Note:* factor loadings between -0.200 and 0.200 are not reported**

First order factor	Culture lover	Friends -and- trends	Active outdoor family	Traditional family	Low-budget and active/ creative
Holiday: all-in-one				0.444	
Holiday: culture lover	0.423				
Holiday: frequent traveller, second home				−0.200	
Holiday: low-budget, active/adventurous					0.246
Holiday: self-organized, family oriented			0.253		
Leisure: creativity					0.922
Leisure: party people		0.937			
Leisure: socially engaged	0.843				
Leisure: sports			0.741		
Leisure: traditional family activities		−0.246		0.607	
Literary interests: culture and current events	0.444				
Literary interests: non-emotional, non-fiction	−0.305				0.289
Literary interests: pro-housing, cocooning			0.628		
Literary interests: style and trends		0.262		0.598	
45.5% variance explained					

Several factors (e.g. family orientation, culture lover) appeared across more than one group of leisure aspect and consequently a second-order factor analysis was performed (Thomas, 1995; Arnau, 1998). This second-order factor analysis used the factor scores from the first analysis as input resulting in five second-order factors: culture lover, friends-and-trends, active outdoor family, traditional family, low-budget and active/creative (see Figure 17).

Direct effects of lifestyles on car use – results of a probit analysis

After having specified how lifestyles can be measured, we now turn our attention to the results of two regressions (one for each of the two lifestyle approaches) in which lifestyles are used as one of the independent variables explaining car use for active leisure activities. Other explanatory variables are socio-demographics, built environment characteristics and car ownership (for a detailed explanation of these variables, see, e.g. Van Acker et al., 2011).
Analyses were performed in the software package Mplus 7. Since car use is in this analysis defined as a binary outcome variable, Mplus 7 uses a robust weighted least squares estimator (WLSMV) as a default and reports probit instead of logit coefficients. This WLSMV – probit framework allows you to think in terms of a continuous latent response variable underlying the categorical outcome variable. Probit coefficients are however not interpreted in terms of probability what one would expect with a categorical outcome variable, but instead probit coefficients are interpreted as the increase in the latent continuous variable underlying car use as for one unit increase in the explanatory variable like a cultural lifestyle or car ownership.

Results of the probit regressions are summarized in Figure 18. We are primarily interested here in how research findings are affected by different lifestyle approaches. Therefore, the discussion of the results will mainly focus on these effects. The first part of this table reports the results for the sociographic lifestyle approach, i.e. when lifestyles are considered to be a behavioural orientation influenced by personal attitudes towards family, work and leisure. Surprisingly, sociographic lifestyle factors were all found to be insignificant. This contrasts to the mechanistic lifestyle approach, i.e. when lifestyles are considered to be a behavioural typology of leisure activities and time use patterns. The second part of Figure 18 illustrates how a cultural lifestyle, an active family-oriented lifestyle and a low budget but active lifestyle are negatively associated with car use. A friends-and-trends lifestyle is positively associated with car use, but its significance level slightly exceeds the 5% level. A mechanistic lifestyle approach thus holds more significant effects, and seems to be more interesting in terms of empirical results and modelling implications compared to the sociographic lifestyle approach.

But although these mechanistic lifestyle factors have a significant effect, those are not the most important predictors of car use. Based on the standardized coefficients, car ownership seems to contribute the most to the regression models. Also the built

	Model 1 sociographic lifestyle approach				Model 2 mechanistic lifestyle approach				Model 3 without any lifestyle			
	Est.	S.E.	Sign.	Std.	Est.	S.E.	Sign.	Std.	Est.	S.E.	Sign.	Std.
Lifestyle												
friends-oriented	0.043	0.110	0.696	0.025								
family-oriented	0.086	0.102	0.398	0.047								
job-oriented	-0.158	0.140	0.259	-0.062								
career-oriented	0.072	0.145	0.621	0.030								
outdoor leisure activities	0.001	0.109	0.991	0.001								
home leisure activities	-0.075	0.062	0.225	-0.061								
culture lover					-0.138	0.067	0.041	-0.111				
friends & trends					0.106	0.060	0.076	0.091				
active family					-0.210	0.079	0.008	-0.147				
traditional family					0.125	0.086	0.143	0.089				
low budget & active/creative					-0.189	0.066	0.004	-0.162				
Built environment												
density	-0.198	0.060	0.001	-0.214	-0.219	0.064	0.001	-0.231	-0.197	0.060	0.001	-0.215
location relative to local centre	0.142	0.060	0.017	0.151	0.139	0.061	0.022	0.143	0.130	0.059	0.027	0.139
location relative to regional centre	0.181	0.066	0.006	0.190	0.194	0.070	0.005	0.198	0.175	0.065	0.008	0.184
local accessibility	-0.118	0.065	0.067	-0.144	-0.139	0.067	0.037	-0.164	-0.116	0.064	0.071	-0.141
regional accessibility	-0.051	0.066	0.442	-0.047	-0.040	0.067	0.550	-0.036	-0.042	0.065	0.515	-0.039
Car ownership	0.323	0.084	0.000	0.247	0.308	0.087	0.000	0.229	0.326	0.083	0.000	0.251
Socio-demographics												
age	0.008	0.007	0.218	0.078	0.011	0.007	0.096	0.106	0.007	0.006	0.247	0.072
gender (female)	0.037	0.122	0.760	0.016	-0.072	0.148	0.626	-0.031	0.026	0.119	0.830	0.011
marital status (single)	-0.231	0.194	0.233	-0.102	-0.371	0.189	0.050	-0.159	-0.207	0.189	0.273	-0.092
presence of children	-0.140	0.164	0.391	-0.048	-0.149	0.163	0.358	-0.050	-0.120	0.160	0.451	-0.041
driving license	0.517	0.196	0.008	0.179	0.489	0.197	0.013	0.164	0.545	0.190	0.004	0.190
education, high	0.234	0.148	0.114	0.100	0.224	0.150	0.135	0.093	0.201	0.144	0.163	0.087
income, 0-1499 € (ref.)												
income, 1500-2999 €	0.020	0.208	0.924	0.008	-0.018	0.209	0.932	-0.007	0.004	0.206	0.983	0.002
income, 3000-4499 €	-0.066	0.212	0.755	-0.029	-0.119	0.215	0.578	-0.051	-0.073	0.210	0.728	-0.032
income, + 4500 €	-0.105	0.250	0.673	-0.030	-0.094	0.250	0.705	-0.026	-0.109	0.246	0.656	-0.032
Constant	-1.658	0.398	0.000	1.469	-1.554	0.397	0.000	1.336	-1.631	0.394	0.000	1.453
R2 (car use)	0.214				0.261				0.207			
Model fit												
Chi2 (df) p	0.000 (0) 0.000				0.000 (0) 0.000				0.000 (0) 0.000			
RMSEA / WRMR	0.000 / 0.001				0.000 / 0.002				0.000 / 0.001			
CFI / TLI	1.000 / 1.000				1.000 / 1.000				1.000 / 1.000			

FIGURE 18

Probit regression results for car use, by lifestyle approach

environment has a non-negligible effect on car use. Especially density seems to be an important spatial characteristic. Higher densities are often related with car discouraging aspects such as more congestion and slower traffic flows, less and more expensive parking spaces, etc. Furthermore, the third part of Figure 18 reports the results of a model without any lifestyle factors included. The sign, magnitude and significance of all socio-demographic and spatial variables are similar across the three models. But comparing R^2 value of this third model with the previous two lifestyle models gives some additional insight in the added value of including lifestyle factors. Including sociographic lifestyle factors (R^2 = 21.4%) or not (R^2 = 20.7%) does not result in higher R^2 value. The explained variance of the latent continuous variable underlying car use is the highest in the second model with the mechanistic lifestyle factors (26.1%), but it is not that remarkably higher compared to the third model without any lifestyle factors (20.7%). Mechanistic lifestyle factors do add some additional explained variance, but are not the prime explanatory variables of car use (Van Acker, 2015).

Direct and indirect effects of lifestyles on car use – results of a path analysis

By now, one might start wondering whether it is useful to extend our travel surveys with such attitudinal and a variety of behavioural questions to measure lifestyles. The additional effort might seem not to outweigh traditional methods collecting data on socio-demographics. However, more research is needed before anything like this can be concluded. After all, the interaction between long-term lifestyles, medium-term

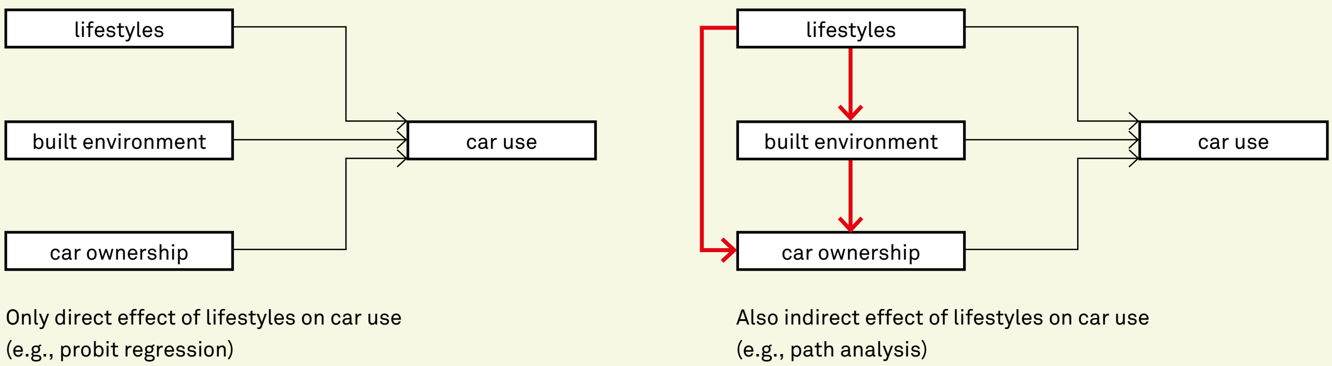


FIGURE 19
Direct and indirect effects of lifestyles on car use

residential location and car ownership decisions, and short-term travel behaviour is much more complex than depicted in the simple probit regressions of this analysis which analyse only the direct effects of lifestyles on car use. Perhaps the effect of lifestyles on car use runs indirectly through the interaction with medium-term residential location and car ownership decisions, as depicted in Figure 3. Such indirect effects can be studied using a structural equation model (SEM).
SEM can be considered as a combination of a factor analysis and regression analysis. The factor analysis aspect in a SEM refers to the modelling of indirectly observed (or latent) variables whose values are based on underlying manifest variables (or indicators) which are believed to represent the latent variable. This measurement model, as it is called, therefore defines the relationships between a latent variable and its indicators. All previously discussed lifestyle factor analyses (see sections 4.2 and 4.3) are in fact measurement models, and these lifestyle factors could be considered latent variables within a SEM. However, the complexity of these factor analyses indicated that it would be too cumbersome to embed all submodels into the structural model, i.e. which measures the effect relations, and estimate all parameters simultaneously. Thus, to reduce the dimensionality of the models, separate factor analyses were conducted and these factor scores were incorporated into the models

as manifest variables. Since all variables, even lifestyle factor scores, are considered to be observed (or manifest) variables, this analysis is solely based on the regression analysis aspect of a SEM. A SEM with only observed variables is called a path model. Consequently, for convenience, this chapter generically refers to 'path model' instead of the general term 'structural equation model'.

In such an approach, a variable can be an explanatory variable in one equation (e.g., car ownership influencing car use) but an outcome variable in another equation (e.g., car ownership influenced by the built environment). Therefore, the concepts 'endogenous' and 'exogenous' variables are used (Raykov and Marcoulides, 2000; Byrne, 2001; Kline, 2005). Exogenous variables are not influenced by any other variable in the model, but instead they influence other variables. In this analysis, the only exogenous variables are socio-demographics and the lifestyle factors. Endogenous variables are influenced by exogenous variables, either directly or indirectly through other endogenous variables. All spatial variables, car ownership and car use are considered endogenous variables in this analysis.

Path models are estimated by finding the coefficients that best match the resulting model-implied covariance matrix to the empirically-based covariance matrix for the data. As in other statistical techniques, a standard estimation technique is maximum likelihood (ML), which assumes a multivariate normal distribution of all endogenous variables in the model (Bentler and Dudgeon, 1996; Kline, 2005). However, the final outcome variable 'car use' is binary and, thus, not normally distributed. As mentioned before, Mplus 7 uses in this case the WLSMV estimator. Cut-off values for different model fit indices are $Chi^2/df < 2.9$, RMSEA < 0.05, WRMR < 1.00, CFI > 0.95 and TLI > 0.95 (Bollen, 1989; Hu and Bentler, 1999; Yu, 2002; Kline, 2005). Model fit indices thus indicate a less than adequate but still acceptable fit for the first model with sociographic lifestyle factors. The model fit of the second model with mechanistic lifestyle factors is slightly better.

Only the significant direct effects among all exogenous and endogenous variables were retained in the path analysis. In doing so, Table 5 shows that car use is directly influenced by density, car ownership and the possession of a driving license. Sociographic lifestyle factors have no significant direct effect, contrary to the mechanistic lifestyle factors of a 'culture lover', 'active family' and 'low budget but active/creative'. These findings are, so far, similar to the results of the probit regressions. Based on this, one might question the usefulness of including lifestyles – and especially using a sociographic lifestyle approach. But when accounting for the complex interactions between lifestyles, residential location choices and car ownership decisions, one might expect to find indirect effects of lifestyles. This is indeed true, but only in the model with mechanistic lifestyles. The indirect effect of a lifestyle like 'culture lover' (-0.048) has a synergistic role that results in an even larger total effect (-0.200) compared to the direct effect of this lifestyle factor. The opposite holds for the lifestyle 'low budget but active/creative lifestyle', of which the indirect effect (0.003) is opposite to its direct effect (-0.153). This indirect effect is however

	Model 1 – sociographic lifestyle approach			Model 2 – mechanistic lifestyle approach		
	Direct	Indirect	Total	Direct	Indirect	Total
Lifestyle						
friends-oriented	–	n/a	n/a			
family-oriented	–	n/a	n/a			
job-oriented	–	n/a	n/a			
career-oriented	–	n/a	n/a			
outdoor leisure activities	–	n/a	n/a			
home leisure activities	–	n/a	n/a			
culture lover				-0.152*	-0.048***	-0.200***
friends & trends				–	0.017*	0.017*
active family				-0.155*	n/a	-0.155*
traditional family				–	0.019	0.019
low budget & active/creative				-0.153*	0.003	-0.150*
Built environment						
density	-0.082*	-0.029***	-0.111**	-0.072*	-0.027**	-0.100*
location relative to local centre	–	n/a	n/a	–	n/a	n/a
location relative to regional centre	–	0.032***	0.032***	–	0.030***	0.030***
local accessibility	–	n/a	n/a	–	n/a	n/a
regional accessibility	–	n/a	n/a	–	n/a	n/a
Car ownership	0.325***	n/a	0.325***	0.309***	n/a	0.303***
Socio-demographics						
age	–	0.005**	0.005**	0.012*	0.006***	0.017**
gender (female)	–	0.047*	0.047*	–	0.053*	0.053*
marital status (single)	–	0.409***	0.409***	–	0.379***	0.379***
presence of children	–	n/a	n/a	–	n/a	n/a
driving license	0.661***	0.211***	0.872***	0.611***	0.187***	0.798***
education, high	–	n/a	n/a	–	n/a	n/a
income, 0-1499 € (ref.)						
income, 1500-2999 €	–	n/a	n/a	–	0.030	0.030
income, 3000-4499 €	–	0.102***	0.102***	–	0.137***	0.137***
income, + 4500 €	–	0.161***	0.161***	–	0.206***	0.206***
Constant	-1.628***			-1.630***		
R2 (car use)	0.166			0.226		
Model fit						
Chi2 (df) p	38.527 (14) 0.0004			53.405 (27) 0.001		
RMSEA / WRMR	0.053 / 1.025			0.040 / 0.962		
CFI / TLI	0.943 / 0.878			0.935 / 0.870		

FIGURE 20

Results of a path analysis of car use (unstandardized coefficients), by lifestyle approach (* = p < 0.001, ** = p < 0.010, * = p < 0.100, - = no significant direct effect and therefore excluded)**

small and not significant so that the total effect (-0.150) is not really different from its direct effect. Interesting to see is that some lifestyle factors like 'friends and trends' do significantly influence car use, but only indirectly. Such indirect influences are neglected from an analysis like the probit regressions reported earlier.

To understand the origins of these indirect effects, Figure 21 illustrates the decomposition of all significant indirect effects reported in Figure 20, and Figure 22 shows the causal links among the endogenous variables in the mechanistic lifestyle model. For example, a 'culture lover' lifestyle not only has a negative direct effect on car use, but also an important negative indirect effect. This indirect effect is caused by the interaction with the residential location choice (i.e., culture lovers tend to

Effects of	Sociographic lifestyle approach			Mechanistic lifestyle approach		
	Mediating variables		Effects on car use	Mediating variables		Effects on car use
	First	Second		First	Second	
Lifestyle						
culture lover				density	car ownership	-0.004*
				car ownership	-	-0.033**
				density	-	-0.011
friends & trends				car ownership	-	0.017*
Built environment						
density	car ownership	-	-0.029***	car ownership	-	-0.027**
location relative to regional centre	car ownership	-	0.032***	car ownership	-	0.030***
Socio-demographics						
age	density	car ownership	0.001*	density	car ownership	0.001*
	car ownership	-	0.003*	car ownership	-	0.004**
	density	-	0.002*	density	-	0.001
gender (female)	car ownership	-	0.047*	car ownership	-	0.053*
marital status (single)	location relative to regional centre	car ownership	0.014*	location relative to regional centre	car ownership	0.012*
	density	car ownership	0.021**	density	car ownership	0.022**
	car ownership	-	0.313***	car ownership	-	0.288***
	density	-	0.060*	density	-	0.057*
driving license	car ownership	-	0.211***	car ownership	-	0.187***
income, 3000-4499 €	density	car ownership	0.008*	density	car ownership	0.013*
	car ownership	-	0.072**	car ownership	-	0.091**
	density	-	0.022	density	-	0.033
income, + 4500 €	density	car ownership	0.009*	density	car ownership	0.014*
	car ownership	-	0.126**	car ownership	-	0.157**
	density	-	0.025	density	-	0.036

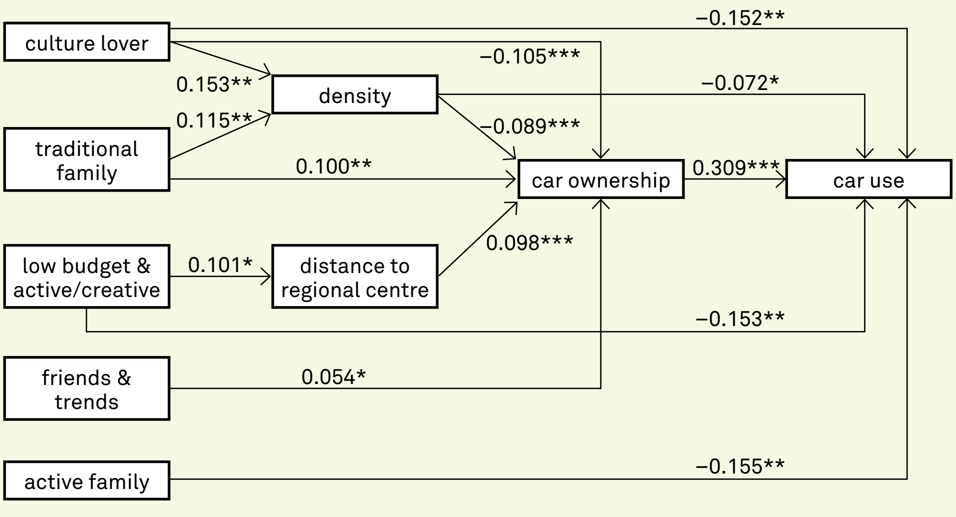
FIGURE 21

Decomposition of the significant indirect effects on car use (unstandardized coefficients), by lifestyle approach

(* = p < 0.001, ** = p < 0.010, * = p < 0.100)**

FIGURE 22

Path diagram of significant direct effects of the endogenous variables on one another in the mechanistic lifestyle approach
(* = p < 0.001, ** = p < 0.010, * = p < 0.100)**



reside in high-density neighbourhoods, and density is negatively associated with car use) but also car ownership (i.e., car ownership is lower among culture lovers, and low car ownership is negatively associated with car use), and the combination of both (i.e., culture lovers tend to reside in high-density neigbhourhoods where car ownership is low resulting in less car use). But it is especially the interaction with the car ownership decision that contributes the most to the indirect effect of a 'culture lover' lifestyle on car use. The indirect effect of a 'friends and trends' lifestyle is less complex and runs only through the car ownership decision. A 'friends and trends' lifestyle is characterized by leisure activities such as going out and partying with friends, as opposed to performing traditional family activities such as doing chores and do-it-yourself. Such a lifestyle not directly results in more car use, but only indirectly through car ownership. Owning a car seems to be very convenient to maintain such an active lifestyle oriented toward the social network of friends. Figure 20 indicated also an indirect effect of a 'traditional family' lifestyle and a 'low budget but active/creative' lifestyle. These indirect effects also run through the residential location decision (with traditional families surprisingly residing in high-density neighbourhoods, and low budget lifestyles residing further away from a large regional city centre) and car ownership. However, these indirect effects are small and insignificant, and therefore not detailed in Figure 21.

Conclusions

This chapter illustrated how a lifestyle approach provides useful insights into modal choices such as car use. Car use is not simply based on considerations of prices, speed and comfort, but is also related to social relationships, attitudes, status, preferences and constraints at various levels.

Despite its frequent and colloquial use, there is yet no agreement on the definition of the 'lifestyle' concept. Most empirical studies use the concept rather pragmatically, whereas this chapter presented an theoretical overview of the 'lifestyle' concept. This eventually resulted in the formulation of the basic notion of 'lifestyles' as "the way by which the individual indicates his or her social position through specific patterns of behaviour, mainly in consumption and leisure behaviours". Such patterns of behaviour are actually lifestyle expressions which can be measured by a mechanistic lifestyle approach using data on consumption behaviours, activity patterns and time use. These behaviours or lifestyle expressions are explained by underlying opinions and orientations, or lifestyles sensu strico which can be measured by a sociographic lifestyle approach using data on values, attitudes and preferences. There is, however, little evaluation of which of the two formal classification systems are more useful. This chapter tried to add some evidence on this issue using data on attitudes and leisure activities from a sample of highly-educated respondents in Flanders, Belgium. Although most respondents were highly educated, different modal choices for active leisure activities still occurred within this otherwise homogenously considered population group.

A sociographic lifestyle approach using attitudes towards family, work and leisure did not obtain significant results, neither directly in the probit regression or nor indirectly in the path analysis that considered the complex interaction with residential location choices and car ownership decisions. This finding suggests that general attitudes towards family, work and leisure are possibly not that useful in travel behaviour research. It gives the impression that including such 'subjective' variables into our transport models does not result in a better understanding of transport demand, and that we can continue using our classic models based on 'objective' factors such as prices and costs. It however does not mean that travel surveys should not ask for any attitudinal statements at all. Especially the debate on residential self-selection has indicated that travel-specific attitudes are important in the residential location choices (Bohte et al, 2009; Cao et al., 2009; Naess, 2009). This debate in the transport research field indicates that travel surveys must formulate such 'subjective' statements in a much more specific and targeted way.

A mechanistic lifestyle approach using leisure behaviours seems more useful in terms of empirical results and modelling implications. Although asking for a variety of leisure activities will extend a travel survey considerably, it is worthwhile doing so. However, more research is needed before one can conclude a mechanistic lifestyle approach to be superior to other lifestyle approaches. For example, other modal choices such as public transport or walking and cycling might possibly be more a reflection of attitudinal-based lifestyles than car use. At least for car use, mechanistic lifestyle factors do add some explanatory power to the models although these lifestyles are not the prime explanatory variables of car use. This study suggests car ownership and residential density as more important predictors of car use for active leisure activities. But more importantly, the results of a path analysis considering the interaction between lifestyles, residential location and car ownership gives more profound insights into which type of people (in terms of lifestyles) is associated with urban residential choices (i.e., residing in high density neighbourhoods close by a regional city centre) and car ownership decisions. Lifestyle-based research thus 'tells different stories' underlying residential location and car ownership decisions that eventually influence car use that otherwise would be neglected.
This finding potentially has important policy implications. The results suggest that 'objective' factors such as income and density remain important in explaining car use. Sustainable mobility patterns can thus be achieved by applying price mechanisms such as increasing fuel costs or introducing road pricing and by spatial planning policies such as densifying and fostering residential developments close to town and city centres. However, the results of this chapter also point out that such policies might only be successful for a specific group of inhabitants. Non-traditional lifestyles such as culture lovers are associated with residing in urban neighbourhoods and not owning a car. But it might be harder to convince other lifestyle groups (in this analysis, for example, the friends-and-trends lifestyle). Residing in an urban neighbourhood and not owning a car does not fit every lifestyle. Some might therefore be persistent in using their cars, and it might take time to change lifestyles. Policy should thus not only focus on designing and developing objective plans (e.g.,

a more sustainable lay-out of residential neighbourhoods) but should also be aware of the long-term subjective implications of it (e.g., changes in lifestyles are required but will need time).

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INCLUDING TRAVEL SATISFACTION IN TRAVEL BEHAVIOUR – LAND USE INTERACTION RESEARCH

Jonas De Vos
Ben Derudder
Frank Witlox

Introduction

>> Over the past decades, sprawling patterns of land development in most western countries have resulted in long average travel distances and consequently in a great reliance on the car (e.g., Glaeser and Kahn, 2004; Handy et al., 2005). However, as increasing car use diminishes the positive effects of cleaner cars for the environment and increases road congestion, studies since the 1970s started analysing people's activity pattern and accompanying travel behaviour in order to look at why we travel in a certain way and how we can reduce (long-distance) car use. First, studies tried to explain travel-related choices (e.g., travel mode choice) by using discrete choice modelling (e.g., Domencich and McFadden, 1975; Train and McFadden, 1978). These studies tried to explain travel patterns by primarily focusing on objective elements, indicating that people trade off travel costs and travel time when choosing a certain travel mode (McFadden, 1986, 2001). Other studies show significant differences in travel behaviour between people with various socio-demographic characteristics (e.g., income, age) (Hanson and Hanson, 1981; Pas, 1984; Recker and Schuller, 1982) or try to explain travel behaviour by analysing people's daily activity pattern (Hanson, 1982; Kitamura, 1988; Pas, 1984). Numerous studies also show significant effects of the built environment on how people travel (for an overview, see Badoe and Miller, 2000; Ewing and Cervero, 2010; Saelens et al., 2003). People living in a compact, mixed-use neighbourhood travel shorter distances and travel less by car compared to people living in a suburban-style neighbourhood. Some studies also focussed on the effect of subjective elements, such as lifestyles and especially attitudes, on travel behaviour. Some of these studies go back to the 1970s (e.g., Reibstein et al., 1980) while most of them are more recent (Anable, 2005; Choo and Mokhtarian, 2004; Steg, 2005; Van Acker et al., 2010). These travel-related attitudes might not only affect travel behaviour directly, but can also influence residential location preferences and choices as the physical characteristics of neighbourhoods can restrict the use of certain modes (Schwanen and Mokhtarian, 2005).

These travel behaviour studies have been picked up by transport policy makers. Transport policies over the past decades have mainly focused on improving the effects of travelling on society, and this primarily from an economic point of view. From this viewpoint, travel, and travel time in particular, is a cost to be paid in order to participate in a certain activity at the destination of the trip. Therefore, travel time savings have always been one of the most important components of transport policies in order to convert 'unproductive' time into economically valuable time (Jain and Lyons, 2008; Lyons et al., 2007; Metz, 2008). Although given less attention, transport policy also tries – from an ecological point of view – to minimise greenhouse gas emissions and other forms of pollution by stimulating the use of active travel (walking and cycling) and public transport as alternatives for the car. Initiatives to realise this goal range from developing compact, mixed-use neighbourhoods with good public transport accessibility (e.g., Transit-Oriented Development) to charging car use per kilometre travelled (i.e., road pricing).

Due to a growing interest in subjective well-being over the past years, attention to the social and individual aspect of transport has increased. As travelling enables activity participation and travel restrictions can consequently result in social exclusion (Jones and Lucas, 2012; Lucas, 2012), travel has a clear effect on people's quality of life. Furthermore, travelling can be perceived as an activity itself, with its own qualities and values of perception. Recently, studies have analysed which emotions people experience during trips and how they evaluate their trips (e.g., Ettema et al., 2011), indicating that travelling itself can possess a positive utility and that people do not always perceive travel time as wasted time (Jain and Lyons, 2008; Redmond and Mokhtarian, 2001). Since people spend on average more than one hour a day travelling to various activities (such as work and leisure activities) (Metz, 2008; Mokhtarian and Chen, 2004; Schafer and Victor, 2000) it is important to know how people experience this time and how it affects (i) their mood during and after the trip, (ii) their performance of – and satisfaction with – activities at the destination of the trip, and (iii) their overall well-being.

Travel and well-being

Well-being is a rather vague and all-embracing concept, which can have various meanings for different people (Atkinson, 2013). First of all, well-being can refer to objective factors. Therefore, policies often use objective indicators, such as income and health status at the individual level and Gross Domestic Product (GDP) and life expectancy at the aggregate level, as measures of economic and social progress. However, these measures are being criticised as they do not include inequality within regions or countries and cannot capture all elements of quality of life. For instance, frequent traffic congestions might increase GDP due to increased fuel consumption, but it will not evoke feelings of happiness of daily commuters (Stiglitz et al., 2009). Therefore, alternative measures focus more on the subjectively experienced well-being, including perceptions and emotions. These measures look at how happy and satisfied people are with various domains in life (e.g., work and social relationships) and life in general (e.g., Ryan and Deci, 2001). As a result, a range of countries have experimented with measures of gross national happiness and national well-being (Schwanen and Atkinson, 2015).

From a psychological point of view, this personal, subjective well-being can be subdivided into two types. Hedonic well-being refers to the experience of happiness or pleasure through the satisfaction of various needs and consists of three components: the presence of positive feelings (such as contentment, pleasure and affection), the absence of negative feelings (such as sadness, anxiety and frustration) and overall satisfaction with life (Diener, 2009; Kahneman et al., 1999). Eudaimonic well-being, on the other hand, emphasises on the meaning of life and achieving personal growth (Ryan and Deci, 2001; Ryff and Singer, 2008). It is possible that people do not satisfy their short-term needs (possibly resulting in lower hedonic well-being) in order to realise certain goals in life (improving eudaimonic well-being), for instance when a person chooses to use a bicycle not for the pleasure of cycling but for the fitness and health benefits it generates in the long run.

As (hedonic) well-being is fed by the fulfilment of needs (Nordbakke and Schwanen, 2014b; Ryan and Deci, 2000), it is important that policy measures not only help people realise their present needs, but also future needs (Dodds, 1997). Based on this assumption of sustainability, it is necessary that policies reduce greenhouse gas emissions, for instance by stimulating the use of non-motorised travel by creating compact, mixed use neighbourhoods. Furthermore, the level of realised needs is not only shaped by objective, but also by subjective elements. Holding a driving license, for instance, improves the ability to realise certain needs made possible by out-of-home activity participation (Nordbakke and Schwanen, 2014a).

Although well-being is often regarded as connected to the individual, the concept might also be treated as more collective. Policy measures can directly improve people's well-being, for instance by providing green spaces in cities or reducing neighbourhood deprivation (e.g., Foo et al., 2014). The residential environment can have a direct effect on subjectively experienced well-being. An increasing number of studies show that life satisfaction tends to be lower in larger cities characterised by greater density and diversity (e.g., Brereton et al., 2008; Dolan et al., 2008; Schwanen and Wang, 2014), while Kennedy and Adolphs (2011) state that greater density and diversity means that places offer more opportunities for satisfaction of individual's needs. Furthermore, policy makers should be interested in subjective well-being not only because of its inherent value to citizens, but also because individuals' subjective well-being can have positive spill-over benefits for the society as a whole (Diener, 2006). Improving people's well-being will benefit the region's economy as happy people have, among others, a higher productivity and a lower chance of being sick (Lyubomirsky et al., 2005); collective benefits of the aggregation of individual experiences exist.

Happiness and well-being are often regarded as a desired outcome at the individual level (Atkinson, 2013). Based on the assumption that people will try to maximise their happiness, people will – in a decision-making process – choose the alternative that satisfies their needs most and results in the highest levels of happiness (Kahneman and Krueger, 2006; Kahneman et al., 1997). This decision-making process has been analysed frequently in travel behaviour studies. According to these studies, people will choose a mode that gives them the highest utility in a certain circumstance, based on elements such as travel cost and travel time (Domencich and McFadden, 1975; McFadden, 1986, 2001). However, it is also possible to perceive this well-being not only as a desired endpoint but also as a predictor of elements in life, such as health conditions, employment and work productivity. Studies have indicated that happy people seem to be more successful in life (Atkinson, 2013; Diener, 2000; Lyubomirsky et al., 2005; Myers and Diener, 1995). Decision-making could also be regarded as a process, in which present, past and future are woven together into a complex amalgam of temporalities through acts of imagining, anticipation, memory and learning (McCormack and Schwanen, 2011). The way a decision is perceived and evaluated can affect future choices. When given the choice of which time-span or activity to repeat, individuals tend to choose the alternative that gave them the highest satisfaction in previous choices (Kahneman and Krueger, 2006). Building on this train of thought, it is plausible to assume that people's travel mode choice is affected by the satisfaction of previous trips with that mode, at least insofar as the built environment or other considerations (e.g., income) will not constrain the use of that mode.

Starting in the 1980's academics in the field of psychology have created scales in order to measure people's subjectively experienced well-being. Most of these scales ask people how happy and satisfied they are with their life in general (such as the frequently used Satisfaction with Life Scale (Diener et al., 1985)) or with certain aspects of their life (such as the Positive and Negative Affect Scale (Watson et al., 1988)); mainly based on the hedonic view of well-being. Subsequent studies have analysed how elements like employment, health and marriage affect this well-being (e.g., Helliwell, 2006; Helliwell and Putnam, 2004). Although travel occupies a considerable share of our daily time budget (especially when excluding activities with a mandatory character, such as sleeping and working) and enables activity participation, the effect of travel on well-being has only been analysed to a limited degree. The first studies incorporating travel in well-being studies indicate that commuting is perceived rather negatively compared to other daily activities (e.g., Kahneman et al., 2004).

Recently, academics have created travel-specific scales for analysing how people perceive their travel (De Vos et al., 2013, 2015b; Ettema et al., 2011). Studies using these scales have indicated that people's satisfaction with their travel is affected by elements such as trip duration and traffic congestion (Ettema et al., 2013; Stutzer and Frey, 2008). Remarkebly, all studies analysing travel satisfaction indicate that travel satisfaction differs according to the travel mode people choose. Public transport users – especially bus users – perceive their travel most negatively, while active travel results in the highest levels of travel satisfaction (Abou-Zeid, 2009; De Vos et al., 2015a, 2015b; Duarte et al., 2010; Ettema et al., 2011; Friman et al., 2013; Olsson et al., 2013). This satisfaction with travel could affect people's overall well-being, whether or not through activity participation (Bergstad et al., 2011); although studies analysing this effect are limited.

Although travel behaviour studies have recently started analysing the link between travel and well-being, these studies are still in their infancy and do not analyse all potential links between travel behaviour and well-being. Some links (e.g., of mode choice and trip circumstances on travel satisfaction) are starting to be examined while others (e.g., of travel satisfaction on mode choice) still remain unexplored.

Travel and the built environment

Previous studies have shown that land use and travel can affect each other. Improvements in transport technology – stimulated by major political, social and cultural changes – since the end of the nineteenth century have affected the land use pattern of western cities to a large extent (Brueckner, 2000; De Vos and Witlox, 2013; Geels, 2005; Glaeser and Kahn, 2004; Newman, 1992). The Industrial Revolution, starting at the end of the eighteenth century in the United Kingdom, encouraged great numbers of people to live and work in urban areas as factory work replaced many former farm jobs. These small and dense cities, where all destinations were within a reasonable walking distance (Newman and Kenworthy, 1996), rapidly became overpopulated. The technological development of passenger trains and trams in industrialised countries (e.g., United Kingdom, Belgium) at the end of the nineteenth century made it possible for factory workers to work in the city but live in the countryside. This resulted in a first wave of decentralisation; cities spread outwards generating sub-centres around public transport nodes (Newman, 1992; Newman and Kenworthy, 1996). The car, first produced at the end of the nineteenth century, becomes a dominant transportation mode after the Second World War. The technological development of the car, accompanied by mass production, standardisation and increasing household incomes makes it possible for a substantial share of households to own a car. It became the transport mode that shapes the land; the car made it possible to develop in nearly every direction. Low-density suburban neighbourhoods, designed to be well-accessible for cars, arose in most western countries. People were no longer forced to live either near their place of employment or a public transport stop to transport them there (Gillham, 2002; Glaeser and Kahn, 2004). Throughout the past decades, transport improvements have created a land use pattern making people highly car dependent. Some countries (e.g., The Netherlands, Germany) restricted this urban sprawl by actively implementing spatial planning regulations and clustering activities within clearly designated urban areas, limiting the rise of car use. Other countries (e.g., Belgium, USA) – only applying a limited amount of spatial planning regulations – were less successful in restricting urban sprawl, resulting in high levels of car use (Buehler, 2011; De Vos, 2015b; Dieleman et al., 1999; Schwanen et al., 2004). At the scale of the city, city size and the population density within cities seem to affect residents' mode choice. The larger the city size (based on amount of inhabitants) and the higher the population density within cities, the lower the share of car use becomes (De Vos and Witlox, 2013; Dieleman et al., 2002; Newman and Kenworthy, 1989; Kenworthy, 2006; Sung and Oh, 2011).

The urban sprawl that characterises the land use pattern of most western countries over the past decades has resulted in different types of residential neighbourhoods where people might live in. From the late 1980s onwards, studies have analysed how the residential location affects people's travel behaviour (see Ewing and Cervero, 2001, 2010). Most of these studies have analysed whether differences in the neighbourhoods' physical characteristics could influence residents' mode choice and travel distance. A distinction was often made between urban (or neo-traditional) neighbourhoods and suburban neighbourhoods (see Badoe and Miller, 2000). The former are characterised by compact and mixed-use developments and relatively small building blocks while the latter have a lower density and diversity, and often a street network with relatively large building blocks, a lot of T-intersections and dead-end streets (Cervero, 1996; Friedman et al., 1994; Saelens et al., 2003). It might not come as a surprise that the differences in physical characteristics of the neighbourhoods result in varying travel distances. Especially the elements density and diversity affect the average distance travelled; the higher density and diversity are, the closer potential destinations become (e.g., Cervero and Kockelman, 1997; Chen et al., 2008; Frank and Pivo, 1994; Kitamura et al., 1997). However, the street network can also influence average trip distance. A grid pattern with small building blocks will result in shorter average distances compared to a curvilinear street pattern with a limited amount of intersections, a lot of T-intersections and culs-de-sac, even when density and diversity are the same (Cervero, 1996; Saelens et al., 2003). The physical differences in neighbourhoods do not only affect travel distance, they can also affect travel mode choice, for a large extent explained by these varying travel distances. Various studies have indicated that – although regional differences exist – people living in urban neighbourhoods frequently walk, cycle or use public transport, while people living in suburbs use the car for the lion's share of their trips (e.g., Cao et al., 2009; Cervero and Kockelman, 1997; Frank and Pivo, 1994; Friedman et al., 1994). Although suburban neighbourhoods might be enjoyable places to walk and cycle for recreation, in order to reach destinations active travel and public transport use are often not feasible since destinations are mostly not within walking or cycling distance and public transport services are limited. This might force people to own and use a car and consequently creates car dependency. The design of the neighbourhoods can also influence people's mode choice (Aditjandra et al., 2012; Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Friedman et al., 1994). Elements like wide, well-lit sidewalks, separated cycle lanes and bus lanes – which are regularly present in urban-type neighbourhoods – stimulate walking, cycling and public transport use. Density, diversity and design are often referred to as the three Ds (Cervero and Kockelman, 1997). However, some studies also include two other Ds of the built environment: distance to public transport (i.e., the distance between residence or work place and the nearest rail station or bus stop) and destination accessibility (i.e., ease of access of trip destinations), sometimes referred to as the five Ds (Ewing and Cervero, 2010). Car use increases with increasing distance to public transport and decreasing destination accessibility. Other studies also include distance to a city centre as an additional D; whereby distance travelled by car is positively related with distance to a city centre (Næss, 2006, 2009).

Due to increasing awareness of the negative consequences of car use (such as congestion and air pollution) and growing evidence of the influence of the built environment on mode choice, urban planners have tried – from the 1990s onwards – to reduce car use by adapting the built environment (Cervero, 1996; Friedman et al., 1994). Concepts such as New Urbanism (in the USA), the Compact City (in Europe) and Transit-Oriented Development (in the USA and later in Europe and Asia) aim to reduce car use and travel distances by creatingcompact, mixed-use neighbourhoods with a high density, a high diversity and a high accessibility towards public transport and non-motorised travel.

Although studies in the 1970s already analysed the effect of attitudes on travel behaviour (e.g., Reibstein et al., 1980), a more recent wave of studies from the field of social psychology indicate that attitudes (i.e., a general stance toward specific elements), lifestyles (i.e., individual's opinions and motivations, or orientations towards general themes such as leisure, family and work) and habits (i.e., behaviour that is repeated regularly, often resulting from unconscious decisions) also seem to have an important impact on travel behaviour (e.g., Anable, 2005; Van Acker et al., 2010, 2011). The use of a certain travel mode is not only affected by the built environment, but also by a person's stance towards that mode. An individual with an affinity for cycling, for instance, will try to cycle as much as possible, as long as destinations are within cycling distance. As previously stated, destinations are often not within feasible cycling distance for people living in suburban neighbourhoods. As the choice of travel mode is restricted by the residential location, the attitude towards a specific mode might also affect the preference for living in a specific type of neighbourhood (e.g., Handy et al., 2005). A person might prefer a neighbourhood which enables him or her to easily travel with the preferred travel mode. This would mean that the cycling-loving person would prefer to live in an urban neighbourhood, where relatively short distances and good cycling infrastructure make it possible to cycle on a frequent base. This residential self-selection process, however, leaves us with a question of causality (Bagley and Mokhtarian, 2002; Cao, 2014; Cao et al., 2009; Mokhtarian and Cao, 2008). What affects mode choice most, the built environment or travel-related attitudes? Neglecting travel-related attitudes in explaining travel mode choice might result in an overestimation of the effect of the built environment on mode choice. Although residential self-selection seems to attenuate the effect of the built environment on travel, most studies still found statistically significant associations between the built environment and travel behaviour, independent of self-selection influences (Cao et al., 2009; Ewing and Cervero, 2010; Mokhtarian and Cao, 2008; Næss, 2014). According to Chatman (2009), travel-related residential self-selection causes both underestimation and overestimation of built environment effects, resulting in modest residential self-selection bias. From another point of view, this residential self-selection can be regarded as a demonstration of the influence of residential location on travel behaviour. If there were no such influence, people preferring car use, for instance, would not have a preference for living in a suburban-style neighbourhood in the first place (Chatman, 2009; Næss, 2014)

Studies indicate, however, that people do not always live in their preferred residential neighbourhood (De Vos et al., 2012; Kamruzzaman et al., 2013; Schwanen and Mokhtarian, 2005). People who do not live in their desired type of neighbourhood (i.e., dissonant residents) – due to elements such as income or distance to work – can face difficulties in travelling with their preferred travel mode. A person who does not like to drive a car will often be forced to do so when living in a suburban neighbourhood, due to relatively long average distances and limited public transport services. A car-loving person living in an urban neighbourhood, on the other hand, might be forced to walk, cycle or use public transport due to congestion, parking problems or car-free pedestrian zones within urban areas. In both cases, the built environment can restrict the use of the preferred mode.

It might be possible, however, that not only attitudes affect (travel) behaviour, but that (travel) behaviour influences attitudes. According to some studies, such a two-way relationship between attitudes and behaviour exists (e.g., Dobson et al., 1978; Golob, 2001; Tardiff, 1977). They state that attitudes and behaviour are mutually dependent on each other: attitudes both affect – and are conditioned by – choices. It is therefore possible that mode choice affects travel-related attitudes. According to Reibstein et al. (1980) the frequency of bus use positively affects the attitude towards bus use. More recent studies found that a mode shift from car to public transport was accompanied by improved attitudes toward public transport (Abou-Zeid et al., 2012; Fujii et al., 2001; Fujii and Kitamura, 2003). It is also possible, however, that a cyclical process between travel-related attitudes and mode choice exists; a positive stance toward a certain mode can increase the use of that mode, while using that mode frequently might improve (or diminish) the attitude toward that mode (Bohte et al., 2009; Van Acker et al., 2011).

It might also be possible that the built environment has an effect on people's attitudes toward travel; changing land use characteristics might change mode-specific attitudes (e.g., Kitamura et al., 1997). Increasing diversity and providing wide, well-lit sidewalks, for instance, might improve people's attitude toward walking, as walking becomes more feasible and comfortable. However, due to a lack of longitudinal data, no travel behaviour study so far has actually captured these behavioural changes due to adaptation in the built environment (e.g., Bagley and Mokhtarian, 2002).

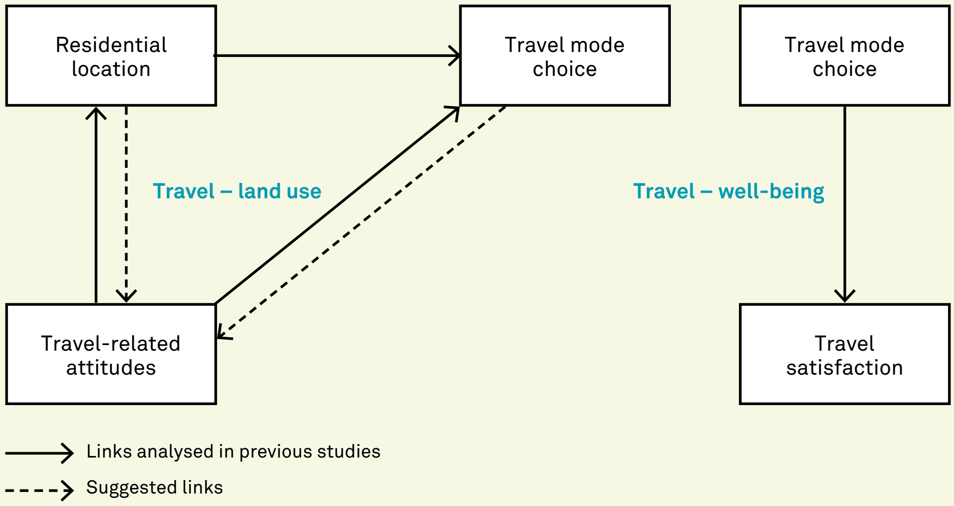
Travel, well-being and the built environment

As the residential location sets the parameters within which many travel choices (such as travel mode choice and destination choice) are made for a considerable period of time, it is important to consider the residential location within the link of travel and well-being. People who do not live in their desired type of neighbourhood, due to elements such as income and distance to work, might experience reduced travel satisfaction because the built environment restricts the use of their preferred travel mode and forces them to use an alternative mode. Dissonant residents who are able to travel with their preferred travel mode can also experience reduced travel satisfaction. A person who lives in an urban neighbourhood but with a preference for suburban living and car-based travel patterns may be pleased to be able to drive a car. Yet, this person may still experience low satisfaction with car trips, for instance because living in an urban setting means that he or she often experiences congestion and parking problems. It has to be noted, however, that residents may overstate the benefits of their current neighbourhood and downplay those of other neighbourhoods in order to support their residential location choice and reduce psychological stress (i.e., cognitive dissonance reduction (Festinger, 1957; Schwanen and Mokhtarian, 2007)). This could reduce the diminishing effect of residential dissonance on travel satisfaction. Since the residential location influences residents' travel behaviour for a considerable period of time, repeated positively or negatively experienced trips (resulting from a combination of people's travel-related attitudes and the residential location) can affect well-being both directly and indirectly, through long-term (dis) satisfaction with activities at the destination of the trip.

It might also be possible that travel-liking attitudes can affect the residential location choice and satisfaction with travel. It is, for instance, plausible that people who dislike travel (e.g., people who think travel time is wasted time) might prefer living in an urban neighbourhood where destinations are nearby, making it possible to limit travel (in distance and time). People with a more positive stance toward travelling, on the other hand, might not mind living in a suburban-style neighbourhood, where travel distances are larger. Hence, an alternative self-selection hypothesis might occur. Furthermore, travel-liking attitudes might also affect travel satisfaction. People with a more positive stance toward travelling in general will probably also perceive and evaluate their trips more positively. It can consequently be assumed that suburban residents will be more satisfied with their travel due to self-selection processes.

In sum, numerous studies over the past decades have indicated that both the residential location and travel-related attitudes affect travel mode choice. Furthermore, an influence of the residential location and travel mode choice on travel-related attitudes seems plausible, although this has not been analysed thoroughly. A limited amount of recent studies also indicated that travel mode choice affects travel satisfaction (Figure 23). In this paper we will show that travel satisfaction is not only affected by mode choice, but also by the residential location and travel-related attitudes, and consequently also by residential self-selection and residential dissonance. Furthermore, satisfaction with trips might also change attitudes toward the used mode and can therefore also affect future mode choices. As travel satisfaction is related with mode choice, residential location and attitudes, it is important to include travel satisfaction in travel behaviour-land use research.

FIGURE 23
Relationships between residential location, travel mode choice, travel-related attitudes and travel satisfaction



The effect of travel-related attitudes, the residential location and residential dissonance on people's travel satisfaction

De Vos et al. (2015a) and De Vos and Witlox (2015) – analysing leisure trips within the city of Ghent (Belgium) – indicate that both the built environment and travel-related attitudes affect travel behaviour. People living in suburban neighbourhoods make longer trips (in distance and time) and travel more by car compared to people living in urban neighbourhoods. Furthermore, mode-specific attitudes significantly affect mode choice, while travel-liking attitudes significantly affect travel distance and time. On average, a car-loving person travels more by car than a person preferring another mode of transport, while people with a positive stance toward travelling have longer average travel times and especially longer average travel distances compared to people who perceive travelling as a necessary evil.
A remarkable result from De Vos et al. (2015a) is that people living in urban neighbourhoods are less satisfied with their travel compared to people living in suburban neighbourhoods. Especially urban respondents with a preference for car use and a suburban style of living perceive their travel negatively, indicating that residential dissonance can negatively affect travel satisfaction. Congestion and parking problems in urban areas might force urban residents to use public transport or active travel, or when they are able to use the car, they experience their trip rather negatively. However, variances in travel satisfaction according to the residential location are to a large extent explained by age differences between urban and suburban respondents. As age has a strong positive effect on travel satisfaction (for all modes) and suburban residents within the city of Ghent are considerably older compared to urban respondents, this can partly explain travel satisfaction differences according to the residential location. An alternative explanation for the effect of residential location on travel satisfaction is that neighbourhood preferences are – besides non-travel related aspects – not only affected by attitudes towards various travel modes, but also by attitudes towards travelling in general. De Vos and

Witlox (2015) suggest that people with a negative stance toward travelling self-select themselves in urban areas, where potential destinations are nearby making it possible to limit (excess) travel. As travel liking has a significantly positive effect on travel satisfaction, urban residents have a lower travel satisfaction than suburban residents. Since travel satisfaction seems more affected by travel-liking attitudes than by the residential location, urban travel lovers have a higher travel satisfaction than suburban travel haters. This might be explained by the fact that suburban residents are often forced to travel relatively long distances due to a low density and diversity, while urban residents can choose to travel longer distances than necessary.

The mutual relationship between travel mode choice and travel satisfaction

Recent studies have shown that the selected travel mode has a clear effect on how people perceive and evaluate their trip. As satisfying experiences enhance the tendency to repeat the same course of action (e.g., Aarts et al., 1998; Kahneman and Krueger, 2006), it is reasonable to assume that people (will try to) choose a travel mode which gave them a high travel satisfaction in previous trips. Since attitudes are an important determinant of travel mode choice and since it is plausible that satisfaction with a trip can improve or diminish attitudes toward the used mode, attitudes might affect the link between mode choice and travel satisfaction. De Vos et al. (2015a) indicates that mode choice affects travel satisfaction. In line with other studies (e.g., Abou-Zeid, 2009; Duarte et al., 2010; Ettema et al., 2011; Friman et al., 2013; Olsson et al., 2013), active travel – walking in particular – results in the highest levels of travel satisfaction, while people using public transport are least satisfied with their trip. Furthermore, the evaluation of a trip is closely related to the attitudes toward the chosen mode, suggesting that a positive evaluation of a trip made with a certain mode will presumably increase the probability of that mode being chosen for the next trip. In order to explore this full cyclical process between mode choice and travel satisfaction in detail, De Vos et al. (2015c) employed a Structural Equation Model (SEM) for respondents walking and cycling to their most recent leisure activity. Results indicate that the evaluation of a trip positively affects the attitude toward that mode, which in turn has a significant influence on choosing that mode. Although the used data of this study are cross-sectional and cannot detect changes in attitudes over time, the model does suggest that positive reinforcement caused by a satisfactory trip can improve mode-specific attitudes and increase the tendency of people choosing the particular mode for a future trip of the same kind, possibly shaping habitual patterns. De Vos et al. (2015c) showed that travel mode choice is not only affected by elements such as the built environment and travel-related attitudes, but also by the evaluation of previous trips, which in turn indicates that travel satisfaction is not only an outcome of travel mode choice (and other travel characteristics) but that it is also a predictor of future travel mode choices. This last relationship has often been neglected in previous studies analysing travel satisfaction.

Conclusion

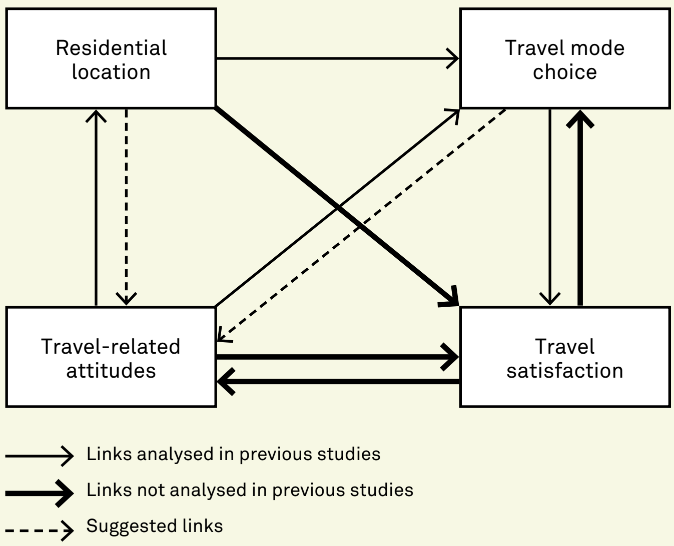
In sum, in this paper we have – based on the results of De Vos (2015a) – analysed the relationship between travel behaviour and well-being by focussing on the links between travel mode choice, travel satisfaction, the residential location (choice) and travel-related attitudes. Although some of these links have already – to a certain degree – been analysed in previous studies, other links remained unexplored (Figure 24). The link of the residential location on travel mode choice has been analysed thoroughly (see, among others, Badoe and Miller, 2000; Cervero and Kockelman, 1997; Ewing and Cervero, 2001, 2010), while the effect of travel mode choice on travel satisfaction has only recently found its entry in travel behaviour studies (Abou-Zeid, 2009; De Vos et al., 2015a, 2015b; Duarte et al., 2010; Ettema et al., 2011; Friman et al., 2013; Olsson et al., 2013). The influence of travel-related attitudes on travel mode choice (e.g., Anable, 2005; Kitamura et al., 1997; Van Acker et al., 2011) and on the residential location choice (e.g., Cao et al., 2009; De Vos et al., 2012; Handy et al., 2005; Kamruzzaman et al., 2013; Schwanen and Mokhtarian, 2005) has also been acknowledged frequently over the past years, often in the context of travel-related residential self-selection.

In this paper we further explored possible relationships between mode choice, travel satisfaction, the residential location and attitudes; relationships which have not – or only to a limited extent – been analysed in previous studies. De Vos et al. (2015a) and De Vos and Witlox (2015) indicate that travel-related attitudes (i.e., mode-specific attitudes, land-use preferences and travel-liking attitudes) have a significant effect on travel satisfaction. For instance, people with a preference for car use and a suburban neighbourhood to live in are more satisfied with a car trip compared to people with a preference for public transport, active travel and an urban type of residential neighbourhood. Furthermore, people who like to travel have a higher travel satisfaction compared to people who dislike travel. De Vos et al. (2015a) also examined the effect of the residential location (i.e., urban and suburban) on travel satisfaction. Results show that suburban respondents are more satisfied with their leisure trips compared to urban respondents, and this for all travel modes. These differences in travel satisfaction according to the residential location might be explained by self-selection processes. People disliking travel and consequently having a relatively low travel satisfaction might prefer to live in an urban neighbourhood where they can limit excess travel, while travel lovers with a higher travel satisfaction might not mind living in a suburban neighbourhood where travel time and especially travel distance are higher (De Vos and Witlox, 2015).

This paper also indicated that travel mode choice and travel satisfaction are related with each other (De Vos et al., 2015a, 2015b). In analogy with other studies, we found varying levels of travel satisfaction for different travel modes. Although most studies analysing this link assume that travel satisfaction is an outcome of the travel mode choice, we indicated that (based on cross-sectional data) trip satisfaction might affect future mode choices, through travel-related attitudes. A positive evaluation of a trip improves the attitude toward the used mode, which in turn increases the chance of choosing this mode for future trips of the same kind (De Vos et al., 2015c). This also suggests that travel satisfaction might influence the residential location choice, through travel-related attitudes. A person who frequently evaluates his or her walking trips positively, for instance, might create positive walking attitudes, which in turn might create preferences for living in an urban neighbourhood where frequent walking is easily feasible due to short distances. This is in line with Cao and Ettema (2014), stating that people move to residential locations allowing them to have 'happy travel'.

With this paper we have tried to improve our knowledge on the links between the residential location, travel mode choice, travel satisfaction and travel-related attitudes. Doing so, this might help policy makers to (i) make changes in people's travel mode choice in favour of non-motorised travel and consequently reduce the negative effects of car use (such as air pollution and congestion) and (ii) improve people's well-being by measures that can help to increase travellers' satisfaction during a trip.

FIGURE 24
Relationships between residential location, travel mode choice, travel-related attitudes and travel satisfaction analysed in this paper



Note: This paper is based on the following doctoral dissertation: De Vos, J., 2015. Travel satisfaction: Analysing the link between travel behaviour, residential location choice and well-being. Doctoral dissertation. Ghent University, Ghent, Belgium.

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SUSTAINABLE, ACTIVE TRANSPORT

Veerle van Holle
Lieze Mertens

A PUBLIC HEALTH PERSPECTIVE

Introduction

>> Engaging in sustainable transport (transport-related walking and cycling or 'active transport') for short trips offers a cheap and non-polluting alternative to the private car and may partly solve local traffic congestion problems [1]. However, active transport on a regular basis also has important health-related implications. In this chapter, active transport will be discussed from a Public Health perspective. First, health benefits of active transport will be discussed. Secondly, an overview will be provided on how Public Health researchers generally measure active transport, and next, the influencing factors of active transport will be presented, with a specific focus on the physical environment. In this latter part, a distinction will be made between so-called 'macro-environments' and 'micro-environments'. Results from Belgian research on the association between macro- and micro-environments, and active transport of four different population age subgroups will be provided. In conclusion of this chapter, limitations of the existing studies will be discussed, and opportunities for future research and collaboration will be outlined.

Active transport is a type of physical activity
Next to examining risk behaviours such as smoking or dietary habits, a substantial part of Public Health research focuses on the role of physical activity in the prevention of non-communicable diseases. Research has shown that regularly engaging in sufficient levels of physical activity decreases the risk of developing cardio-vascular diseases, type II diabetes, and some types of cancer (e.g., colon and breast cancer). In addition, physical activity lowers blood pressure levels, improves the lipoprotein profile and plays an important role in weight management [2]. Physical activity also has positive effects on well-being and mental health, for example by reducing anxiety and depressive symptoms [3].

To achieve such health benefits, a minimum threshold of physical activity of at least moderate intensity should be achieved. Moderate-intensity physical activity includes those activities that require a level of effort at which an individual should experience some increase in breathing or heart rate, but should still be able to have a conversation during the activity. Examples of such activities include walking and cycling. For adults (18-65y) and older adults (65y+), the Public Health Recommendations prescribe to accumulate a minimum of 30 daily minutes of moderate-intensity physical activity, preferably in bouts of at least 10 consecutive minutes, in order to reach long term health benefits [4]. For children (6-12y) and adolescents (12-18y), specific guidelines have been developed, which state that at least 60 minutes per day of moderate-intensity exercise should be accumulated [4].

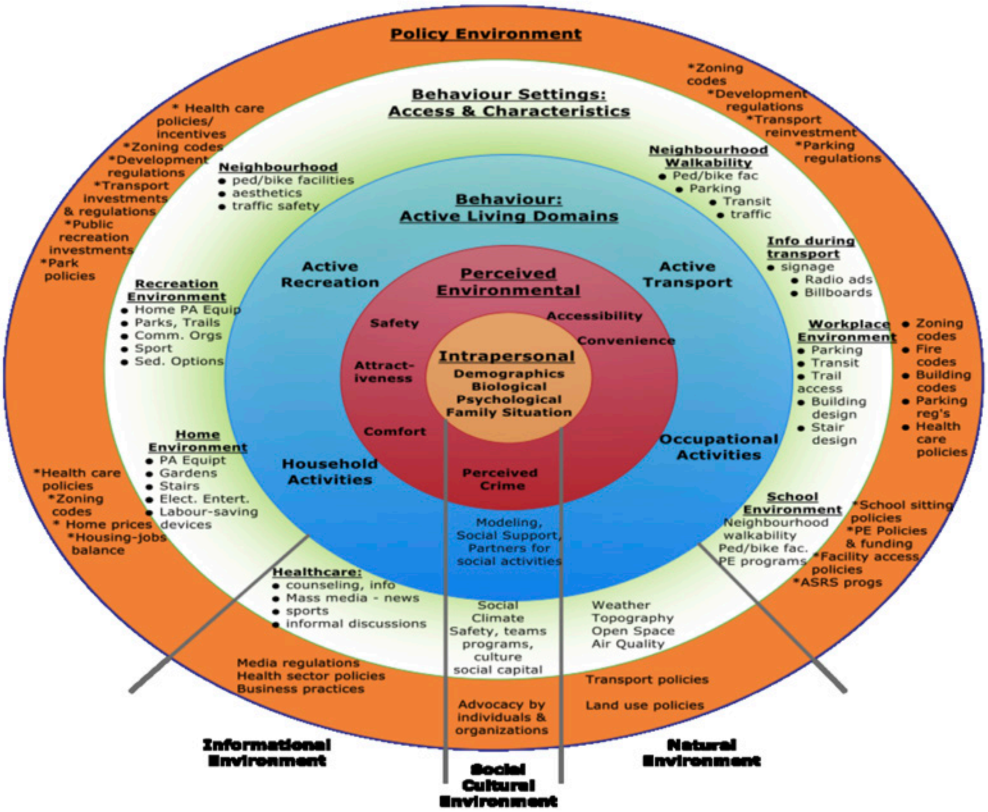
The importance of active transport for public health and mobility
Active transport is quite easy to integrate into the daily routine of all population age subgroups. For instance, children and adolescents can walk or cycle to and from school, adults may use active transport to go to the workplace, and older adults can walk or cycle to visit acquaintances or run for errands. In Belgium, people living in semi-urban (300-600 inhabitants/km²) or urban (≥600 inhabitants/km²) neighbourhoods [5] can relatively easily engage in active transport, because trip length is generally small. Moreover, also specifically for active transport, the Public Health literature has identified that this type of physical activity can significantly contribute to preventing several acute and chronic diseases in all age groups [6–9]. This makes active transport an ideal physical activity behavior to promote in different population subgroups living in Belgian cities and their suburbs. Increasing active transport levels may be beneficial for both mobility and health-related purposes and therefore, it has been incorporated in cross-national and local policies on mobility and health (WHO, 2000; Pucher and Buehler, 2012; United Nations Economic Commission for Europe, 2002; Vlaams Agentschap Zorg en Gezondheid, 2009). Hence, collaboration between both research domains is desirable [12, 13].

Measuring active transport in public health research
In Public Health research, active transport levels are mostly measured using questionnaires, which can be self-administered (paper and pencil, or online computerized versions) or interviewer-assisted (through telephone, or face-to-face). The most widely used questionnaire among adults and older adults is the International Physical Activity Questionnaire or IPAQ [14]. This document is available in a short and long format, of which the latter includes items on the frequency and duration people engage in active transport, with separate questions on walking and cycling. For Flemish children and adolescents, an adapted version of the IPAQ questionnaire is available [15, 16]. This questionnaire is called the Flemish Physical Activity Questionnaire (FPAQ) and is mostly filled out by the child/adolescent's parents, with the assistance of the child/adolescent itself. The FPAQ also distinguishes between active transport to and from school, and active transport during leisure time, for example cycling to a friend's house.
Despite the well-known benefits of active transport for health, air quality and mobility, a substantial proportion of children, adolescents, adults and older adults living in developed countries do not engage in sufficient levels of physical activity. Thus, interventions to promote physical activity need to be developed and are likely to be successful if they focus on active transport. To inform policy makers and researchers on how to stimulate active transport levels, it is necessary to have a comprehensive understanding of the factors influencing this behaviour among each of the four above-mentioned age groups.

Influencing factors of active transport
Before the year 2000, research on the influencing factors of physical activity (and thus, active transport) focused mainly on the contribution of personal and psychosocial factors (e.g., attitudes towards active transport; receiving social support

from others to engage in walking). However, despite that interventions targeting such factors have shown their effectiveness, they explained only a modest proportion (20-40 percent) of variance in the behaviour [17] and sustainment of the changes induced by such interventions was rather low [18]. Individual-oriented interventions are based upon theories that do not explicitly account for the broader community, organisational and policy influences [19]. Relapse into the initial, unhealthy behaviour might be due to other influential factors that did not change during the intervention, such as the environment in which people live.
On the other hand, interventions targeting aspects of the environment in which people live may affect whole communities and may therefore have better long-term effects. Hence, so-called 'social ecological models' for explaining physical activity have been of growing interest from the year 2000 onwards. These models posit that physical activity is influenced by multiple factors, which interact across different levels [20, 21]. Several ecological models have been developed, of which the model of Sallis et al. [20] is used very often in Public Health research on active transport (See Figure 1). The socio-ecological model of Sallis et al. [20] distinguishes between four domains or contexts of active living, namely the 'occupational' domain (work setting, school setting), the 'household' domain (household physical activities, gardening), the 'active recreation' domain (exercise, leisure walking and cycling), and the 'active transport' domain (walking and cycling for transport purposes). Of particular interest in these ecological models is the environmental level, including the physical environment. Davison and Lawson defined the physical environment as 'the objective and perceived characteristics of the physical context in which people spend their time (e.g., home, neighbourhood), including aspects of urban design, traffic density and

FIGURE 25
The ecological model for physical activity by Sallis et al. (2006)



speed, distance to and design of venues for physical activity (e.g., parks), crime and safety' [22]. As physical environmental attributes are changeable and such changes can influence health-related behaviours such as active transport, insight into physical environmental correlates of active transport is crucial when developing interventions to promote this type of physical activity.

Categorisation of physical environment characteristics

According to Swinburn et al. [23] environments can be categorised into two broad categories. A first category involves macro-environmental characteristics. For the physical environment, the macro-environment includes the more 'raw' urban planning features (e.g., street network density, residential density and land use diversity). A second category involves micro-environmental characteristics, which includes specific characteristics of environmental features within a streetscape (e.g., the evenness of the pavement, safety of bike paths).
Both categories will be discussed separately in this chapter, and their importance for explaining active transport in different age groups will be documented with findings from studies conducted in Flanders (Belgium).
The central research questions of these Belgian studies can be defined as follows:

- For the macro-environment, our research focuses on how transport-related activity-friendliness (or 'walkability') of people's residential neighbourhood environment relates to their participation in transport-related walking and cycling. Specifically, four large-scale studies with a similar research design were conducted in four different age groups: older adults (65y and older), adults (18-65y), adolescents (13-15y), and primary school children (9-12y). Differences and similarities between different age groups will be discussed in this chapter.
- For the micro-environment, our research examined how specific environmental characteristics (such as vegetation, upkeep, evenness of cycle paths) influence a street's appeal for transport walking or cycling using manipulated photographs. Specifically, three large-scale studies with similar research designs were conducted among older adults (65y and older), middle-aged adults (45-65y), and primary school children and their parents (9-12y).
- For both the macro- and micro-environment, we will outline limitations of current public health research and the opportunities for future studies.

The Macro Environment

Measuring urban form or the macro-environment: the 'walkability' index
A substantial part of trips start or end at the home residence (e.g., trips to school or the workplace, grocery shopping) and thus, active transport trips has a significant component within the residential neighbourhood. This implies that physical environmental characteristics of the residential neighbourhood may be of particular importance for predicting active transport levels in all age groups.

In the Public Health literature, a commonly studied aspect of the neighbourhood physical macro-environment is its activity-friendliness in terms of 'walkability'. The walkability concept reflects the physical environments' convenience for physical activity, primarily for transport walking [24]. Walkability is most often expressed as an index based on three key components; 'street connectivity', 'residential density', and 'land use mix diversity'. These walkability components can be assessed both objectively through Geographic Information Systems (GIS) and as self-report variables through questionnaires. Environments characterized by many interconnected streets, a high residential density and a mixture of different land uses (e.g., residential, commercial, institutional) are considered highly walkable. An in-depth description of the objective walkability calculation is provided in part 2.1.2 (BEPAS), when a large-scale study in Belgium is described.
The walkability index was developed by researchers and urban planners from the US [24], who studied the environmental characteristics that influence adults' physical activity as part of the Neighborhood Quality of Life Study (NQLS) from 2000 onwards [25]. Two years later, researchers from Australia conducted a similar study, called the PLACE study [26]and in 2007, the design of both studies was also used to develop the Belgian Environmental Physical Activity Study (BEPAS) [27]. These three studies had common study designs and data collection methods, and could therefore be compared internationally. Since there is great environmental variability between Australia, America and Western Europe, this also creates the opportunity to pool data from different countries and investigate the association between walkability and active transport in a broader context. The studies in the US, Australia and Belgium provided the basis for creating the International Physical activity and the Environment Network (IPEN) [28], founded by Prof. James Sallis from the US, Prof. Neville Owen from Australia and Prof. Ilse De Bourdeaudhuij from Belgium.

The Belgian Environmental Physical Activity Study in four different population subgroups

In Belgium, a large-scale study was initiated to investigate the relationship between the neighborhood in which people live and their physical activity levels. This study is called the Belgian Environmental Physical Activity study (BEPAS), and has been conducted in approximately 450 older adults, 1200 adults, 650 adolescents, and 600 children. BEPAS was conducted separately for each of these four age groups. Participants of these BEPAS sub studies were all recruited in Ghent, a medium-sized city (250,284 inhabitants; 157.96 km^2; 1,584 inhabitants/km^2) in Flanders (the Northern part of Belgium). For the BEPAS studies in older adults, adults and adolescents, participants were recruited through the municipalities and contacted directly in their own residential neighbourhoods. These neighbourhoods were selected from the 201 existing statistical sectors. Every statistical sector contains approximately 1000 inhabitants, and a neighbourhood comprised clusters from 1 to 5 adjacent sectors. For the BEPAS study in children, participants were recruited through schools, and parents provided the children's home addresses to derive information on the walkability of their residential neighbourhood.

To determine a neighbourhood-level walkability index, geographical data were obtained through the Service for Environmental Planning in Ghent. Cadastral data (residential land use, street centerline data, zoning data) and census data were integrated in a Geographic Information System database to create the walkability index for each statistical sector. *Residential density* per neighbourhood was calculated using the ratio of residential units to the land area devoted to residential use. *Street connectivity* was represented by the ratio of the number of true intersections (three or more streets) to the land area in each neighbourhood. *Land use mix* indicated the degree of diversity of land use types in each neighbourhood. Five land use types were considered: residential, retail (supermarkets, bakeries, butchers, banks, and clothing shops), office, institutional, and recreational (sport and non-sport). Subsequently, values were normalised and Z-scores were calculated. The *walkability index* was computed using an adjusted version of the formula of Lawrence D. Frank and colleagues [24]: *Walkability = (2∗ Z-connectivity) + (Z-residential density) + (Z-land use mix).* The original formula was developed in the US and included a fourth measure of *"floor retail area ratio"*. This measure is calculated by dividing the retail floor building area by the total retail land area. Because in the US, retail opportunities are mostly centralised into large shopping malls, the floor retail area measure was included in the US walkability formula because it reflects the pedestrian access to shops. However, Western-European countries such as Belgium are characterised by a more compact urban structure and most often, shops can be accessed walking or cycling. Therefore, floor retail area ratio is less relevant from a Belgian perspective and was omitted from the walkability calculations. Neighbourhoods included in the BEPAS studies were ranked based on the modified index. The top and bottom quartiles represented 'high-walkable' and 'low-walkable' neighbourhoods, respectively. Subsequent to classification of the neighbourhoods according to walkability, the neighborhoods were also matched on *neighborhood income levels*, derived from neighbourhood median income data (National Institute of Statistics – Belgium, 2008). This was done because neighbourhood socio-economic status (for which income levels are often used as proxy measures) can have a direct association with physical activity [29, 30]. Income data were categorised as 'high-income' and 'low-income.' The matching of the walkability and income neighbourhoods resulted in *four neighbourhood types*: high-walkable/low-income neighborhoods, high-walkable/high-income neighbourhoods, low-walkable/low-income neighborhoods and low-walkable/high-income neighbourhoods. For older adults, 20 neighbourhoods were selected to recruit participants. Adults and adolescents were recruited in 24 and 32 neighbourhoods, respectively. Within each neighborhood, it was aimed to recruit 30 to 50 participants.

In all BEPAS subgroups, *self-reported levels of active transport*, expressed in 'minutes per week' were assessed using questionnaires. Older adults and adults self-reported their active transport levels through IPAQ [31, 32] (walking/cycling for transport), whereas adolescents and children self-reported their active transportation levels through FPAQ [15, 16] (walking/cycling to and from school; walking/cycling for transport during leisure time). The BEPAS studies aimed to identify associations between the walkability of the residential neighborhood and active transport levels. Another goal of these studies was to investigate whether these associations were different in low- versus high-income neighbourhoods. Below, the BEPAS findings regarding walkability and the association with active transport are listed for each subgroup separately.

Older adults

Community-dwelling (i.e., non-institutionalized) older adults (65y and older) living in high-walkable neighbourhoods reported to walk more for transport than low-walkable neighbourhood residents of the same age group [33]. High-walkable neighbourhood residents reported about 60 additional minutes of walking for transport/week than their peers living in low-walkable neighbourhoods. These findings were observed for residents of both low- and high-income neighbourhoods. There were no differences in transport-related cycling levels between older adults living in high- versus low-walkable neighbourhoods. These findings imply that for community-dwelling older adults, accessibility of relevant destinations may contribute to enhancing active transport, but only to walking. Walking is the most common type of physical activity in this age group.

Adults

In adults (18-65y), BEPAS results showed that objectively-measured walkability was positively associated with active transport (walking and cycling) in both low- and high-income neighbourhoods [27]. Adults living in high-walkable neighborhoods reported approximately 80 additional weekly minutes of walking for transport than adults living in low-walkable neighbourhoods. A similar trend was observed for transport cycling levels, with adults living in high-walkable neighbourhoods reporting an average of 40 additional weekly minutes of transport cycling, compared to their peers living in low-walkable neighbourhoods. These findings suggest that proximity of destinations near the home residence play an important role for the active transport behavior of adults. Moreover, self-reported motorized transport time (also assessed through IPAQ) was analysed in BEPAS adults as well. The findings on motorized transport time showed that adults living in high-walkable neighbourhoods reported less motorised transport time than adults living in low-walkable neighbourhoods. This difference in motorised transport time was about 35 minutes per week.

Adolescents

BEPAS-Youth [34] was conducted in adolescents aged 13-15 years. Results from this study showed that walkability was not associated with the active transport levels of Belgian adolescents, neither active transport in leisure time, nor active transport to and from school. Apparently, youngsters are less likely to be influenced by the design of their residential neighbourhood environment when it comes to predicting their active transport behaviour. Because young adolescents are still considerably dependent on the decisions and rules made by their parents, it is likely that their active transport levels are predicted by home rules and/or parental habits, irrespective of the neighbourhood walkability.

Children

In children aged 9-12 years, a positive association was observed between higher walkability of the neighbourhood and more weekly minutes of transport walking during leisure time [35]. However, this was only observed in children that lived in low-income neighbourhoods. In high-income neighbourhoods, walkability was unrelated to children's transport walking during leisure time. Probably, people living in low-income neighbourhoods have less access to the private car because of lower household budgets. Hence, it is possible that children living in low-income neighbourhoods cannot be driven to certain places by their parents so often, and may engage in more transport walking to go from place to place. Regarding children's cycling for transport during leisure time, there was no association between neighbourhood walkability and this type of active transport. Moreover, the researchers found no association between walkability of the residential neighbourhood and active transport (walking, cycling) to and from school.

Similarities and differences between BEPAS findings: Implications and challenges

It is important to acknowledge the implications and challenges of the Belgian Environmental Physical Activity Study, conducted among different age groups living in the same neighbourhoods. Because neighborhood physical environmental interventions affect all inhabitants of a neighbourhood, making changes to the physical environment may have opposite or no effects on different population subgroups. Therefore, the challenge for urban planners, intervention developers and policy makers is to create active living neighbourhoods that are activity-friendly for as many people as possible.

Regarding *walking for transport*, the results suggest that neighbourhood walkability is most important in adults and older adults. For these two age groups, *proximity of destinations* (e.g., shops, local services, public transport stops) seems to be key for predicting transport walking levels. Because in children living in low-income neighbourhoods, better walkability was also related to transport walking in leisure time, proximity of destinations may be important for this population subgroup as well, but intervention developers should have a specific focus on low-income neighbourhoods. In contrast, walkability seems not important in explaining transport walking to school, neither in adolescents, nor in children.

Regarding neighbourhood walkability in relation to *cycling for transport*, results of BEPAS suggested that only in adults, those living in high-walkable neighbourhoods also reported more transport cycling. This suggests that adults aged 18-65y may be more likely to *actively commute* to work, or partially use active transport for transit purposes (e.g., cycling to the railway station). Results of BEPAS may imply that for active commuters, high walkability could be beneficial for mobility of adults. On the contrary, in the three other age groups, no associations between walkability and cycling for transport were observed. It could be that older adults', adolescents' and children's transport cycling is more dependent on other factors, irrespective of walkability. For instance, these population subgroups may have higher needs in terms of traffic safety.

In summary, on macro-environmental level, the BEPAS studies showed that walkability is important in explaining active transport of adults, transport walking in older adults, and transport walking during leisure time in children of low-income neighbourhoods. These results indicate that provision and accessibility of destinations seems to be key to predict the active transport behavior of these specific population subgroups. Besides, these above-mentioned positive associations between walkability and active transport were also observed in several international studies conducted in older adults [36-39], adults [24-26] and children [40], which suggests that the importance of walkability is similar across geographic regions.

However, despite the relevance of walkability for explaining active transport, overall findings from these BEPAS studies showed that the importance of neighbourhood walkability for active transport couldn't be generalized across all population subgroups that were studied. BEPAS findings imply that there is no univocal or 'one neighbourhood fits all' solution at macro-environment level for all types of active transport, especially not for transport cycling (all subgroups) and active transport to school (adolescents and children). As traffic safety issues might play an important role, a possible solution may be to create neighbourhoods with a low connectivity for motorised transport, but a high connectivity for walking and cycling. This could be achieved by providing a lot of sidewalks and cycle paths that are separated from or prohibited for motorised transport [41].

In addition, based on the BEPAS results, it may also be recommended that more research is conducted on the definition of urban form variables (including walkability) that are most influential on active transport. For instance, the lack of association between walkability and cycling for transport observed in older adults, adolescents and children may also be due to the fact that for these population subgroups, '*bikeability*' could differ from 'walkability', and these concepts may be sufficiently distinct to have unique associations with active transport levels [42]. To date, little research has specifically focused on the constitution of an internationally uniform 'bikeability' index, but it is highly recommended to assess its importance in predicting transport cycling in different age groups. Similarly, it could be that different definitions of walkability itself should be considered and that these concepts need to be defined separately for different population subgroups. As proposed by D'Haese et al. [35] it may be more appropriate to also assess the *'playability'* or *'moveabillity'* of the residential neighbourhood for the younger population subgroups (children, adolescents), and assess these new indices' link with active transport behavior in children and adolescents.

Along with the differential definitions, the Modifiable Areal Unit Problem (MAUP) may need to be taken into consideration. MAUP highlights that the observed results in a study depend on how an area of interest is defined geographically. In case of BEPAS, this may apply to the way in which neighbourhood walkability was calculated (i.e. based on predefined census blocks). MAUP implies that the walkability-active transport association may have been different if the 'neighbourhood' would have been defined in another way. Moreover, varying definitions of 'the neighbourhood' could apply to different population age groups because they have other activity radii: an

adolescent who is still able to ride a bike may be able to be active further away from the residential house than an older adult with a mobility impairment, who can only walk small distances. Hence, it might be suggested to create age- or even individual-specific definitions of 'the neighbourhood'. Global Positioning System (GPS) measures may be appropriate to use in future research on the transport behaviour of varying population age subgroups. If these measures are combined with activity registrations (e.g. accelerometry, smartwatches), and GIS-data on each specific GPS data point, a more individualized image of the walkability-transport association might be created. Also in the 'bikeability' and 'playability' case, it may be beneficial to reconsider the definition of a neighbourhood to examine environment-transport associations and to do this separately for different age groups.
In summary, there is still some future research needed to identify which urban form measures can be most useful to explain active transport, how to define them and how to link these measures with transport behaviours. However, it should also be noted that urban form research is already relatively extended and urban form is not the only physical environmental factor that plays a role in explaining why people use sustainable transport modes. With regard to the physical environment, micro-environmental characteristics, such as quality of the infrastructure, are equally important. The added value and importance of this micro-environment for active transport-related research will be discussed in the next part.

The Micro Environment

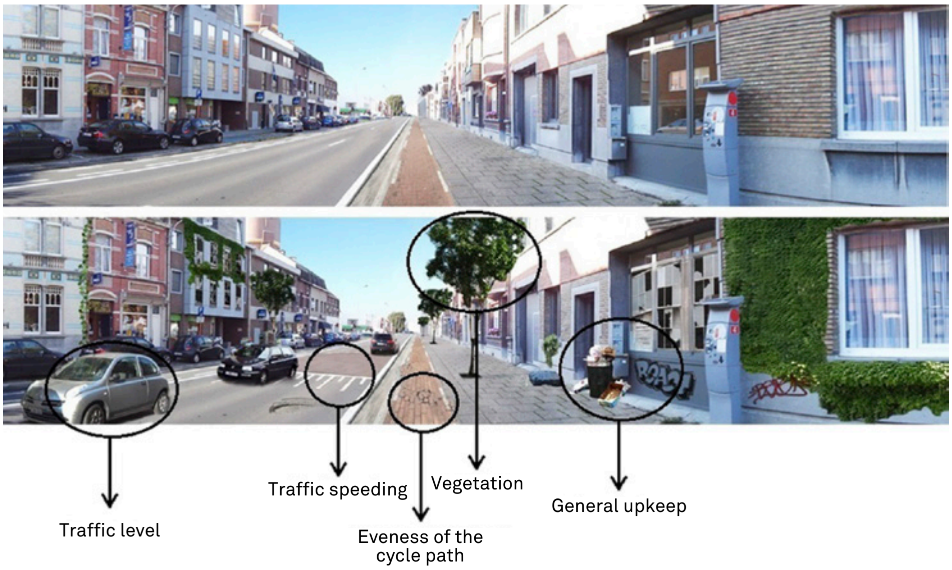
In the previous part of this chapter, the importance of the macro-environment in relationship with active transport was highlighted. However, these macro-environmental characteristics may sometimes be difficult to change in existing neighbourhoods, because this requires strong collaboration between authorities. Macro-environmental characteristics are essentially beyond the influence individuals and even for governments and nongovernmental organisations it is usually difficult to influence these characteristics because of their size and complexity [43]. This makes them less practical to target for environmental interventions in existing neighbourhoods. In contrast, micro-environmental characteristics (e.g. vegetation, upkeep, evenness of cycle paths or traffic related safety) are relatively small-scaled and potentially influenced by individuals or local actors [43], making them easier to change in existing neighbourhoods. Therefore, micro-environmental characteristics compared to the macro-environments are more practical and promising to target in environmental interventions in existing neighbourhoods.

Photograph experiments in three population subgroups: pilot studies and protocol

The Ghent University research group of Physical Activity and Health, and the research group of Health Promotion and Education study the micro-environment in relationship with active transport using experiments with manipulated photographs. These controlled experiments were gradually built up and were performed for different population subgroups, namely older adults (≥65 years), middle-aged adults (45-65 years) and children (10-12 years) with their parents. Because this is an innovative research line, a stepwise approach was used prior to conducting the controlled experiments with the manipulated photographs. Similar protocols were used among the different population subgroups, but these protocols will varied a bit depending on the outcome measure (i.e. transport walking or cycling) and hence, the content depicted in the photographs. Additional, not all research steps were implemented in each population subgroup. The following stepwise approach was applied:

- First, an exploratory phase was conducted in each population subgroup separately to increase the knowledge on environmental correlates of active transport. As existing literature showed that different environmental characteristics might relate to different physical activity contexts, it was decided to focus on different active transport behaviours, depending on the population subgroup. Since walking is popular activity that can be performed by almost all older adults [44-46], research in this age group focused on walking (rather than cycling) for transport. In contrast, research on adults and children together with their parents focussed on transport cycling because this behaviour is more prevalent in this age group [47]. In this research step, a literature research was conducted to describe which environmental characteristics could be identified as correlates of adults' (aged 18-65 years) physical activity in existing research [48]. In addition, qualitative walk- [49] and cycle-along [50] studies were performed to elicit rich information on micro-environmental characteristics that were perceived to influence walking or cycling behavior by doing walk- or cycle- along interviews.
- The second preparatory research step was a 'cross-sectional' study aimed to identify the key environmental characteristics using non-manipulated panoramic photographs. This research step was conducted among older adults for transport walking [51] and among adults for transport cycling [52]. During a home visit, participants had to rate photographed streets one by one on how invited they found those streets to walk/cycle along for transport. They did this by awarding a score to the photographs, ranging from zero (not inviting at all) to ten (very inviting).
- In a third step, two similar experimental photograph manipulation pilot studies were conducted, one in older adults [53] and one in middle-aged adults [54], respectively showing a walking and a cycling environment. For each study, one standardised panoramic photograph street (i.e. depicting a streetscape during daytime, under dry weather conditions) was manipulated on different micro-environmental characteristics using Adobe Photoshop. A selection of key environmental characteristics was manipulated in those photographs and was depicted in two categories, the presence of absence of the positive environmental characteristic (e.g. evenness of the sidewalk was depicted as either 'an even sidewalk' or 'an uneven sidewalk'). Figure 26 gives an example of two manipulated photographs used in the pilot study for transport cycling among middle-aged adults, with five environmental factors manipulated (i.e. traffic level, traffic calming, evenness of the cycle path, general upkeep and vegetation). Each developed panoramic photograph differed from the others in at least one environmental manipulation. During a

FIGURE 26
Examples of manipulated photographs used in the pilot study for transport cycling among middle-aged adults with 5 environmental factors manipulated.



home visit, participants had to sort these photographs on their appeal for walking or cycling for transport on a Likert-scale ranging from not inviting at all (zero) to very inviting (six for older adults or ten for adults). In the meantime, participants reported qualitative information on the reasons why they had sorted the pictures in that way.

The overall aim of these pilot studies was to examine the effect of manipulating photographs of micro-environmental characteristics on (older) adults' perceptions of the environmental invitingness for transport walking/cycling.

In conclusion, these studies contributed to the research on which physical environmental changes would be beneficial to increase the overall PA levels of adults and older adults. However, these pilot studies have two important limitations. First, only a limited number of micro-environmental characteristics could be included due to the chosen methodology (sorting task). Secondly, only one street setting or macro-environment was used in this study, a typical street environment in a semi-urban (300-600 inhabitants/km^2) Belgian municipality [5]. To develop interventions, it is essential to include all potentially relevant micro-environmental characteristics and to determine whether these findings can be generalised to other street settings or macro-environments (e.g. an environment with low building density and single land use compared to an environment with high building density and mixed land use). Before conducting the photograph experiments and manipulating all possible micro-environmental characteristics in the photographs, it was considered useful to know whether one or more street settings or macro-environments should be used in the photograph experiments. For practical implications, it is essential to know if one intervention could be implemented in different macro-environments. If micro- and macro- environmental characteristics are interacting, interventions focusing on micro-environmental characteristics may have to differ depending on the macro-environment. This methodological intermediate step was not implemented in each population subgroup, but only among adults and among children with their parents. Results from this study showed that in each macro-environment, similar micro-environmental characteristics are important, which is promising for interventions. Additionally, these results tells us that it is not necessary to include multiple macro-environments in our photographs experiments. From these previous preliminary research steps, there was a need to carry out a large-scale study in which the effects of all relevant micro-environmental characteristics were studied. These relevant micro-environmental characteristics were carefully selected based on the results of previous research steps. Next, for each remaining factor different gradations (levels) were created through photograph manipulations. Findings obtained from these controlled experiments can provide guidelines for interventions that use micro-environmental modifications to create more supportive environments for transport walking or cycling. These final photograph experiments were described below, for each subgroup population separately.

For older adolescents (17-18 years) and young adults (18-25 years), a different approach was applied instead of the photograph experiments, since the physical environment appeared to be less important in these subgroup populations. Previous research suggested that compared to adults, physical environmental factors are less consistently related to physical activity of adolescents (De Meester et al., 2012). Other determinants such as high autonomy, short travel time, low financial costs and good social support seem to be more important. So, other approaches instead of modifying the physical environment are required in these subgroups to promote active transport.
Below, the findings regarding the relationship between micro-environmental characteristics and active transport are listed for each population subgroup separately (i.e. older adults, middle-aged adults, children with their parents).

Outcomes of the photograph experiments

Older adults

The last study performed on the micro-environmental characteristics among older adults was a large-scale conjoint study using manipulated photographs. In total, data from 1131 Flemish older adults were collected through (1) an online questionnaire or (2) an interview version of the questionnaire. The questionnaire included a choice-based conjoint exercise with manipulated photographs of a street. The panoramic photographs were all modified versions of one 'basic' panoramic photograph and were manipulated on nine different micro-environmental characteristics (sidewalk evenness, separation from traffic, obstacle on sidewalk, traffic volume, speed limit, traffic calming device, overall upkeep, benches and vegetation) using Adobe Photoshop® software. The manipulated environmental characteristics had two (e.g. absence vs. presence of a bench) or three levels (e.g. very uneven, slightly uneven and even sidewalk). The selection of these environmental characteristics was based on previous research (described above) investigating the environmental

FIGURE 27

An example of a randomly assigned choice task used in the questionnaire among older adults.

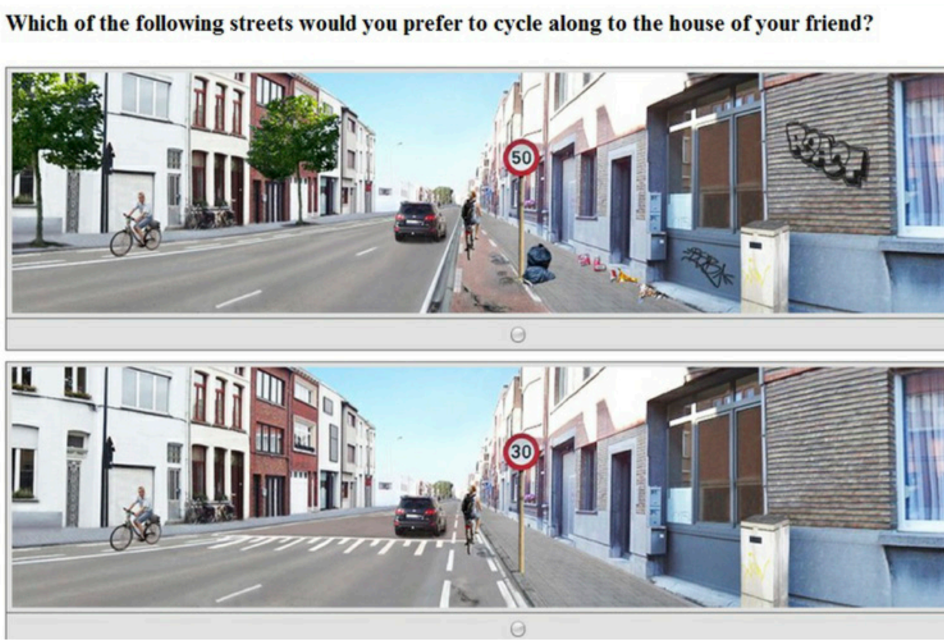
characteristics affecting older adults' walking for transport behavior [49, 51, 53] During the choice task, participants chose which of two presented streets they would prefer to walk for transport. Figure 27 shows an example of such a choice task.

Results from this study indicated that sidewalk evenness was by far the most important characteristic affecting the street's appeal for transport walking among older adults. The other micro-environmental characteristics had limited importance compared to sidewalk evenness.
In this sample, four subgroups that differed in their environmental preferences for transport walking were identified. In the two largest subgroups (representing 86% of the sample) sidewalk evenness was the most important environmental attribute. Moreover, for the vast majority of our sample, participants reported their sidewalk to be very or slightly uneven. In a smaller subgroup (7% of the sample) traffic volume and speed limit were the most important environmental attributes. In the last subgroup (7% of the sample) presence of vegetation and a bench were the most important environmental attributes. This latter subgroup included a higher percentage of service flat residents than the other subgroups. The results suggest that the provision of even sidewalks should be considered a priority when developing environmental interventions aiming to stimulate older adults' transport walking.

Middle-aged adults (45-65 years)
The final research step among adults was a large-scale conjoint study including all possible micro-environmental characteristics in the manipulated photographs [55]. The main aim of current study was to determine the relative importance of micro-environmental characteristics for a street's appeal for transport cycling

FIGURE 28

An example of a randomly assigned choice task used in the questionnaire among adults.



among middle-aged adult's (45-65 years), resulting in an order of importance of all micro-environmental characteristics. Second, interaction effects among micro-environmental characteristics on the street's appeal for transport cycling will be determined to investigate the effect of combinations between micro-environmental characteristics. In total, 1950 participants completed a web-based questionnaire and completed a series of choice tasks with manipulated photographs. The same protocol was used as with older adults, only the used manipulated photographs differed because of the different outcome, cycling for transport. The manipulated photographs originated from one panoramic photograph of an existing street that was manipulated on seven micro-environmental characteristics (type of cycle path, speed limit, speed bump, vegetation, evenness of the cycle path, maintenance and traffic volume) and consisted of at least two possible levels. Figure 28 shows an example of a choice task used in current study.

Results from this study indicated that providing streets with a cycle path seems to be the best strategy to increase the appeal of the environment for adults' transport cycling. A cycle path marked by white lines can already contribute to this, but a separation between cycle path and motorised traffic by means of a curb, or even better a hedge appears to be the most preferred type of cycle path. An additional separation with the walking path by color was even more preferred. In situations where it is not possible to provide a cycle path in the street, adjusting the speed limit from 50 km/h to 30 km/h appeared to be the most important characteristic to increase the appeal of the environment for transport cycling. Furthermore, when a better cycle path was provided, the relative importance of 'evenness of the cycle path' increased, except for situations where cycle paths were equipped with a hedge as separation. Moreover, when the most preferred cycle path is present (separated from traffic with a hedge and separated from walking path by color), the relative importance of the environmental characteristics became more similar; making it less relevant which micro-environmental characteristics should be given priority to adapt in this situation.

Children

The second study conducted in children and their parents was the large-scale conjoint study using manipulated photographs including all possible micro-environmental characteristics. This current study experimentally investigated the relative importance of micro-environmental characteristics for children's transport cycling. In total, 1232 children and their parents were recruited via 45 randomly selected schools across Flanders (Belgium). The same protocol and photographs as with the adult population were used (see figure 4). The only difference was that both the children and their parents had to fill in the online questionnaire with the choice-based conjoint (CBC) task, making it possible to create child-parents pairs. During this task, children had to choose for themselves between two possible routes (photographs) and parents has to indicate which route they preferred to (let their child) cycle along. Results for this subgroup indicated that type of cycle path was the most important characteristic among both children and their parents, followed by traffic density, maintenance and evenness of the cycle path among children. Among parents, second most important characteristics were speed limits and maintenance, followed by evenness of cycle path and traffic density. Findings indicated that improvements in micro-environmental characteristics might be effective to increase children's transport cycling, since they increase the supportiveness of the physical environment for transport cycling. Investments in creating a clearly designated space for the young cyclist, separated from motorised traffic, appears to be most effective to increase the supportiveness.

Similarities and differences between the photograph experiments

Findings from the final experiments could provide advice to local or regional authorities for the development and monitoring of urban mobility policies and could inform which specific environmental characteristics should be given priority to change in different environmental situations.

As with walkability, it is difficult to establish one general 'solution' for all different population subgroups. Nevertheless, traffic safety micro-environmental characteristics appear to be very important for all ages to encourage active transport. Overall, findings from the large-scale conjoint study conducted as the final step of the photograph experiments showed that providing streets with a cycle path seems to be the best strategy to increase the appeal of the environment for children and adults' transport cycling. Investments in creating a *clearly designated space for cyclists* appears to be most effective to increase the supportiveness; a cycle path marked by white lines can already contribute to this, but a separation between cycle path and motorised traffic by means of a curb, or even better a hedge appears to be the most preferred type of cycle path. An additional separation with the walking path by color could benefit even more. For encouraging transport walking among older adults, results suggest that the provision of *even sidewalks* should be considered a priority. From a previous study we know that our findings are not only valid for the street context depicted in the photographs of the current study, but also for other street contexts [56, 57]. Future research should confirm our laboratory findings with experimental on-site research in order to see if our results can be translated to real environments and actual transport behaviour.

Older adolescents and young adults

For older adolescents (17-18 years) and young adults (18-25 years), the physical environment appeared to be less important in directly explaining active transport, compared to other determinants such as high autonomy, short travel time, low financial costs and good social support. In these population subgroups, other approaches instead of modifying the physical environment to promote active transport are required. Encouraging sustainable travel behaviour in this age group is important because this transport choice might persist into adulthood. Since this is an often neglected age group, knowledge about determinants affecting the transport behaviour is needed.

Therefore, a first study conducted in this subgroup was a qualitative study using focus groups to explore which characteristics influence transport choice for short distance travel to various destinations [58]. Separate focus groups were conducted: five with older adolescents, three with students and three with working young adults (five to seven participants/group). The focus group followed a semi-structured discussion guide and aimed to uncover facilitators and barriers of all types of transport. Content analysis was performed using NVivo 9 software (QSR International). Using grounded theory, the results could be categorised in three main themes with several sub-categories: personal characteristics (high autonomy, low costs and health), social characteristics (good social support) and physical environmental characteristics (short travel time, good access to transport modes and to facilities, good weather, an adapted physical environment, perceived safety and ecology). Results from this qualitative study indicated that autonomy, travel time, financial cost and vehicle ownership were very important characteristics for choosing between different transport modes when travelling short distances to various destinations. Furthermore, characteristics such as safety, ecology and health seemed not to have a big influence on their transport mode choice.

Differences in preferences between students and working young adults was mainly based on income and living situation. When promoting active transport in older adolescents or young adults, characteristics as cycling instead of walking, flexibility, speed, good social support, low costs, more bicycle storage and workplace facilities has to be emphasized instead of health or ecological benefits. Interventions should not encourage young adults to own a private car, but has to optimise the public transport system to fit their needs. Results from this qualitative study gives a first indication that compared to the other subgroups, the physical environment appeared to be less important. Future quantitative research in a larger sample is warranted to explore these determinants more.

Therefore, a second quantitative study was conducted in this age group aimed to examine potential differences in walking, cycling, car use and public transport use between older adolescents, college/university students (18-25 years) and working young adults (18-25 years) [59]. In total, 562 older adolescents (17-18 years) and 1307 young adults (18-25 years) completed a web-based questionnaire assessing socio-demographic variables, commuting (to work or school) and transport to other destinations. Results from this quantitative cross-sectional study indicated that older adolescents were most likely to cycle, college/university students were most likely to walk and use public transport and working young adults were most likely to drive by car. Furthermore, for the entire group, men were more likely to cycle than women and women were more likely to commute by car to work/school than men. Additionally, female older adolescents were also more likely to drive by car to other destinations. These results indicated the at risk group of female emerging adults and the importance to maintain the habit of cycling after reaching the age at which it is possible to obtain a driver's license. Furthermore, as this is often a neglected subgroup, more research on the transport behaviour of this subgroup is needed. When travelling longer distances, the combined use of active and public transport might help to decrease car use.

Conclusions

In summary, this chapter aimed to provide an overview on existing Belgian active transport studies within a Public Health research framework. These Belgian macro- and micro-level studies on the role of the physical environment to explain active transport showed that it is important to look at different population subgroups and take into account different needs of each of these groups.
Similarities across macro-environment studies suggested that active transport (mostly walking) in older adults, adults and some children (i.e., those residing in low-income neighbourhoods) may be predicted by the presence and accessibility of relevant destinations. However, we also concluded that it might be useful to refine the measurement methods to assess urban form measures such as walkability. In fact, walkability, playability and bikeability may have to be reconsidered as distinct concepts.
Similarities across micro-environment studies suggested that micro-environmental characteristics concerning traffic safety appear to be very important for all ages to encourage active transport. Investments in creating a clearly designated and separated space for cyclists appeared to be most effective to increase the supportiveness among children and adults. In addition, investments in sidewalk quality were found to be most effective to encourage transport walking among older adults. These findings may have important policy implications as they suggest that safety measures may be more effective to promote active transport than measures to improve the aesthetic appeal of a street. These results are in contrast with the idea of creating 'shared space streets', in which much of the infrastructure (road markings, traffic signs, separations between vehicles and vulnerable road users) is removed and may

automatically imply that all road users, including drivers, are more attentive and consequently, this would result into lower traffic speeding [39]. However, in a study on pedestrians' and drivers' perceptions of shared spaces, Kaparias et al. [58] observed that pedestrians prefer conditions that ensure their presence is clear to the other road users. The authors described these conditions as 'low vehicular traffic, high pedestrian traffic, good lighting and pedestrian-only facilities'. Similar results were demonstrated in the photograph experiments. Further research regarding the concept of 'shared space streets' is definitely needed here. For older adolescents or young adults, our research gives a first indication that the physical environment appeared to be less important compared to the other subgroups. Their transport choice is generally determined by the quickest and easiest option.

Results of the present research in the Public Health domain have proven that physical environment innovations could be an interesting intervention strategy to increase physical activity of the population, because large populations may be influenced and environmental changes possibly have long-lasting effects. However, we would like to highlight the importance of developing multidisciplinary interventions. The physical environment, together with social and individual attributes, can explain socio-ecological models state active transport. Therefore, the best-sustained results can be obtained by combining psychosocial programs (short-term effects) with physical environment interventions (long-term effects in large populations).
A possible 'limitation' of present research is that the importance of the physical environment regarding mobility is mostly approached from a pedestrian or cyclist point of view (i.e. active transport). However, urban planners and designers also need to get insight into how motorised vehicle drivers respond to the physical environment. Therefore, it is recommended that the gap between different road users needs to be bridged, and both behaviour of vulnerable road users and motorised vehicle drivers are taken into account when urban spaces are (re)designed.
A second limitation of the presented research is that the assessment of active transport behaviour (predominantly using questionnaires and travel diaries), may need improvement. For instance, objective assessment of active transport trips may provide new insights in the purpose and specific geographic location of active transport trips. A possible way to do this is adopting crowd data approaches to identify which destinations are so-called 'hot spots' that can be reached by means of active transport. Researchers are optimising crowd based data collection using Bluetooth scanners [60], or devices providing location data (e.g. GPS) [61–63]. Also some recently developed smartphone applications [64] could be useful to identify trip purpose and hot spots. Using this information, local urban planners can be informed about specific characteristics on walkability and destination type. In addition, it might be useful to investigate possible avoidance behaviour based on these crowd based technologies (e.g., avoidance of busy roads by children and older adults). Consequently, environmental characteristics of 'not spots' may be identified and improving these environments' activity-friendliness could be targeted. Although crowd-based technologies often map anonymous trips [60], they may be able to improve measurements of the active transport behaviour itself by adding

important objective information to the generally used active transport data obtained through individuals' self-reports. As opposed to self-report data that rely on retrospective (recall) information on active transport, such crowd-based techniques can accurately track the actual trip and are able to determine transport mode in real time. Large-scale studies using these crowd-based techniques may shed new light on non-self-reported travel behavior in different population subgroups.

Thirdly, residential self-selection may play a role in how the built environment is associated with transport behaviors. Namely, do individuals choose to live in an environment because of its activity-friendliness (self-selected), or are they active because they live in an activity-friendly environment, which invites them to engage in active transportation (actual 'effect' of the physical environment)? Although several studies observed that self-selection mostly did not alter the association between the environment and physical activity, some studies observed an attenuation of such associations (McCormack & Shiell, 2011). This calls for future studies to examine self-selection, before developing environmental interventions. Special attention might be paid to the self-selection issue in the older adults population age subgroup, where little research on this topic has been conducted.

Fourthly, there are endless possibilities for selecting and manipulating micro-environmental factors in the photograph experiments. For example, it is possible to look at very detailed environmental factors or to change the gradation of the factors by adding more levels. However, from a practical point of view, manipulating one level or one more factor will double the number of photographs. Therefore, based on the outcomes of our previous research steps, we made a selection of the micro-environmental factors that appeared to have the strongest association with the street's appeal for walking/cycling for transport. Nevertheless, the photograph experiments can be strongly extended or varied.

Lastly, an important next step in physical environment research would be to conduct natural experiments, whereby strong collaboration with local governments and urban planners is necessary. Environmental interventions in real life settings are necessary to find out whether changing the physical environment will affect actual transport behaviour. Currently, more and more policy and environmental changes are happening, but they are not evaluated, so we don't know which strategies work effectively.

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>> Technology and individual travel

QUEUEING MODELS FOR THE PERFORMANCE EVALUATION OF SHARED-MOBILITY SYSTEMS

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Introduction

>> One of the major applications of queueing theory over the past decades is undoubtedly the performance evaluation of communication systems, where information needs to be carried from a given source to a given destination. In particular, an important boost to queueing-theoretic research was given by the advent of digital telecommunication networks, where information is transported in the form of digital packets. Network congestion may lead to long delays and loss of information packets, and has a negative impact on the quality of service and the quality of experience of the network' users. The performance prediction of communication systems and networks can therefore assist the optimal system design in order to meet given user requirements. We refer to [9] for a recent survey on suitable related models.

Queueing theory (or more general probability theory and stochastic modeling) has also been used intensively to aid in several subdomains of mobility and road traffic management and operations. Queueing-theoretic results are, for instance, essential in estimating the effect of infrastructural modifications (e.g. the presence of turn lanes, the location and operation of traffic lights, etc.) on traffic congestion. A popular research topic in this respect is the estimation of traffic congestion for vehicles at road intersections. In [6, 7, 16] queueing phenomena at unsignalized intersections are investigated, while the focus is on intersections with signalization in [10, 29]. In [8], a queueing model is proposed to examine blocking by vehicles having different destinations. Not only the impact of intersections is modeled and analyzed by means of queueing theory. Queueing-theoretic formulas are also used to explain characteristics of uninterrupted traffic flows, see e.g. [31]. This is done by assuming that a road can be split up in different sections, which make up the queueing places in a queueing system. A related model is the ASEP (the Asymmetric Simple Exclusion Process), see [2, 11], where each item (vehicle) can jump one position (section of the road) further if that position is empty. In this paper, we review queueing models for another application in mobility, namely models for the performance analysis and optimization of shared-mobility systems, such as bike-sharing or (electric-) car-sharing systems.

Shared vehicles are deemed to be the future replacement of vehicles as ownership. The obvious advantage is the 'multiplexing gain', i.e., the fact that one vehicle can be used by different persons at different times, therefore needing less vehicles. For instance in [17], it is reported that the fraction of time that cars in the USA were parked, and therefore not used, was about 90% in 2001. Therefore less cars and parking spots are necessary under the shared-vehicle paradigm, which in turn has a positive ecological impact and makes cities more livable. Multiplexing gain is also obtained for bike-sharing systems, where the usage rates vary globally from around three to eight trips per bicycle per day, see e.g. [13]. However, flexibility of private ownership of vehicles should be approached as much as possible in order to increase the popularity of shared-vehicle systems. The important advantage of private vehicles is that they are available whenever needed. This lack of flexibility has always been the Achilles' heel of shared mobility until now. Intelligent Transport Systems (ITS) however could be the important catalyst that is required. By means of ITS, users can be given information on (future) availability of vehicles as well as parking spots, or can make reservations (for instance if one needs a shared vehicle after using public transport). This information can also be used to distribute or relocate vehicles when needed, either by staff members or by users by means of pricing incentives.

In queueing models for shared-mobility systems parked vehicles are modeled as customers in a queueing system, where returners and renters of vehicles correspond to arrivals and departures (of vehicles) in the queueing system. Multiple stations can, in turn, be modeled as a queueing network. The analysis of such queueing models is useful to study the performance of shared-mobility systems, for instance in terms of the expected availability of a vehicle and/or a parking spot. As such, the impact of fleet size, number of stations, number of users, relocation strategies, reservation protocols, etc. can be researched in a generic way. Based on this, a clear view can be obtained on the tradeoff between the quality of service offered to the users and the cost of maintaining the system and operational choices can be made. Additionally, by comparing queueing models emerging from different paradigms, strategic decisions benefit as well. An important strategic decision to make is for instance to opt either for one-way vehicle sharing or for round-trip vehicle sharing. These lead to distinct queueing models and different operational choices.

In this paper, we focus in detail on queueing models that can be developed for different shared-mobility systems. Therefore, in Section 2, we first review some different forms of shared-mobility systems, each with their typical performance issues. Section 3 then discusses a number of queueing models for single shared-vehicle stations, with a distinction between studies for one-way sharing and round-trip sharing. Due to the restriction to a single station, such models are often more amenable to mathematical analysis. An overview of related performance results from literature is also given there and it is indicated how these results can assist system operators in making well-grounded decisions. For instance, the analysis of a suitable queueing model for a round-trip sharing system can help operators to determine their required vehicle fleet size in such a way that a good compromise is reached between the vehicle utilization ratio and the level of user satisfaction (due to vehicle availability). Next, in Section 4, the focus is on queueing models for networks consisting of several vehicle-sharing stations. It is shown there that under some restrictions so-called closed queueing networks allow to address the fleet-sizing problem of rental companies and to evaluate the impact of parking reservations or vehicle redistributions. Finally, some concluding remarks and an outlook on future research are given in Section 5.

Different forms of shared-use mobility systems

Vehicle-sharing systems such as bicycle-sharing or car-sharing allow persons to rent a vehicle at one of several rental stations, use the vehicle for some amount of time, and then return it. Recent literature surveys on bike-sharing and car-sharing programs are given in [13] and [17] respectively. Shared-use mobility systems have many advantages. For instance, bike-sharing systems offer an environmentally sustainable alternative to the use of cars for short-distance transportation inside a city. The existence of bike-sharing or car-sharing systems is also favorable for the use of public transportation services as trains or public busses in two ways. First, users can combine public transport with vehicle sharing (especially bike sharing) in a multimodal way in order to realize a more flexible first or last stretch.
Secondly, car-sharing systems can act as occasional alternative for public transport (for instance, for recreational purposes in the weekend). The performance, and consequently also the popularity, of a vehicle-sharing system largely depends on the extent at which the system is able to cope with the fluctuating demands for vehicles and parking spaces at vehicle rental stations. The user satisfaction or quality of service of a vehicle-sharing system is indeed determined by the availability of vehicles at the origin and the availability of parking spaces at the destination.

Several types of vehicle-sharing systems exist, with different operation modes, each with their particular issues. A first distinction is made between felexible one-way and more restricted round-trip (two-way) vehicle sharing, see e.g. [3, 20]. In case of two-way vehicle sharing, users are required to return a vehicle to the original pick-up station. As a consequence, the rental and return flows of vehicles are more or less balanced over the course of a day and the main challenge is therefore to handle temporal imbalances in renting and return rates. Depending on the location of a sharing station, the station may indeed be more popular for vehicle renting in the morning, when many persons use a vehicle to go to work, or in the afternoon, when vehicles are mostly used to go home. On the contrary, in case of one-way vehicle sharing, users may decide to return a vehicle to a different station. A one-way sharing approach is widely used for bike-sharing systems, and still less frequently for car-sharing systems. In case of one-way sharing, there may not only be temporal imbalances, but also persistent imbalances over the course of a day. For instance, bike-sharing stations at the top of a hill will typically have higher renting rates than return rates. In order to obtain a satisfactory quality of service, the fleet size (total number of vehicles) of a vehicle-sharing system needs to be dimensioned adequately, in order to keep the fraction of blocked users at an acceptable level. Due to the inherent demand imbalances, an optimal dimensioning of the fleet size alone will however often not be sufficient. In addition, repositioning of vehicles between stations is needed. Several vehicle-repositioning strategies are possible. In case of static repositioning, see e.g. [23], vehicles are relocated only during periods of low usage, e.g. during the night; static repositioning mainly handles persistent imbalances. On the contrary, dynamic repositioning takes place during the day, in order to deal with temporal imbalances, see e.g. [21]. In case of bike-sharing the static or dynamic

repositioning could be done by means of trucks that transport bikes between stations. In case of car-sharing, on the contrary, a group of operators typically drive cars from one station to another. The relocation could also be user-based in this case, where users with the same origin and destination are asked to either share the ride in case of a shortage of vehicles at the origin station, or to use different vehicles in case of a shortage of vehicles at the destination station, see e.g. [5].
The tradeoff between the cost for vehicle repositioning and the increased user satisfaction needs to be carefully studied. Another interesting option is the use of incentive-based repositioning, where users can be given a financial incentive to switch to a different sharing station when needed, see e.g. [14,21]. For instance, in case of a looming shortage for bike lockers at a bike-sharing station, users could be offered a price incentive to return their bike to a nearby station where more free lockers are available. An important research topic here is the design of adequate pricing schemes for vehicle-sharing systems. A final approach to deal with fluctuating demands is the use of prior vehicle booking or, in case of one-way vehicle sharing, parking space reservation. In general, reservations allow to reduce demand uncertainty. A parking reservation policy could e.g. be such that upon renting a vehicle, a user has to declare the destination station and a parking space is reserved immediately at the destination; if no parking space is available for reservation, the vehicle cannot be rented, see e.g. [18].

Models for single vehicle-sharing stations

Looking at a vehicle-sharing station, we basically have a system with a number of vehicle docks, i.e., spots where vehicles can be parked such as bike lockers or car parking spaces. This number of docks is usually referred to as the capacity of the station, and will be denoted by C in the sequel. Users arrive to the station either wanting to rent or return a vehicle. We distinguish below between models for one-way and round-trip vehicle sharing.

One-way vehicle sharing
The most basic model to describe the users' behavior in case of one-way vehicle sharing is by means of two independent Poisson arrival processes with rates λ (for vehicle returners) and μ (for vehicle renters). This then comes down to the use of a basic $M/M/1/C$ queueing model for the station, where the queue content corresponds to the number of vehicles available at the station, a Poisson arrival process with rate λ for vehicle returns and exponential service times with rate μ corresponding to vehicle rentals. The transient solution of the $M/M/1/C$ model is a known result in literature; see e.g. [27,30]. It gives the time-dependent distribution of the inventory level of the vehicle-sharing station for a given initial state i, i.e., the probabilities $\pi_{i,n}(t)$ = Prob[state n at time t, given initial state i at time 0]. In particular, closed-form expressions are obtained for the probabilities $\pi_{i,C}(t)$ of having no parking spots for returned vehicles or $\pi_{i,0}(t)$ of having no vehicles for rent available at the station at time t. In [26], these results are used to determine constraints on the initial vehicle

inventory level of a station such that a satisfactory service can be guaranteed. In particular, the fractions of time over a period T (say for instance a day) the station is empty or full are calculated respectively as

$$\frac{1}{T}\int_0^T \pi_{i,0}(t)\,\mathrm{d}t \text{ and } \frac{1}{T}\int_0^T \pi_{i,C}(t)\,\mathrm{d}t\,,$$

and the range of initial inventory levels is obtained for which the above fractions of time remain below given threshold values.

As noted in [26], the basic M/M/1/C model assumes that the arrival rates of renters and returners during the observation interval can be assumed stationary. In reality, however, arrival rates at a station are usually time varying and, moreover, rent and return rates for vehicles often exhibit fluctuating imbalances. Therefore, a more realistic model of a shared-vehicle station is as depicted in Figure 29. In this case two time-inhomogeneous (i.e., non-stationary) Poisson arrival processes with time-dependent rates λ_t and μ_t are used. These rates are typically estimated from user behavior measurements at a given station. The number of vehicles available at the station then constitutes a first-order continuous- time Markov chain (CTMC), of which the state-transition diagram is shown in Figure 30. In this case, no closed-form results for the probability distribution of the states of the chain, i.e., the probabilities $\pi_{i,n}(t)$, are available. In [22], an efficient numerical approach is presented to obtain $\pi_{i,n}(t)$ and to assess the user dissatisfaction level. This is done by attaching a penalty p_0 to each renter finding an empty station and a penalty p_C to each returner finding a full station. The user dissatisfaction D_T over an observation interval of length T is then expressed as (see [22])

$$D_T = \int_0^T \left(\pi_{i,0}(t)\,\mu_t\,p_0 + \pi_{i,C}(t)\,\lambda_t\,p_C\right)\,\mathrm{d}t\,,$$

and the impact of the initial inventory level of vehicles at the station on the user dissatisfaction is evaluated during a period T, e.g. a day, during which no relocation of vehicles takes place.

FIGURE 29
Basic graphical representation of a one-way vehicle-sharing station.

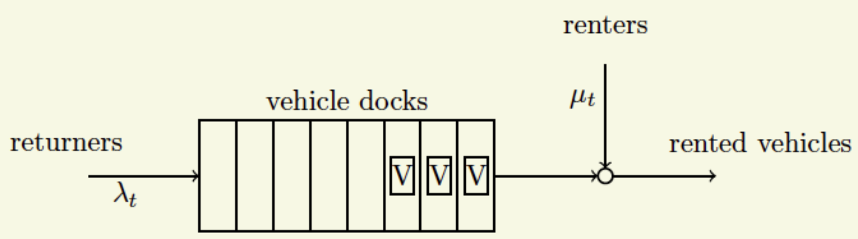
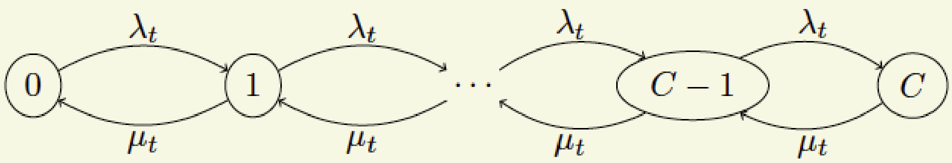


FIGURE 30

State-transition diagram of the corresponding continuous-time Markov chain.



The above model assumes that users (renters or returners) that cannot get service immediately due to the lack of vehicles or parking spots upon their arrival, decide to abandon the station right away, i.e. customers are considered to be impatient. An even more realistic model could also take some degree of patience of customers into account. In such model it could e.g. be assumed that renters will be prepared to wait at the station for an arriving vehicle as long as the total number of waiting renters does not exceed a certain number C_1. Similarly, returners will decide to wait at the station for a vehicle dock to become available as long as there are not more that C_2 returners waiting. This model is depicted in Figures 31-33, showing 3 different situations: stalled vehicles (situation 1), waiting returners (situation 2), and waiting renters (situation 3). The corresponding Markov chain is shown in Figure 34. Note that the structure of the CTMC of Figure 6 is basically the same as of the one depicted in Figure 30, so no new analysis method is needed for this extended model. One only needs to appropriately interpret the state probabilities: $\pi_i(t)$, for $0 \le i \le C_1$ denotes the probability of having C_1 waiting renters at the station (and no vehicles present), $\pi_i(t)$, for $C_1+1 \le i \le C_1+C$ denotes the probability of having i-C_1 vehicles stalled at the station (and no waiting returners), and $\pi_i(t)$, for $C_1+C+1 \le i \le C_1+C+C_2$ is the probability of having I-C_1-C users waiting for an available vehicle dock.

FIGURE 31

Extended graphical representation of a one-way vehicle-sharing station, situation 1.

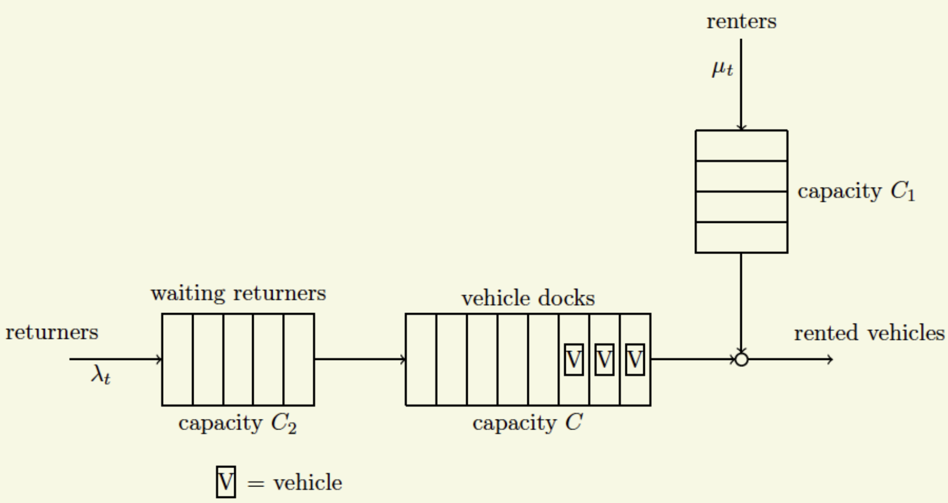


FIGURE 32

Extended graphical representation of a one-way vehicle-sharing station, situation 2.

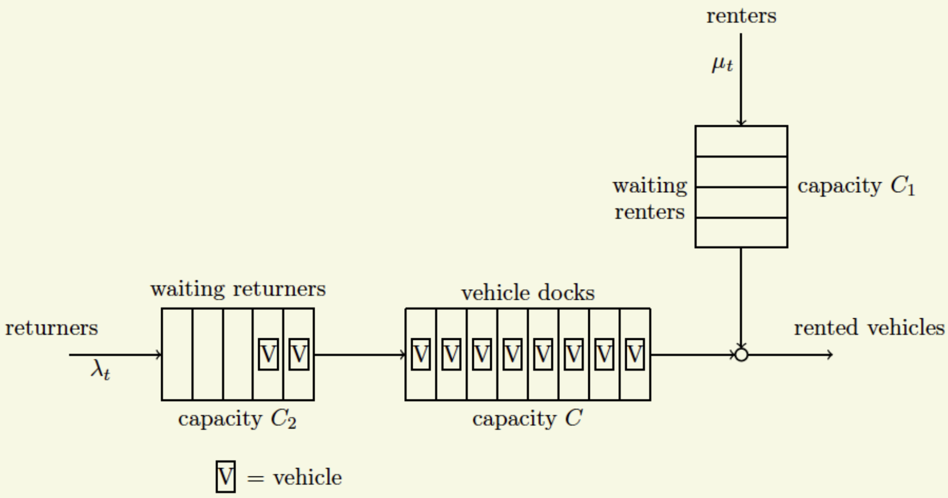


FIGURE 33

Extended graphical representation of a one-way vehicle-sharing station, situation 3.

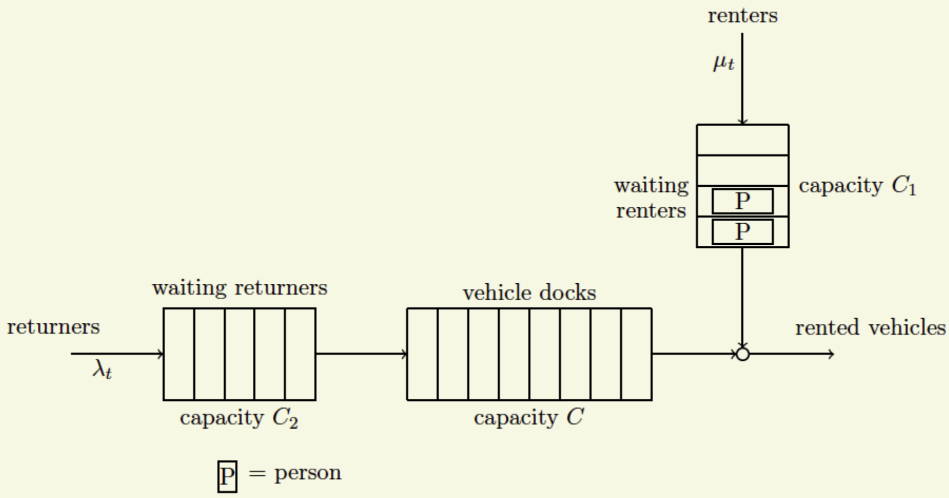
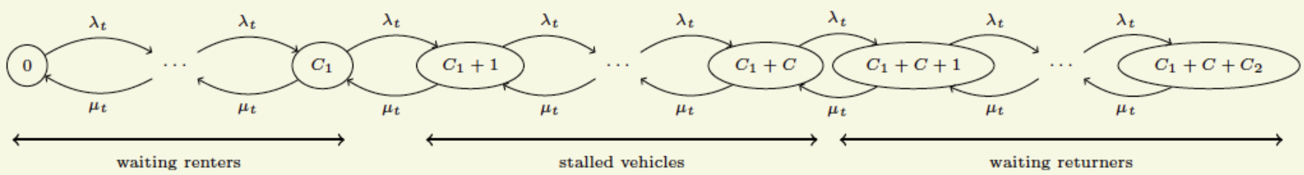


FIGURE 34

State-transition diagram of the continuous-time Markov chain for the extended model.



Variants of the CTMC model of Figure 34 have been discussed and used in [22] and [19]. In [22], it is assumed that the rate at which renters or returners effectively enter the station depends on the number of renters or returners already in front of them and the capacities C_1 and C_2 are set to infinity. Infinite C_1 and C_2 are also considered in [19], where two different arrival rates for renters and two different arrival rates for returners at the station are used, depending on whether or not vehicles (for renters) or parking spots (for returners) are available at the station upon arrival. We note in passing that pricing incentives as described earlier could be taken into account by changing the arrival rates for returners and/or renters in states that are nearer to the boundary. For instance, if returners are encouraged to return their vehicles to another station when the number of stalled vehicles is above some threshold, the arrival rate of returners will be lower when the state of the system is above this threshold.

Round-trip vehicle sharing

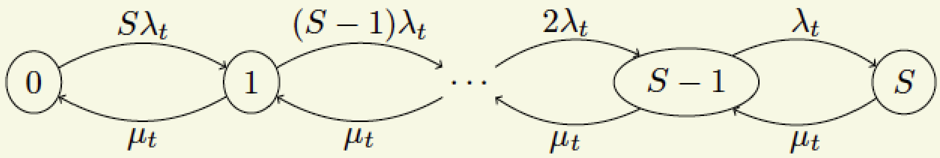
For a round-trip vehicle-sharing station there is typically a fixed fleet size of S vehicles assigned to the station. As the number of vehicle docks at the station is designed accordingly (i.e., $S \leq C$), unavailability of parking spaces is not an issue in this case, but the fleet size S needs to be dimensioned in such a way that the probability of having no vehicles available is kept below a given threshold value.

Due to the fixed fleet size S, it is clear that the arrival rate of returners to the station will depend on the number of vehicles already stalled at the station. Indeed, in case there are i vehicles parked at the station, S-i vehicles are in use and could possibly be returned after the end of their utilization time. The simplest station model is then obtained by assuming a Poisson arrival process of vehicle renters with rate μ_t and exponentially distributed vehicle utilization times with parameter λ_t. Figure 35 shows the state-transition diagram of the continuous-time Markov chain representing the number of vehicles available at the station. For a given initial state i at time 0, e.g. at the beginning of a day, the problem then again comes down to the derivation of the probability $\pi_{i,0}(t)$ of having no vehicles available at time t and the calculation of the required fleet size S such that the fraction of time the station is empty over an observation interval T, e.g. a day, remains below a given maximum value. Alternatively, a cost function based on this fraction of time no vehicles are available and on the vehicle utilization ratio [24] could be optimized. The vehicle utilization ratio is defined as the fraction of vehicle-hours vehicles are used over the total available vehicle-hours of the fleet:

$$U_T = \frac{1}{ST} \sum_{j=0}^{S} \int_0^T j\pi_{i,S-j}(t)\,\mathrm{d}t\,.$$

Operators obviously want U_T to be close to 1.

FIGURE 35
State-transition diagram of the continuous-time Markov chain for the round-trip vehicle-sharing station.



Until now, we assumed an infinite user population. If the number of users in a round-trip vehicle sharing system is small, a finite user population M should be taken into account. The arrival process of renters should then depend on the number of rented vehicles at that time. A research question here could be the required fleet size S as function of the user population M such that the fraction of time the station is empty over an observation interval is below a certain predefined threshold. If the population size grows over time, this could guide vehicle-sharing operators on when the fleet size should be increased.

We conclude this section with a discussion of models where customers are classified in different classes. In [25], two user classes are defined. Rent and return rates can be different for both classes as well as the cost of non-availability. In vehicle-sharing systems, one could for instance differentiate in prices and therefore in quality of service, or one could distinguish between clients with a subscription or one-off users. Operators can then decide that a certain class of clients is no longer allowed to rent a vehicle if less than a given number of vehicles are in stock. This would change some of the arrival rates of renters in the models described above.
The vehicles can also be split in several classes. For instance, a bicycle fleet could exist of regular bikes and electric bikes, but it can also be as simple as cars with or without child seats, see [17]. Some renters might not care which type of vehicle they drive, while others can have a preference for a certain type (or are only interested in one type of vehicle). Queueing models for these systems are related to models with skill-based servers that are for instance used in call centers (see [1]), where (some) operators can only serve a subclass of the customers.

Network models for shared-vehicle systems

Next, we concentrate on network models for shared-vehicle systems. These models typically consider a network of several vehicle-sharing stations, where one-way trips between the stations are allowed. Important is then to study how the distribution of vehicles over the various stations evolves during a given observation interval. This is also useful to develop adequate strategies for the repositioning of vehicles or the reservation of parking spots in order to obtain a good user satisfaction. Basically two extreme approaches can be observed: network models can be simplified to make an analytic analysis feasible, or they can be made extremely detailed, such that only computer simulations are possible.The advantage of the first approach is that more structural information can be obtained, while more realistic scenarios can be studied with the second approach. Along the lines of Section 3, our focus here is mainly on the first type of models.

Let us consider a network consisting of N vehicle-sharing stations and a fixed total fleet size of S vehicles circulating among the stations. Users arrive at a station, pick up a vehicle and return it after use to their station of choice. As explained in [15], such network can be modeled as a closed queueing network under some restrictions. As in the basic model of Section 3, vehicle renters are assumed to arrive to each of the stations according to a Poisson process, where μ_i denotes the arrival rate at station i. Also as before, renters are assumed to be impatient and therefore do not queue if no vehicle is available upon their arrival, but immediately abandon the system. An extra restriction of [15] is that each station has a sufficient capacity of vehicle docks such that no blocking of vehicle returners occurs. Users' destinations are modeled by means of a routing matrix $R = [r_{ij}]$, where r_{ij} denotes the probability that a vehicle rented from station i is returned to station j. Finally, a vehicle rented from station i with destination station j has a generally distributed utilization time with mean value $1/\lambda_{ij}$. A closed queueing network model is then obtained by using infinite-server queues to represent the vehicle utilization times. Specifically, the closed queueing network consists of single-server queues with exponential service times representing the vehicle-sharing stations and an infinite-server queue with generally distributed service times in between each pair of connected stations. As such, it belongs to the class of BCMP queueing networks (see [4]), and a product-form solution exists for the steady-state joint distribution of the number of vehicles in the network nodes. This allows to determine the unavailability of station i as the steady-state probability $\pi_0^{(i)}$ of having no vehicles available at station i and the steady-state mean number of vehicles l_{ij} in use from station i to station j. The research question addressed in [15] is how to optimally dimension the fleet size S taking into account both the quality of service and the profit of the rental company. This is done by attaching a revenue ρ_{ij} (per time unit) to each vehicle in use from station i to station j, an unavailability penalty p_i (per time unit) to a renter arriving at an empty station i and a maintenance cost c (per time unit) to each vehicle, and by determining the fleet size S for which the following objective function is maximum:

$$\sum_{i=1}^{N}\sum_{j=1}^{N} \ell_{ij}\,\rho_{ij} - \sum_{i=1}^{N} \mu_i\,\pi_0^{(i)}\,p_i - cS\,.$$

The general modeling framework of [15] is adapted in [12] to study the fleet-sizing problem for an electric-car-sharing system. The extra feature that needs to be taken into account in this case is the necessity for recharge operations of the electric vehicles. As such, for each station a further distinction is made between the number of available fully charged vehicles, the number of available partially charged vehicles and the number of vehicles out-of-power waiting at the station for a free charging position. Partially charged vehicles may only be rented from station i for short trips in the neighborhood of station i, while fully charged vehicles may be used to travel to any station *j*. Hence, the corresponding closed queueing network now includes several types of infinite-server queues that model the possible travel paths of rented vehicles.

Another model variant is studied in [18] to evaluate the performance of a vehicle-sharing system with parking reservations. Different from [15] stations are now assumed to have a finite capacity, where C_i denotes the number of vehicle docks at station *i*, while in order to keep the model tractable, vehicle utilization times are now assumed to be exponential instead of generally distributed. Users arriving at an empty station abandon the vehicle-sharing system and switch to another mode of transportation; consequently they experience an excess time with mean proportional to their original mean travel time $1/\lambda_{ij}$. A comparison is made between the no-reservations policy, where vehicle returners arriving at a full station wait at their destination until a parking spot becomes available and the complete-parking-reservation policy, where users upon vehicle rental need to declare their destination and a parking spot at the destination station is then immediately reserved. The above assumptions again lead to a CTMC model and the performance comparison is based on the excess time users spend in the system due to either queueing for a vacant parking spot or abandoning the system for the use of another transportation mode.

A final model we discuss allows for a first study of incentives and vehicle redistribution among the stations in a vehicle-sharing system. To this end, some further restrictions need to be imposed. The model in [14] assumes a network of N homogeneous stations, all having the same capacity C and the same arrival rate μ of vehicle renters. The total fleet size equals $S = sN$. Destinations are chosen randomly among all stations, and travel times between two stations are exponentially distributed with mean $1/\lambda$. As before, vehicle renters are impatient. Vehicle returners arriving at a full station do not queue for a vehicle dock, but immediately ride to another station, again chosen at random. Under these assumptions, closed-form expressions are found for the proportion of problematic stations (that are either empty or full) and the optimal number s of vehicles per station for which this proportion is minimal, in the limit as N goes to infinity by means of mean-field techniques. The same turns out to be possible as well for two model variants: 1) a two-choice model, where vehicle renters indicate two possible destinations at random and return the vehicle to the one that has the least number of vehicles available; 2) a redistribution model, where a truck moves vehicles one by one from the most to the least loaded station at a redistribution rate γ and trip times of the truck are neglected. Based on these model variants, a first study of the impact of user incentives and vehicle redistribution becomes possible, but clearly more work needs to be done to extend the models to more realistic scenarios.

Concluding remarks

In this paper, we have discussed a number of queueing models suitable to measure the performance of different shared-mobility solutions. A good performance of shared-mobility systems is important since the popularity of vehicle sharing will only increase when the performance and flexibility of these systems are close to those of private vehicles. We have seen that the analysis of appropriate queueing models allows to assess the impact of different parameters, such as vehicle fleet size, number of sharing stations, station capacity, vehicle redistribution strategies, etc., on the system performance. Based on this, the tradeoff between the quality of service offered to the users and the system maintenance cost can be studied and operational choices can be made.

The models and related performance results presented in this paper are, however, only a first step towards the use of queueing theory in shared-mobility systems. To optimize the fleet size, the number of vehicle docks, redistribution protocols of vehicles across stations, etc., queueing-theoretic results need to be used in combination with optimization algorithms. Because of time constraints, these optimization algorithms require closed-form formulas from queueing theory as much as possible.

Therefore, on the one hand, simplification in modeling a vehicle-sharing system as a queueing system or network might be appropriate, and moreover, approximate analysis can be preferred. For instance, the analysis of product-formed closed queueing networks as discussed in Section 4 might be time-consuming for a high number of vehicles and hence alternative methods (such as MVA – Mean Value Analysis) might be opted for. On the other hand, some simplifications that are made in literature (and that we also made here) might be inappropriate. For instance, Poisson processes are used abundantly, because they facilitate analysis. Going beyond these model simplifications while still keeping models tractable for analytic analysis is an important challenge for future research.

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THE NEW SMART CITY

FROM BIG DATA TO SMART CITIZENS

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Introduction

›› As defined by Caragliu et al. (2011), a smart city is a synthesis of hard infrastructure (or physical capital) with the availability and quality of knowledge communication and social infrastructure. The latter form of capital is decisive for urban competitiveness. Digital cities focus primarily on the hard infrastructure; smart cities focus on the way in which the physical, social, institutional and economic infrastructure is used.

FIGURE 36
Six pillars of a smart city [Giffinger]

Smart Cities develop along many dimensions also referred to as pillars. A classification into six major pillars has been established by Giffinger (2007) and has been adopted by the European Union. These are considered as central in identifying a city as a Smart City. In practice, based on their resources, nature of their city and priorities for citizen and public service, cities may focus on one or more of these pillars, touching little on others. For each of the pillars, sets of indicators have been established that can be used to measure the 'smartness' of the city and hence be able to rank it, or assess its success in the transformation process.

1. Smart Economy
   Smart economy is concerned with how attractive and competitive the region is with regard to factors such as the stimulation of innovation, entrepreneurship, productivity and international appeal. New collaboration models can result in new revenue models. On a more functional level, it includes ICT-enabled and advanced manufacturing and delivery of services, ICT-enabled innovation, and new ways of enhancing economy using technology.

2. Smart People
   Social capital is an important pillar. Citizens should be able to acquire e-skills, working in ICT-enabled jobs, having access to education and training, human

resources and capacity management, within an inclusive society that improves creativity and fosters innovation. Smart people have to be empowered to use, manipulate and personalize data for their decision making for example, through appropriate data analytic tools and dashboards, to make decisions and create products and services.

3. Smart Governance
   The local governance of cities requires a careful political and sensitive government that is able to work on three levels: Within the city for its citizens, coordinate and govern upward with the central government and connect to other governments and industry within the region or country. Smart governance includes transparency and e-government in participatory decision-making. Crowd-sourcing is also important as citizens join to develop ideas for smart applications. In general, engaging citizens is very crucial.

4. Smart Mobility
   Smart Mobility is the use of ICT technologies to support and integrate transport and logistical systems in order to make mobility easier, better, more efficient and smarter. All levels of transport can be coordinated and integrated to become a unified virtual transport platform, which would include cars, trains, bicycles and pedestrians. Adopting smart mobility would facilitate clean transport, fast and safe, avoiding traffic problems, providing better parking opportunities and so on. Real-time information can be accessed in order to save time and improve commuting efficiency, save costs and reduce CO_2 emissions, as well as to network transport managers to improve services and provide feedback to citizens.

5. Smart Environment
   Smart environments enrich the city with technology and policies to manage the environment. This includes ICT-enabled energy grids, metering, and pollution control and monitoring, renovation of buildings and amenities, green buildings and green urban planning. Smart applications and procedures enable resource usage efficiency, re-use and resource substitution.

6. Smart Living
   Smart living uses technology to make lifestyles comfortable and easy. ICT-enabled life styles are often built on Internet of Things (IoT). Technology observes and learns behavior, social habits, and related considerations in order to support and enable the citizen. Smart living is also healthy and safe living in a culturally vibrant city with diverse cultural facilities, which incorporates good quality housing and accommodation.

Current initiatives have often taken a technological focus. Research and development is performed mainly in the last three pillars (mobility, energy and living), where technology in ITS, smart grid and assisted living is implemented in order to support or enable smarter processes. This trend is supported by the access to fast embedded and connected processing, which allows to optimize and connect processes in every part of the chain. A side effect of infrastructure becoming smarted with embedded processing is that this generates a lot of data from different aspects of a city (energy, traffic, citizens,…). The next section looks into the smart city as a big data hub and the different type of sensors that are used within a mobility context. However, apart from controlling and measuring, technology can support the other pillars in a smart city. Section 3 of this paper looks into using technology to connect a city with its citizens and moving towards smart governance and smart people.

Smart City as Big Data Hub

Following Moore's Law, the progression in processing power is introducing technology into society at an increasing pace. Whereas smartphones at their introduction 15 years ago carried MHz processors with a few Mb of memory, current smartphones are equipped with high-end multicore processors, rich storage, multiple sensors, touch screen and different networking capabilities. The power of these devices equals that of low-end personal computers, but at a lower cost and with better portability. Their uptake has been spectacular, filling a need in our digital society. Today this means that through their phone, people continuously carry in their daily life sensors and computing power which is an important step towards ubiquitous computing as thought out at Xerox PARC beginning of the 90s (Pentland, 2000).

At the other end of the spectrum, low-cost, low-power and miniaturized processors are stimulating the widespread use of sensor nodes. These sensor nodes typically consist out of sensing, processing and communication modules. They can work stand-alone but their added value comes when building networks of sensor nodes that collaborate on communication and performing tasks. As nodes do not necessarily belong to closed networks but can form a heterogeneous system of interconnected networks, this forms what is called the Internet of Things (IoT) (Atzori et al., 2010). This refers to connected devices that can observe, understand and act upon certain events without human intervention.

FIGURE 37
The four V's of Big Data

VOLUME	VARIETY	VERACITY	VELOCITY
Scale of data	Different forms of data	Uncertainty of data	Analysis of streaming data

If we look at the Smart Mobility pillar, these new developments have allowed cities to build physical ICT-infrastructures of advanced scanning technologies. Broadly speaking, by scanning technologies we refer to data measured by means of detectors that scan specific locations of interest. They are typically used for traffic monitoring where they are located along the roadside and deployed to capture roadside motorized travel behavior. Generally, these technologies can be split into two categories: intrusive and non-intrusive methods. The intrusive methods basically consist of a data recorder and a sensor placing on or under the surface. They have been employed for many years in a traffic context and the most important ones are pneumatic road tubes, piezoelectric sensors and magnetic loops. This has been widely deployed over the last decades but the implementation and maintenance costs can be expensive. Non-intrusive methods are based on remote observations. Manual counting is the most traditional method, where trained observers gather traffic data that cannot be efficiently obtained through automated counts e.g. vehicle occupancy rate, pedestrians and vehicle classifications. In addition, other techniques have emerged based on sensing modalities like radar, infrared, ultrasound and video.

The above detectors are currently in operation for traffic count operations, where the focus lies on estimating traffic volume, possibly annotated with speed and vehicle class and aimed towards motorized transport. Mobility studies today require however a higher level of detail, giving views on (1) network connections and travel flows and (2) all users of the mobility network including pedestrians, bicyclists, public transport users. This requires not only observation of an object in a single location. It becomes necessary to follow an object over a network or site, if not completely than at least for sampled observations of its path. Location-enabled devices are able to give this type of insight.

In this section, we briefly introduce the current state of art in sensors for transport and mobility: camera networks, Bluetooth scanning and location-enabled devices. More than only the observation of transport flows, these sensors also allow to give insight in the mobility behaviour of citizens within a city.

Scanning by Computer Vision and Camera Networks

Closed-circuit television (CCTV) systems have known a widespread use since the 1970s with its main application in surveillance and security. During this time, the technology of video cameras and recording has known significant advances due to the evolution of sensors, computing power and digital transmission. This led among others to the migration from analogue cameras to digital technology, the utilization of the Internet Protocol (IP) for video and remote monitoring and the increased use of pan-tilt-zoom control (Kruegle, 2011). On the video analytics side, better algorithms and increased computing power on the server as well as embedded on the camera has led to more intelligent applications in 2D and 3D.

Highway traffic camera systems for speeding and toll charging are based on automatic number plate reading (ANPR). These systems consist out of three processes: image capture, plate extraction and interpretation. Image capture is a function of the quality and arrangement of the lane equipment – camera, vehicle detection, camera

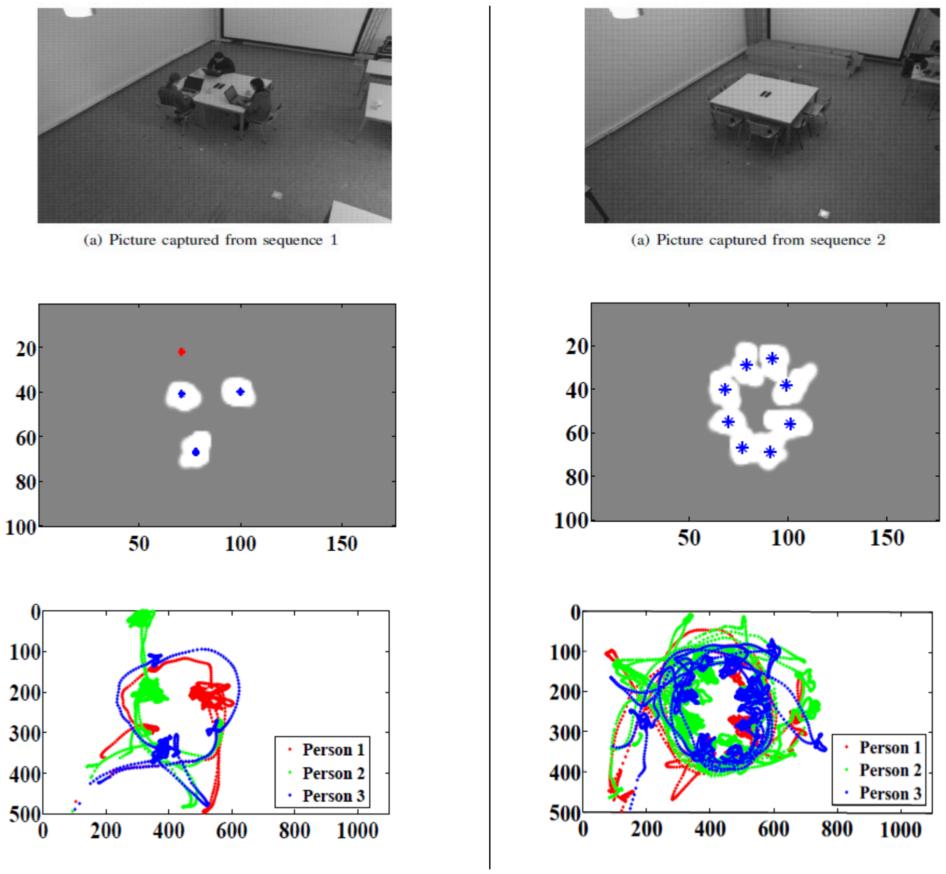
trigger, illumination and the local environment. Plate image isolation and extraction plus the character interpretation algorithms are part of the software engine. The performance depends on the performance of all three components and has been reported to have a 90-94% overall read accuracy under optimal conditions. Errors can be introduced due to bad calibration, bad lighting conditions, obscurity and processing ambiguity.
In addition to ANPR, vehicle classification has been extensively studied for highway and urban traffic settings as reviewed by Buch et al. (2011). Most of the related works deal with the vehicle classification problem under good and steady illumination conditions. More challenging scenarios for urban settings have been studied by comparing the vehicle silhouettes against projected 3D models of several vehicle classes. On the other hand, vehicle classification at nighttime has been studied by Hsieh et al. (2006) employing PCA-based Eigen spaces as appearance feature. Edge maps, SIFT descriptors, and region-based features are the most common methods employed in the literature to describe the vehicle appearance. Jelaca et al. (2013) describes the use of image projection profiles as a fast and compact representation for vehicle identification that can be used for vehicle matching in smart camera networks. In industrial traffic monitoring solutions like Honeywell and Flir, we also find vehicle classification which is often performed under more controlled conditions (e.g. camera view, observed driving) in order to simplify the processing for speed and robustness. Figure 38 illustrates such a system.

FIGURE 38
Example of system for vehicle counting and classification (courtesy of FLIR)

For machines to be able to detect, track and identify people instead of vehicles is more challenging. As people behave in a more erratic way and have much more variation in appearance, sensing of humans has long been one of the hardest machine vision problems to tackle. Success came from a combination of well-established pattern recognition techniques with an understanding of the image generation process. These methods often capitalized on regularities that are peculiar to people,

as for instance human skin color, which is defined on a one-dimensional manifold or the human facial geometry.
There are now several companies that sell commercial face recognition software that is capable of high-accuracy recognition with a database of over 1,000 people, commercially available camera systems that perform real-time face tracking for teleconferencing, and companies like IBM, Microsoft, Mitsubishi and Sony are showing simple vision-based recognition interfaces in commercial applications. Bredereck et al. (2012) performs tracking of people in camera networks by first detecting persons using histograms of oriented gradients in each camera view and then tracking their positions with a particle filter and greedy matching. In Morbee et al. 2010), the concept of probabilistic occupancy mapping is utilized to locate persons in each view and track/fuse using optimization techniques. Figure 39 shows results from Xingzhe et al. (2012), which study the classification of activities into three categories (sitting, standing and walking) based on the estimated trajectories of people in order to infer the position of furniture in a room. The above techniques allow face- or silhouette-based identification and tracking of people from camera to camera, which scale up to the monitoring of rooms or small buildings. On larger scales (e.g. urban areas where 10.000+ people pass daily), performance will drop due to limits in recognition.

FIGURE 39
Learning activities (sitting, walking) from observed trajectories of people and inferring the position of chairs (Xingzhe et.al. 2012).



Bluetooth Scanning

More recently, Bluetooth has been suggested as an interesting alternative tracking technology. Since the Bluetooth protocol allows for wireless discovery and identification of nearby devices, static Bluetooth sensors placed at strategic locations can give insights into human mobility in a variety of contexts: dynamics at mass events, urban design, social studies, travel time estimation of motorized traffic (Versichele et al., 2012), (Eagle & Pentland, 2006).

Initially envisioned as a low-power and open protocol for implementing Wireless Personal Area Networks by Siemens in 1994, Bluetooth has since become an almost ubiquitous technology on modern mobile devices. Prior to the ability for two devices to connect wirelessly through Bluetooth, one device needs to be discovered by the other. This part of the Bluetooth protocol is called the inquiry phase. The master device transmits inquiry packets, to which discoverable devices within its vicinity respond with inquiry response packets. These include the MAC address (which is a 48-bit identifier of the mobile device), and the class of device (COD) code (which gives a general idea about the type of device and some of its functionalities). By mapping detected MAC addresses to a specific timestamp and location where a sensor that made the discovery was located, one can reconstruct proximity-based trajectories. Since an actual connection is not required, tracked individuals are not aware of the presence of Bluetooth sensors and the methodology is in essence completely unobtrusive.

Several studies report on the tracking of Bluetooth sensors over a study area and reconstructing movements by matching the MAC addresses of detected devices with the locations of the detecting sensors. This network-based and non-participatory approach started materializing after a first documented trial in (O'Neill et al., 2006). Since then, a growing number of experimental use-cases have been documented. Particular attention has been devoted to the use of Bluetooth technology for travel time measurements of motorized traffic as it represents a simplified approach in comparison to ANPR (Malinovskiy et al, 2012). Pedestrian mobility has also been investigated. Examples include transit time measurements in airport security checkpoints (Bullock et al., 2010), travel and dwelling time calculations in an urban context (Malinovskiy et al., 2012), and the automatic registration of public transport users (Kostakos et al., 2013; Weinzerl & Hagemann, 2007). The 'Cityware' project used static Bluetooth sensors to capture mobility traces, and coupled these data with user's online social data (Kostakos & O'Neill, 2008).

Scanning using Location-Enabled Devices

Recent technological developments have produced a range of digital tracking technologies that offer a view on the movement of users. Location accuracy and power consumption has improved by better signal processing techniques and tighter integration with various technologies (GSM, GNSS, WiFi, motion sensors). Tracking technology is currently tightly integrated with current mobile phones and personal navigation devices (PND) offering various location based services. The simple and standard solution is GNSS-based devices, carrying chipsets that receive and correlate

incoming satellite signals from GPS, GLONASS and Galileo for positioning.
Less known is the fact that cell communication offers other possibilities to track people continuously. Operating on a phone network requires the network operator to be able to detect the subscriber's proximity to a specific antenna, even when no calls are made. Using multilateration of radio signals between antenna masts on the cellular network and the cell phone, its location can be estimated. In general, the accuracy of tracked mobile devices is lower than GNSS-based devices, ranging from 50 to 100m depending on the density of the cellular network. Projects like MIT's Senseable City have investigated behavior patterns through cell phone activity (Calabrese et al., 2011). The analyzed activity is still limited to presence detection within cells of typically 100m radius and does not take into account dynamic spatial movement patterns. In a similar way, the WiFi network can be used to locate WiFi-enabled devices within a position-calibrated network, as is currently offered as a service by Google in Android.
Floating car data (FCD) comes from so-called probe-vehicles, i.e. vehicles that are equipped with the necessary devices to transmit data to a data center at regular time intervals. The data comprise information on the status of the vehicle, for instance its location and speed. The equipment in the probe-vehicles is typically GSM communication sending out a GNSS positioning signal. This can be a simple black box datalogger, as used in fleet management systems, or can be integrated within an internal or external navigation system in the car. In the data center, data is processed in order to make it useable. The accuracy of the derived information depends on the frequency of the positioning and broadcasting of the data, the accuracy of the GPS and the number of probe-vehicles.
The utilization of FCD has been extensively investigated in a number of papers (Asmundsdottir, 2010). In The Netherlands, the Ministry of Transport, Public Works and Water Management investigated the usefulness of FCD to get an understanding of the possibilities and problems. The experiment was part of a large innovation research program called "Roads to the Future". Approximately 60 vehicles in the city of Rotterdam were equipped with GPS to estimate travel times. Results indicate that the FCD system is fairly accurate and can be applied to traffic information and traffic management systems (Taale et al., 2000). Torp and Lahrmann (2005) propose a complete prototype system that uses FCD for both automatic and manual detection of queues in traffic. The automatic detection was based on analyzing GPS data from the taxis. The manual detection was based on taxi drivers reporting traffic queues by using the equipment in the taxis. Zajicek & Reinthaler (2007) proposed a system that uses FCD to calculate detailed routes and travel times for hazardous goods transport in the Austrian road network. FCD is also used in the production and maintenance of road network databases. This production process requires a lot of work and resources which in addition needs to be in constant update. Instead of manual surveying or mobile mapping, vehicles can be used as proxy in the sense that where there are vehicles, there must be a road. Companies like TomTom, who have altered their map production process in order to receive and process anonymized GPS-data from the navigation devices of their customers. With this data, they are able to build and update their road network database. In addition to simple, static geometry, they are able to extract information on driving direction, speed limits and dynamic travel

time. However, FCD has a major restriction: as devices are typically installed in vehicles, they only monitor the use of the vehicle and therefor typically cover only a unimodal part of an individual's trip behaviour.
The application of portable handheld GPS-devices offered a solution to this issue, but again required the effort and discipline from the respondent to continuously carry the device with him, as forgetting the device would result in unreported gaps in the trip data. The resulting, multimodal tracking data also introduced the new challenge of interpreting the data. In case of passive logging, where tracking is performed without additional input from the user, the survey does not include any information about trip purpose or travel mode. These characteristics can be reconstructed afterwards, either by means of additional surveys (Asakura & Hato, 2004) or by interpreting the data using logical rules, e.g. using speed or GIS information (Tsui & Shalaby, 2006). Splitting the continuous GPS-logging into separate trips by detecting origins and destinations is based on dwelling times at one location. The determination of the travel mode is primarily based on speed characteristics during the trip, which can be complemented with additional GIS-data e.g. about public transportation networks and rail networks or accelerometer data (Hato 2010). Trip purpose can be estimated using land use maps or by analyzing the individual trip chaining. Good results are achieved for determining trip ends and travel modes, but the estimation of trip purposes remains unsatisfying (Gong et al., 2011).
Smartphones bring new possibilities for tracking, having same capabilities as the portable GPS-device but with additional sensors which can offer a more solid base for travel mode determination (accelerometer, Bluetooth, WiFi). Carrying a smartphone has also become a habit and is therefore considered less of a burden, reducing the risk of non-reported trips. Furthermore, smartphones offer the opportunity of running interactive mobile applications, where respondents can report additional trip data, e.g. on trip purpose, travel mode. Although the app requires a manual intervention by the respondent ("active" or "interactive logging"), the burden is limited because the reporting is restricted to short entries at the very moment of departure and arrival. As a consequence, time and location of the departure and arrival can be more accurately detected. Passive or background logging is also possible with consent of the user. On top of location measurements using GPS, WiFi or cell positioning, measurements of the accelerometer of the smartphones can be collected in order to automatically distinguish between different transport modes (pedestrians, cyclists and cars). Example is the smartphone application called CONNECT as used in Vlassenroot et al. (2013) to monitor dynamic, multimodal crowd behavior through smartphone localization and activity.

Over the last few years, the use of mobile applications as an instrument for policy support has seen a rise. Several academic and commercial applications as Waze, Strava, RateYourRide, Positive Drive, TomTom and Google monitor car, bicycle and pedestrian traffic in and around cities. Policy makers watch the collected data with interest, as 'to measure is to know'. If a sufficiently large public is reached, the apps will generate maps concerning traffic speeds, accessibility, origin-destination relations, etc. When combined with traditional data sources, they give additional and continuous insights on mobility.

FIGURE 40
Example of raw car and bike trips collected with the Connect mobile app

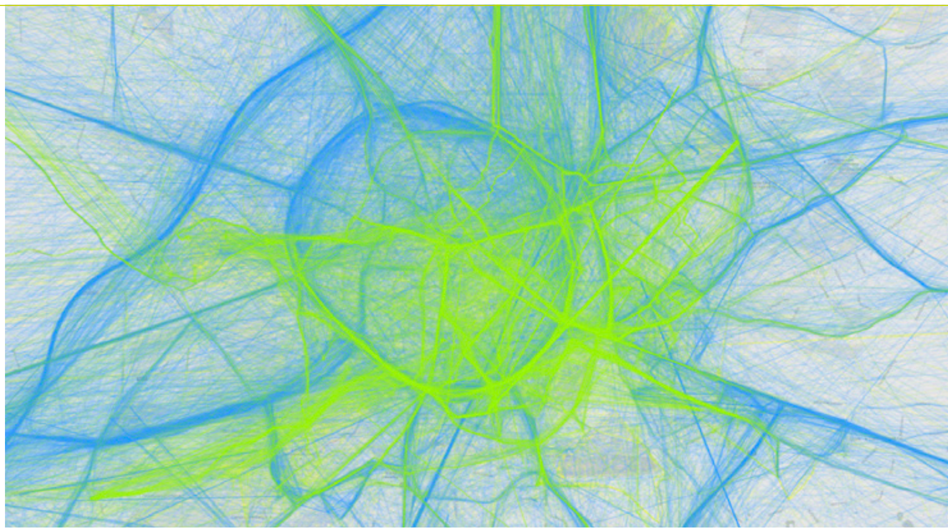


FIGURE 41
Illustration of the CONNECT mobile application in support of mobility studies

From Smart City to Smart Citizen

The above big data sources allow policy makers to generate maps concerning traffic speeds, accessibility, origin-destination relations, etc. However, mobility behavior is more complex than these traffic streams. Understanding activities, behavioral choices and trip chains is crucial to enable mobility policy towards a true mind shift. Ghent University therefore developed several ICT-tools for mobility, ranging from fleet management system for cars and bicycles, over urban sensing networks to mobile apps for the mobility consumer. The MOVE smart city platform integrates different data sources, and has been integrated in several projects in order to support mobility research about individual mobility behavior. The platform is applied in specific 'living labs' (e.g. concerning mobility budget, electric company bikes, …), as well as in public mobility campaigns (such as Biking Map Flanders, M-score, Routecoach).

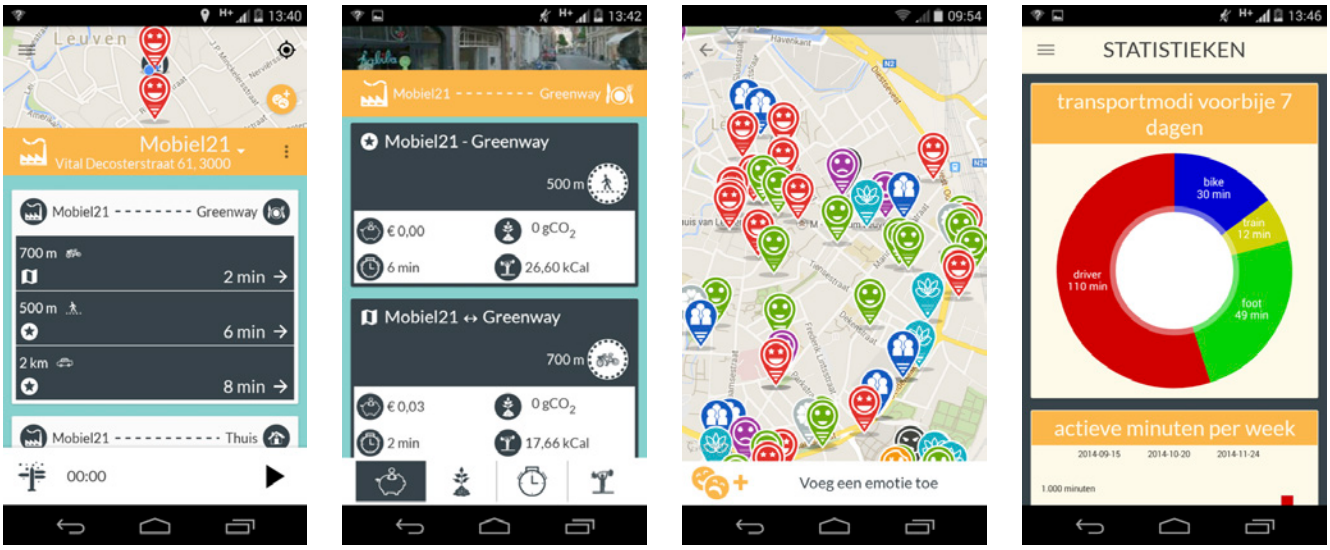


FIGURE 43
Examples of Biking Map Flanders, M-score, Routecoach

We consider the evolution from this technology, from a monitoring instrument towards an instrument for citizen participation and co-creation. An example is the mobile app 'Routecoach', which has been developed for the province for Flemish-Brabant in the frame of the Interreg IVb NWE project NISTO. This offers policy makers an automatic system to communicate multimodal travel advices according to their mobility policy (e.g. taking into account parking zones, networked mobility, preferred routes or travel times). Like its counterparts in media or e-commerce, the system works as a recommender system for personal mobility. The user receives the advices according to his individual mobility profile (such as home location, frequent destinations, preferred travel modes), as an alternative for his current travel behavior. For each advice, the benefits are indicated in term of time, environmental and health impact and indicated in order to show to the user the effect of his travel choices. Meanwhile the app collects the user's location and trip data, which is used to generate multimodal traffic maps and to explore the individual mobility behavior, for example which (types of) advices are more/less easily adopted by the citizens

in general or by specific target groups. This way the app becomes an instrument for policy makers for communicating their mobility vision very directly and personally towards the citizen, but even so for the citizen to give feedback on the relevance of this vision for his personal behavior. This dialogue supports – more than the data collection – the evolution towards a smart city.
The mobile application has been launched using a public campaign (cfr. Figure 44). The campaign focused on attracting citizens to move towards a more sustainable mobility behavior by downloading and using the app. Small challenges have been proposed by the city and communicated to the citizens through the Routecoach-app (e.g. take a bike at least 2 times a week). Completing a challenge earns points and prizes were offered in different categories in order to incentives use of the app. The campaign attracted 8.000 users of which 3.500 actively used the application over a period of six months. In total more than 30.000 trips have been recorded leading to about 400.000 km of recorded data in driving, public transport, biking and walking. This data gives insight in different aspects of local and regional mobility: bike and car accessibility of the city, the observed walkability of the city center, combined use of transport etc. An example is the bike versus car accessibility map, which was constructed, based on observed data (cfr. Figure 45).

FIGURE 44
Illustration of the public campaign for Routecoach as organized by Mobiel21.

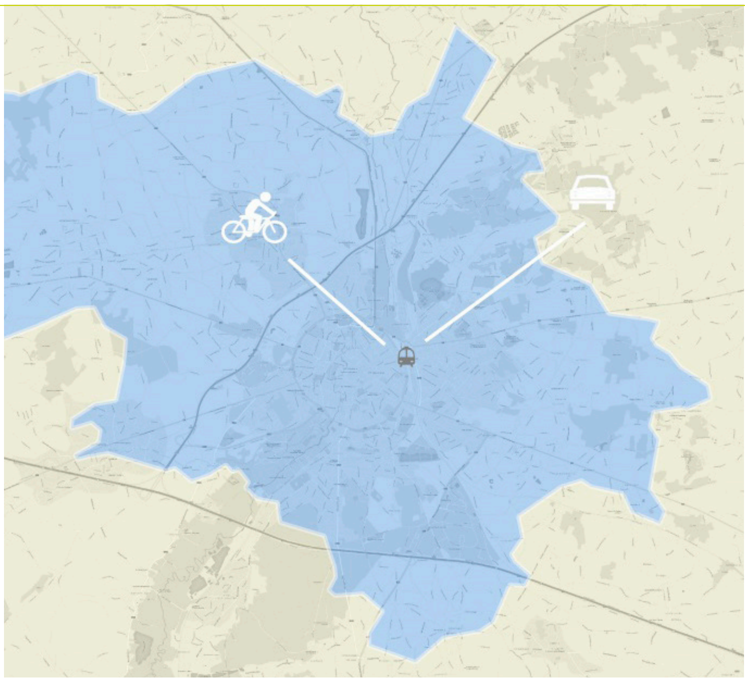


FIGURE 45
Accessibility of the railway station during peak hour as observed with the Routecoach data (In blue the region where bike is faster than car).

Next to pure data collection, the application serves as a communication channel between policy and citizens. Citizens are segmented according to one of eight mobility segment profiles. Figure 45 shows the distribution of these mobility segments. It shows that the application attracted not only citizens with a predominant 'green' profile but also the 'malcontented motorists' and 'devoted drivers'. This segmentation allows policy makers to have a more detailed view on which type of citizen generates which part of the total mobility activity. In terms of behavioral change, the recommender engine behind Routecoach that serves personalized route suggestions, also gives feedback on which suggestions are actually followed up per type of citizen and are effective sustainable alternatives. In this way, the active use of the application by the citizen becomes important and complements the simple data logging in order to make his or hers preferences known to policy makers.

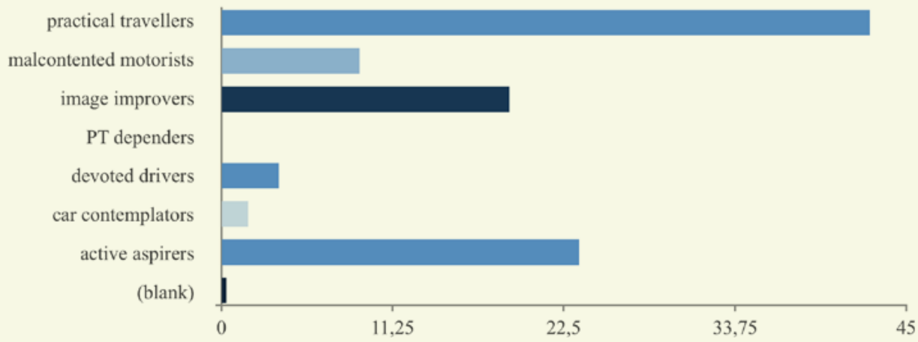


FIGURE 46
Population distribution over different consumer segments in percentage.

Conclusion

In this chapter we have examined different sources of mobility data that can be rolled out in a smart city: camera networks, Bluetooth/WiFi scanners and location-enabled devices. The first two systems are passive systems having the benefit of passively scanning activity without explicit approval of the observed crowd, albeit within the limits of privacy regulation. For vehicle flows, camera networks remain the most accurate if the road conditions allow a good set up. It does remain a costly solution and is restricted to the main road networks. Bluetooth/WiFi scanners offer a low-cost solution to observe activity with the added benefit that it easily extends to pedestrian behavior and works outdoor as well as indoor. Challenge for these scanners remains the upscaling of the observed number of active bluetooth devices to an estimation of the actual number of vehicles or pedestrians within the observed region or road segment. Calibration using other devices or external data is necessary if good absolute estimations are required.

Location-enabled devices and more in particular smartphone applications are a totally different source of information. They require active installation and use by the citizen. Not so much the technology but the campaign used to launch the application as well as the added service offered to the citizen are essential to ensure good data. In return, highly detailed data can be collected on traditional mobility data like routes, travel time and transport mode, as well as more consumer oriented insights like travel purpose and mobility attitude. In addition, more than simply collecting data, smartphone applications can be used to set up the dialogue between citizen and policy maker. Mobility recommender systems are such an example where the citizen's preferences and dislikes as a mobility consumer can be directly related to policy choices. These examples help to move smart cities forward from big data repositories to using technology to enable smart citizens.

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CITY LOGISTICS AND MOBILITY

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TRENDS, CHALLENGES AND POSSIBLE OPERATIONAL SOLUTION STRATEGIES

Introduction

>> The sustainable economic development of a city is strongly dependent on two interconnected critical factors. The first is improved urban mobility and the second is well-managed urban logistics for bringing goods and services to the city's inhabitants. However, the movement of individuals and the delivery of goods and services impact each other significantly and are also major contributors to a variety of urban nuisances, such as air quality deterioration, noise and traffic congestion. Consequently, as urban population keeps growing, their consumption level and the number of vehicles per inhabitant keep increasing, city logistics and urban mobility will continue to be matters of great concern in managing major cities in the world.

Furthermore, the current technological advances have enabled new forms of businesses such as e-commerce, whose impacts on urban mobility and urban logistical systems were in many cases impossible to anticipate. Industrial activities have also been redesigned to efficiently cope with the new urban ways of consumption. In order to deal with economic fluctuations, as well as the ever increasing new types of demand and stricter customer requirements, companies have developed new production and distribution systems such as Just-In-Time and Lean Manufacturing, which also have noticeable effects on the city's transportation network and consequently on the mobility inside these cities.

Last but not least, public interest and awareness about environmental issues related to traffic noise and congestion have grown and cannot be neglected. The green cause has attained remarkable political and economic power. Citizens in major cities expect from their city governance an effective mobility, efficient logistics and safe and environment. The new concepts of city logistics and what is now called smart city has the task of reconciling urban mobility, urban logistics and environmental concerns. These are clearly conflicting objectives requiring some well-thought-out solutions based on a completely new strategic vision of mobility and logistics in a city and using the new technological developments.

Clearly, establishing and operating a steady and sustainable development solution to achieve a best compromise among mobility, logistics and the environment in a city requires that the underlying urban logistical and mobility systems perform at their highest levels of efficiency and effectiveness. Any best compromise solution must reconcile the fact that a city needs industry and commerce to prosper, but industry and commerce heavily depend on freight transport, which in turn has negative consequences on the quality of life experienced by the citizens and on the environment. A well-thought-out trade-off between ensuring economic growth of a city while reducing undesirable impacts of traffic is a prerequisite for any viable strategy.

Defining the borders of this trade-off and engineering feasible solutions are very complex and challenging tasks. Realizing these tasks entails evaluating many alternative approaches and strategies of which all of the control parameters are not in the hands of a single authoritative body, but shared among various stakeholders, such as public administrators, traffic and infrastructure managers, logistics service providers and citizens. To tackle this multi-faceted problem, the concept of city logistics was introduced (see Ruske, 1994; Kohler, 1997; Taniguchi et al. 1999a; Taniguchi and van der Heijden, 2000a). It can be summarized as a global strategy involving a set of coherent action plans aiming at achieving a cleaner, quieter, and safer environment for city residents together with a sustainable economic development via an efficient, effective and environmentally friendly urban freight transport.

Although the concept of city logistics as defined above offers the indispensable framework to develop sustainable solutions for the urban logistics and mobility challenges, the necessary tools to operationalize this framework are still missing. This chapter intends to provide some initial steps in this respect. More precisely, it proposes and discusses some operational strategies to integrate urban logistics and traffic management with the objective of generating Pareto efficient solutions for both urban logistics and traffic performance.

In the remainder of this chapter, city logistics will be further defined and contextualized. The challenges and trends around this concept as well as its connection and impact on mobility will be discussed. Then, some urban logistics and traffic management integrated solution approaches will be presented. Finally, some concluding remarks and reflections on what has been done and what is expected to come on this hot and challenging topic will close the chapter.

City Logistics: what, why and where

Freight vehicles play an essential role in urban areas as they enable movements of goods and ensure many other crucial services to the city's residents. Freight transportation, for instance, is needed to replenish inventories of shops and supermarkets; to deliver parcels and other supplies to offices, households and retailers; to collect household waste; etc. The conditions under which these movements of goods are carried out have multiple consequences on many aspects impacting residents' quality of life. Freight transportation not only represents an important part of product prices but it also impacts the quality and costs of the logistical services themselves. In general, to guarantee lower prices and higher quality of city logistics services, freight transportation activities must not be restricted in any way. However, complete absence of some type of limitations impacts negatively road congestion, air quality, greenhouse gas emissions, noise pollution, public safety, etc.

Trying to mitigate these impacts by simply imposing restrictions on freight companies usually results in higher costs and worse service. For instance, if only cleaner vehicles (e.g., electric trucks) would be allowed in a city, it is likely that the distribution costs would increase, and, consequently, the prices to consumers would rise. On the other hand, combined measures can possibly generate better results. In that same example, the cleaner vehicles could be allowed to partially use the public transport network, such as bus lanes. This could reduce the distance and time they would have to travel and make their use more attractive from an economic point of view while reducing congestion.

In this context, there is a growing interest in understanding the dynamics of logistics and its interactions with mobility, environment, businesses and individuals in urban areas. The concept of City Logistics holds the promise of improving the logistical and mobility models in cities. It is defined by the Institute of City Logistics as the process of optimizing the logistics and freight transport activities in urban areas while taking the traffic conditions, congestion and air pollution into account, with a view of reducing the number of vehicles on the city road networks, through the rationalization of the required operations (see also Taniguchi et al., 2001). The logistical activities and aspects involved in this process include, in addition to transport, handling and storage of goods, the management of inventory and related pickup and delivery operations.

City Logistics aims at acting on the flow of goods, traffic congestion, air pollution, noise, economic and environmental sustainability and development of the city. It does not target logistics operators exclusively. It urges governmental authorities, traffic managers, manufacturers, service providers, retailers, customers and citizens to work together and rethink their relation to freight transportation. This makes it very complex to implement, as the strategies to achieve these objectives are naturally conflicting and require different planning horizons. New business and operation models involving public-private collaboration, innovative partnerships and extensive applications of available technologies are suggested as the shortest path to finding solutions which can mitigate the hinder caused by urban freight transportation.

A recent study from the European Commission on urban freight transportation suggests a categorisation of urban areas according to their number of inhabitants, experienced congestion levels and cultural or heritage importance (DG Move, EC, 2012). This may be useful because it provides an overview of where measures and practices should preferably be applied. The following categorisation was proposed:

- Metropolises: urban areas with over 3 million inhabitants that are likely to experience significant road congestion and air quality issues.
- Other Large Urban Zones: urban areas with more than 500,000 inhabitants which may also present road congestion and air quality issues.
- Smaller Heritage Urban Areas: smaller urban areas that are sensitive environments because of the importance of the town or city in cultural or heritage terms.

- Other Smaller Urban Areas: all other urban areas, which probably experience less significant road congestion and air quality issues.

City Logistics should therefore be approached as an integrated systemic strategy entailing a set of coherent action plans which are tailored to each category. Efficient mobility and economic sustainability of each category might require different action plans.

Challenges and trends

In this section, the current challenges and trends faced in City Logistics are highlighted. The discussion is subdivided in 4 parts:

- Smaller delivery volume and higher delivery frequency
- Cost-effectiveness
- New opportunities in information and communication technology
- Internalisation of external costs

Smaller delivery volume and higher delivery frequency
The explosion of e-commerce is changing the way logistics and physical distribution networks function. E-commerce has triggered an unprecedented flow of business-to-customer shipments, which came as a result of the frequent delivery of small parcels and the relatively low percentage of successful home deliveries due to absence of the receiver, incorrect addresses, etc.

Production systems based on concepts such as just-in-time and lean manufacturing implemented in companies also result in more frequent and smaller deliveries. Among other goals, these systems aim at reducing stock levels and processing smaller batches. This has clear impacts on the distribution strategies.

Another point, which cannot be overlooked, is the fact that cities are progressively prohibiting the traffic of large vehicles for safety, environmental or heritage protection reasons. As a consequence, loads must be divided into a larger number of smaller vehicles.

Cost effectiveness
Cost-effective transportation has always been the main goal of both traffic and logistics management, and in the last decades, the rising environmental concerns were also included in cost calculations. But while companies and governments spent lots of efforts to optimize the existing businesses, distribution systems and transportation networks, the demand for products and services also reached levels, which few would have predicted. Creative thinking and out-of-the-box solutions are now needed to deal with the problem.

New packaging approaches, for instance, have been developed by manufacturers in order to reduce the volume needed in trucks to transport the goods and ease the loading and unloading operations. The challenges faced by companies which tried it, went from technical product-related issues, such as perishability and handling difficulties at the retailers, to marketing and branding strategies, since customers generally associate packaging design to product quality.

New opportunities in information and communication technology
Fortunately, technology has opened possibilities, which were unimaginable, a couple of years ago. Advancements in information and communication technology, allied with the proliferation of internet and GPS-enabled mobile devices, can certainly aid the consolidation of loads from different shippers, carriers and customers within a smaller number of vehicles, and thus improve fleet utilization. Nevertheless, choosing the technologies to be exploited and building operationally feasible strategies are still open questions.

Internalisation of external costs
The users of transportation networks reach their decisions by analysing how the network impacts their businesses and tend to ignore how their businesses impact the network. For instance, companies place their facilities in the most economically convenient areas without thinking about how this may cause congestion or other nuisances, and service providers schedule their activities during rush hours if it is profitable for them. Since the costs of these inconveniences are not included in the calculation of the users' profits, they are labelled as external costs and are ultimately shared by the whole society. The process of bringing these costs to the decision making process of users is called internalisation of external costs and has two main advantages: charging the right price to every user and forcing them to rethink their actions.

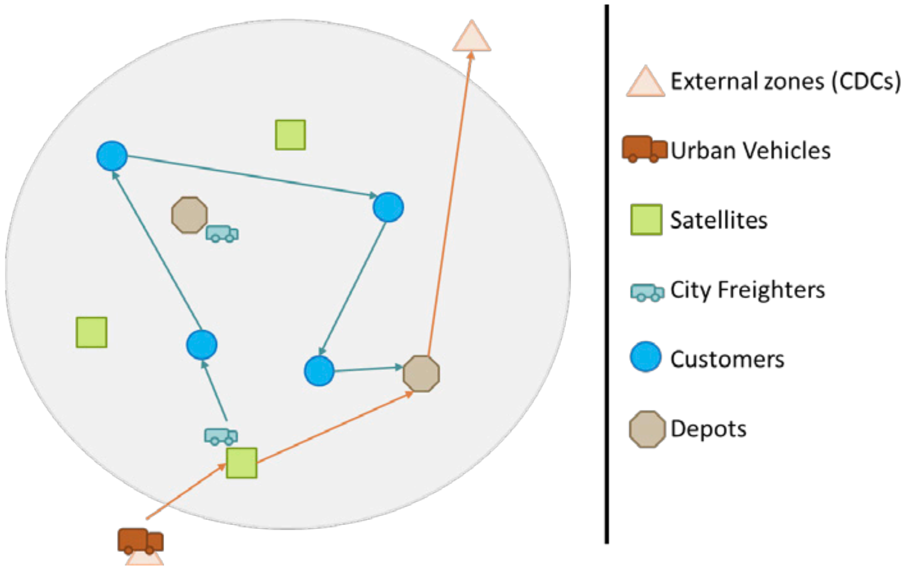
Possible measures for the internalisation of external costs include increasing the costs for users who generate nuisances (e.g., congestion pricing) and decreasing the costs for users who would avoid them (e. g., tax reduction for cleaner vehicles). Two big challenges are inherent to this process: the first is to correctly assess and monetise the external costs; the second is to find and implement adequate measures, which fulfil all technical, political, legal and economic constraints.

Operational strategies and modelling

This section discusses some possible solutions and strategies to cope with the current City Logistics challenges discussed above. The section is subdivided in 3 parts:

1. **Development of new distribution strategies**
2. **Methods to avoiding suboptimal solutions in a non-cooperative environment**
3. **Integration between logistics and traffic management systems**

FIGURE 47
An example of a two-tier system



Development of new distribution strategies
Many strategies or systems have been proposed to efficiently and effectively manage freight transport in urban areas. A first strategy involves a single-tier system, in which inbound freight is consolidated at one or several city distribution centres (CDC), located at the city limits, and is then delivered to the customers inside the city. Single-tier systems, suitable for small to medium-sized cities, implement direct distribution strategies, serving customers in the city centre by vehicles operating tours starting and finishing at some CDC facility.

A second strategy, involving two-tiered systems, typically appropriate for large cities, are based on a so-called consolidation-distribution strategy, which uses a second level of facilities and different vehicle fleets in order to avoid the presence of large vehicles in the city centre, and improve the ratio of load to travelled distance. The replenishment of the intermediate warehouses, together with the coordination and synchronization of the flows in each of the two-tiers, constitute a major challenge in this strategy. This strategy is depicted in 47.

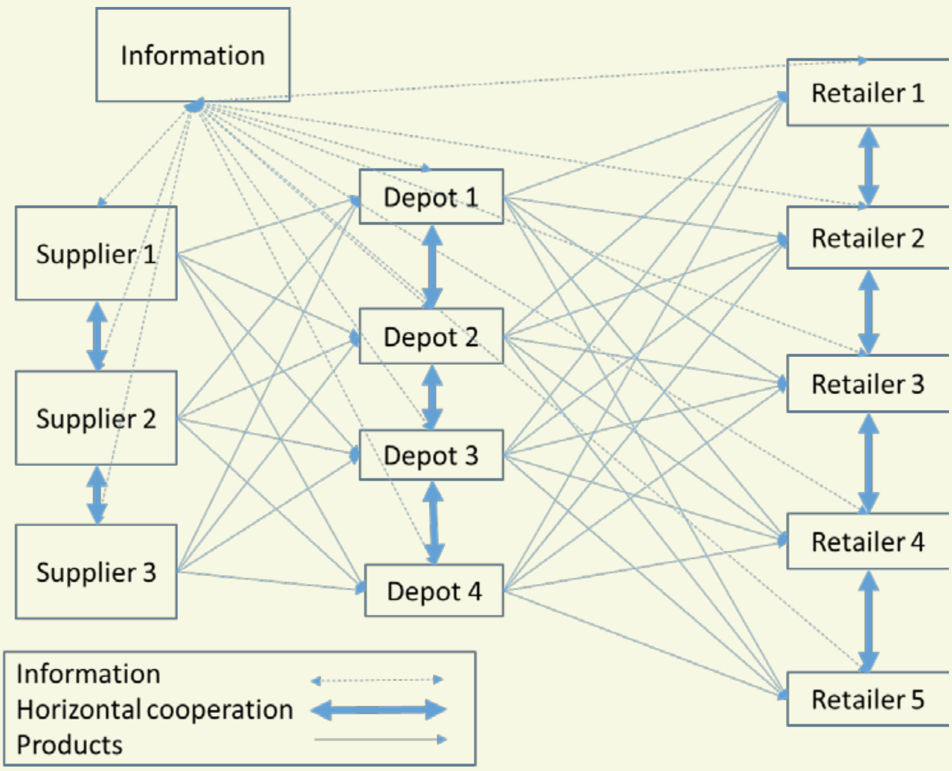
The outer tier deals with the urban freight transport from CDCs, usually situated on the outskirts of the city and therefore referred as external zones, to depots or satellites, which are intermediate facilities (e. g. parking lots) strategically located in the interior of the city. The transportation in this tier is performed by urban vehicles, which have relatively high capacities but are not allowed in all areas of the city and in most cases cannot directly serve the customers.

The inner tier deals with the transport of the goods from the intermediate facilities to the customers. This is performed by smaller vehicles, or city freighters. Urban vehicles and city freighters meet at appointed times at depots or satellites, where the goods are transferred from the former to the latter vehicles. Intermediate storage may or may not be allowed at a specific depot or satellite. After being loaded, city freighters make delivery routes in order to fulfil the customer demands.

Urban vehicles and city freighters are normally allowed to wait at external zones or depots when they are not travelling, but mostly they may not remain too long at satellites or customers. Besides, the installations may have limitations on the number of vehicles, which are simultaneously present on it. Delays due to congestion and delivery time windows are examples of complications, which cannot be overlooked in the design of a solution. Mathematical models for routing and synchronization of vehicles operating in two-tiered systems have been developed and different solution methods are studied (see Crainic et al., 2009; Amaral and Aghezzaf, 2015).

The advent of these new distribution strategies also enables additional forms of cooperation between businesses. It is known that producers are progressively using independent companies to outsource tasks, which are not their main competence (so-called core-business) in order to reduce fixed and administration costs. Transportation of raw materials and products is one of these tasks, which can possibly be outsourced. If this outsourcing strategy is carried out in a cooperative manner, as is shown in figure 48, the use of the transportation network can be further optimized. By sharing information and taking advantage of the shared vehicles and facilities (e.g., depots and warehouses), logistics operations can be planned in a more efficient manner, resulting in faster, safer, cheaper and cleaner services.

FIGURE 48
Information sharing and horizontal collaboration



Methods to avoid suboptimal solutions in a non-cooperative environment.
It is known that suboptimal solutions are often achieved when multiple interacting

stakeholders try to optimize their business separately. This has been extensively studied the last half century. In economics and game theory, these suboptimal solutions constitute what is called Nash-Equilibrium: a stable state of a system with two or more participants, in which no one can profit by changing his strategy while the others keep their strategies unchanged (Nash, 1950). A system may have multiple Nash-Equilibria and not all of them are necessarily suboptimal, although this is commonly the case.

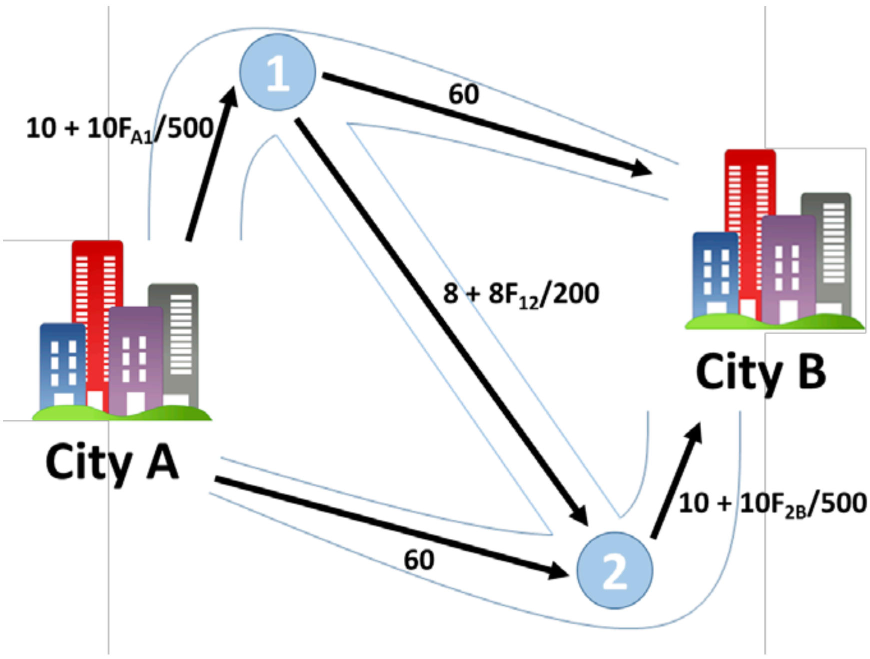
Transportation networks are an example of a system which is susceptible to this kind of equilibrium. The users of a transportation network, i.e., citizens, logistics companies, service providers, etc., usually choose their routes in an independent and uncoordinated way in order to minimize their own travel times. However, in the congested roads of a city, the decision of each user affects the duration of everyone's trips. To illustrate this fact, consider that 1,000 vehicles use the small theoretical network displayed in Figure 49 to move from city A to city B.

There are three possible routes: A-1-B, A-2-B and A-1-2-B. The travel times in minutes for the links A-1, 1-2 and 2-B are respectively given by $(10+10F_{A1}/500)$, $(8+8F_{12}/200)$ and $(10+10F_{1b}/500)$, where F_{A1}, F_{12} and F_{2B} are the number of vehicles which use the corresponding link. The links A-2 and 2-B are non-congested and have a travel time of 60 minutes.

The equilibrium flows and total travel times are calculated according to Wardrop's first principle of route choice, which states that the journey times on all the routes actually used are equal, and less than those which would be experienced by a single vehicle on any unused route (Wardrop, 1952). Applying this principle to the example, we find that all three possible routes are used: 180 vehicles take route A-1-B, 180

FIGURE 49

A network in which non-cooperative behaviour leads to suboptimal solutions



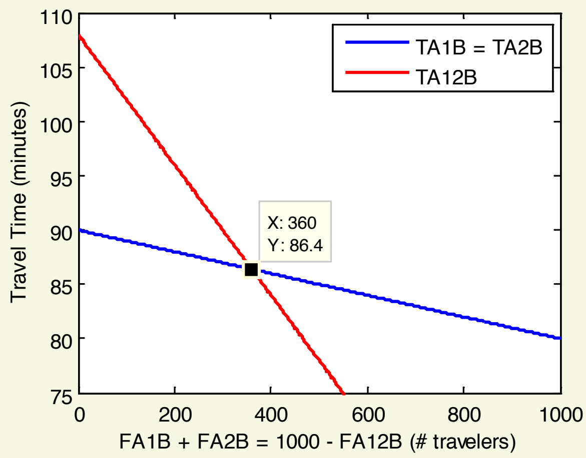


FIGURE 50
Equilibrium flows and travel time for the network shown in Figure 49 (Amaral and Aghezzaf, 2014)

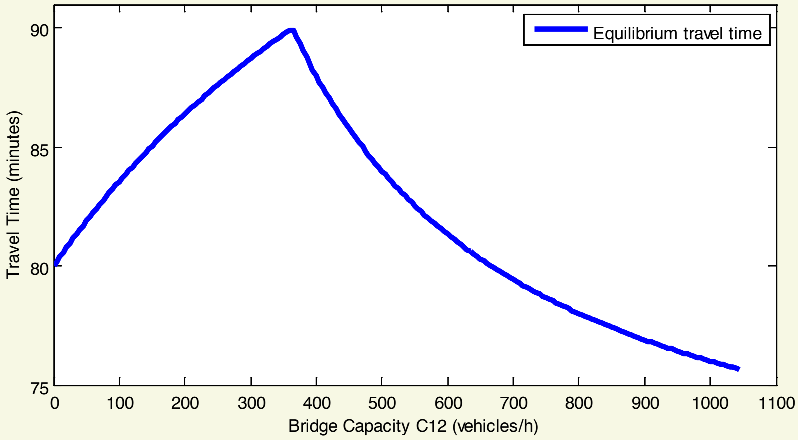
vehicles take route A-2-B, and 640 vehicles take route A-1-2-B, and in all the cases the travel time is 86.4min. Since routes A-1-B and A-2-B are somehow equivalent, the number of travellers, which take each one of these routes, is equal. Therefore, the equilibrium solution can graphically be represented in a two-dimensional graph as in Figure 50.

The two lines show the travel times for each route as a function of the sum of travellers who take routes A-1-B and A-2-B. This value is the same as 1000 minus the number of travellers who take route A-1-2-B. Both curves have negative slopes, which means that the travel time for every route is shorter when more travellers take routes A-1-B and A-2-B. In fact, if the users would use only routes A-1-B and A-2-B, dividing themselves equally among these two routes, the travel time for every traveller would be 60+(10+10*500/500) = 80min. But this is not a stable state, because under these circumstances the travel time for route A-1-2-B is only (10+10*500/500)+(8+8*0/200) +(10+10*500/500) = 28min, and users will be inclined to switch to this route. They will keep doing so until the travel times become the same for all three possible routes.

A curious aspect of such analysis is that increasing the capacity of the link 1-2 can actually deteriorate the equilibrium solution. The capacity of this link is indicated by the value 200 in the expression ($8+8F_{12}/200$). For a constant flow F_{12}, a higher capacity will decrease the travel time in the link. However, if this value would be 224, for instance, more users would shift from routes A-1-B and A-2-B to the route A-1-2-B. In equilibrium, 150 vehicles would take route A-1-B, 150 vehicles would take route A-2-B, 700 vehicles would take route A-1-2-B, and the resulting travel time would be 87min.

The travel time in the link 1-2 can be expressed in terms of its capacity as ($8+8F_{12}/C_{12}$) and the equilibrium travel time from city A to city B calculated for different values of C_{12}. The result is shown in Figure 51. Unless C_{12} is greater than 667 (approximately), the equilibrium travel time can be shortened by forbidding the users to use this link.

FIGURE 51
Equilibrium travel time in function of the capacity of the inner link (Amaral and Aghezzaf, 2014)

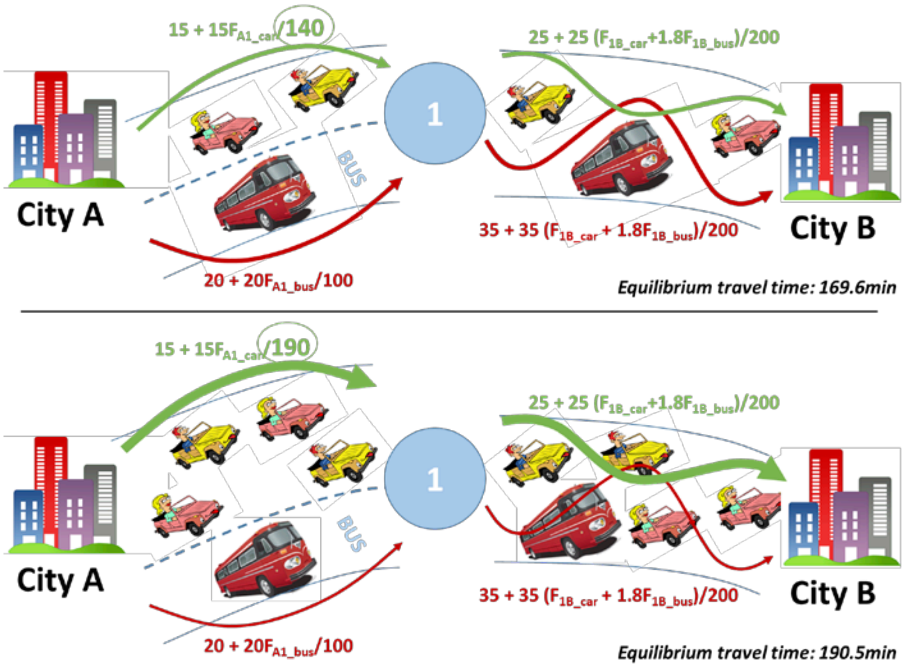


The fact that an increase of the capacity of a link can worsen the overall network performance is known as Braess Paradox (Braess, 1968). The Downs–Thomson paradox (Downs, 1962), also known as the Pigou–Knight–Downs paradox, states that the speed of car traffic at equilibrium on a road network is correlated with the speed at which equivalent trips are made by public transport. This means that if an improvement in the road network impacts negatively public transport, it can actually make the congestion worse. Although such paradoxes require some specific network configurations to occur (Steinberg et al., 1983; Roughgarden, 2005), they have been detected in real traffic networks in cities such as Stuttgart (Germany), Seoul (South Korea), London (UK), New York City and Boston (USA) (Kolata, 1990; Youn et al., 2008).

Recent studies have shown that this sort of paradoxes also occurs in multimodal and interactive networks (Amaral and Aghezzaf, 2014). The expansion of roads in a city, for example, may motivate people to use their cars more frequently, and that has a negative impact on the travel time of buses sharing the same lanes. As a consequence, bus users who were initially satisfied with their travel times start using their cars too, but the increased congestion causes the equilibrium travel time to become worse than before. The network depicted in Figure 52 illustrates such a case.

For the calculation of the equilibrium travel times, it was once more considered that 1,000 travelers must go from City A to City B, but now using private cars or buses. There are dedicated bus lanes on some parts of the road, while on other parts, the buses share the road with private cars. The link A-1 represent the parts in which there are dedicated bus lanes. On these parts, the travel time by car depends only on the flow of cars (F_{A1_car}), while the travel time by bus depends on the flow of buses (F_{A1_bus}). The links 1-B represent the other parts of the road. There the travel time of each transportation mean depends on both flows (F_{1B_car} and F_{1B_bus}). Because the congestion impact of buses is higher than the one of cars, a Passenger Car Equivalent for buses is used as a averaging factor for F_{1B_bus}. The travel times are calculated using the expressions next to the arrows on the figure.

FIGURE 52
Increasing the capacity of a link in a multimodal network may also increase the equilibrium travel time



The links A-1 and 1-B on the network diagram do not necessarily represent real traffic roads. Instead, they just represent the fragments of the road where the two distinct conditions apply, i.e., parts where there are dedicated bus lanes and parts where the lanes are shared by cars and buses share. In this sense, point 1 may actually not exist and, therefore, travelers are not allowed to change from cars to buses, nor vice-versa. Mathematically, this fact implies that $F_{A1\_car} = F_{1B\_car}$ and $F_{A1\_bus} = F_{1B\_bus}$. Finally, it was considered that buses take 10 travelers, which means that $F_{A1\_car} + 10F_{A1\_bus} = 1{,}000$.

Having made all these observations, the equilibrium travel time can be calculated. That was done for two different capacities of the car lanes on link A-1, represented by the values 140 and 175. The outcomes are respectively displayed on the left and right graphs in Figure 53.

FIGURE 53
Equilibrium flows and travel times for the network represented in Figure 52 (Amaral and Aghezzaf, 2014)

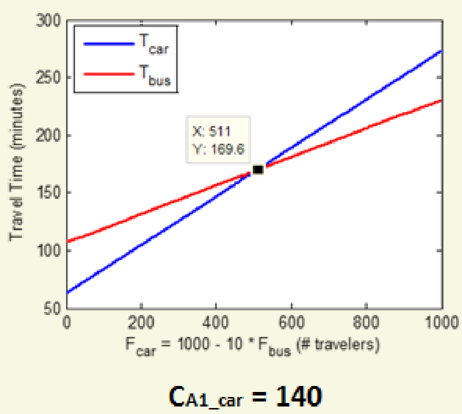
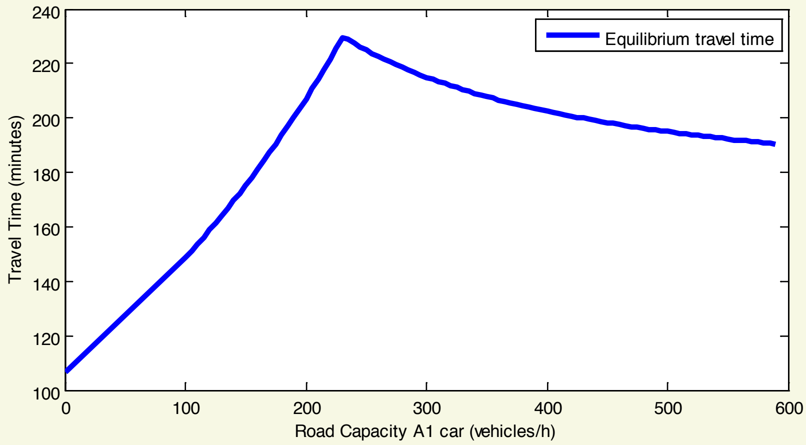


FIGURE 54

Figure 54: Equilibrium travel time in function of the capacity of road A-1$_{car}$ (Amaral and Aghezzaf, 2014)



In the same fashion as for the previously studied paradoxes, a higher capacity results in a longer equilibrium travel time. The calculation of the equilibrium travel time was repeated for many values of the mentioned capacity and the result is presented in Figure 54.

For simplicity, the user equilibria calculated in the examples above were based only on travel times. More complex models could use other variables to represent user perspectives and restrictions, such as personal comfort preferences. From these variables and travel times, travel costs could be derived and these would be used in the equilibrium calculations. Nevertheless, the simplification does not affect the analysis made.

Economists have summarized two reasons for the paradoxes. The first reason is latent demand, i.e., when the capacity of a route is expanded, it is likely that the number of users of that route will increase. The second reason is that congestion is mispriced, since drivers do not pay for the losses they impose on others. Bearing this in mind, some authors recommend congestion pricing as the most logical way to mitigate the unwelcome consequences of this uncooperative behaviour (Arnott et al., 1994). By wisely setting fees for using congested roads, an adequate marginal cost is included in the travel costs and users are pushed to choose a near-optimal solution.

Technologies for applying congestion pricing, such as electronic toll collection, are widely available and the technical implementation is not the main matter of concern. It is possible to charge users entering certain areas of the city or using particular streets and faster lanes in highways. For each case, mathematical models have been developed in order to determine the optimal price according to the demand and to the objectives of the regulatory authority, which can vary from minimizing congestion to maximizing revenues.

The congestion pricing concept was first implemented in Singapore in 1975, followed by Bergen (Norway) in 1986, Oslo (Norway) in 1990 and Trondheim (Norway) in

1991, Durham (UK) in 2002, London (UK) in 2003, Stockholm (Sweden) in 2007, and in Milan (Italy) in 2011. There are current proposals to implement it in major cities as San Francisco (USA), Beijing (China) and São Paulo (Brazil). However, it has not achieved the necessary public support in all places where it was suggested, and has already been rejected in several places including Edinburgh (UK) in 2002, New York City (USA) in 2007, Birmingham (UK) and Manchester (UK) in 2008. After analysing recent successful and unsuccessful cases, researchers have pointed out two important reasons for rejection: the uncertainty about its effectiveness and the lack of information on how it would be applied in practice (Hensher and Li, 2013). Other criticisms on congestion pricing are that it may harm local businesses and the economic activity in general, since it constitutes another form of tax. Furthermore, companies would possibly pass the added costs on to consumers, which could increase the risk of price inflation in the city and would still not help reducing congestion.

While congestion pricing increases travel costs in order to influence the network users to avoid busy roads, other measures can be taken to reduce the costs for users using alternative paths. Granting incentives to companies for using alternative transportation means such as boats, electric bikes, etc. or allowing them to use public transport infrastructure such as dedicated bus lanes and trams during non-rush hours are examples of initiatives which have already been successfully – and also unsuccessfully – implemented in European cities (Van Rooijen and Quak, 2014). The aims of such actions are not restricted to reducing congestion; instead, they comprehend the mitigation of all other sorts of nuisances caused by traffic.

From a game-theoretical point of view, these measures attempt to rationalize the competition performed by the users of the traffic network, creating a favourable setting for the interaction between the competitive strategies, which the network users tend to follow. It tries to ensure that the Nash Equilibrium is closer to the Pareto optimum, as Nash equilibrium is frequently Pareto inefficient seldom ensures maximal payoff.

Another possible approach, which can also be combined with the above-mentioned measures, is to instigate people and companies to act in a more collaborative way even when, at first sight, they have something to lose with it. Although such an idea seems irrational and unlikely to be effective, some changes in human behaviour in other areas of economy indicate that it can be a fruitful alternative. For example, a considerable number of people is consciously paying higher prices for organic food and fair trade products, driven by environmental and societal concerns.
It shows that the values of the society are changing towards a more sustainable world. Governments can foster this change, using media and other means to make people more aware of the damages they may cause with their transportation and consumption decisions, while this awareness is an opportunity for companies to create a competitive advantage by being green and sustainable. In fact, such change in the public's mind-set increases the costs for the non-sustainable users, in the sense

that they are not be perceived as worthy of confidence and acceptance. The collaborative approach perfectly fits in the game theoretical framework.

All the suggested strategies require considerable investment, from research and feasibility studies to practical execution and maintenance. As any public expenditure, they should be carefully evaluated from an economic point of view, meaning that the returns must compensate the efforts. However, savings and costs may come from different sectors of the economy and in different spans of time. For instance, the use of non-motorized vehicles, such as bikes, can have a positive impact on healthcare costs in long-term by avoiding cardiovascular, obesity and other diseases. This is one of the reasons why some governments decided to pay bike commuters per kilometre ridden.

The competitive and cooperative strategies discussed in this section consider how citizens and corporations may be influenced to act – and interact – towards the goals of making the transportation network more efficient and less unfriendly to the environment. However, network planning and design, as well as traffic management and control, are centralized by public authorities. In the next section, we discuss the possibility of sharing these decisions with other users, in particular with the logistics operators.

Integration between logistics and traffic management systems

Traffic management and logistics optimization have been extensively studied as two separate classes of problems, for which numerous methodologies, mathematical models and algorithmic solutions are discussed in literature. However, traffic managers and logistics operators have devoted little attention to the interactions between the variables involved in these problems and the consequences of the decision-making processes carried out independently. As a consequence, both systems may be operating at suboptimal levels. This happens because some exogenous variables to logistics problems are endogenous to traffic management, and vice versa. The flow demand, for example, is partially determined by the first class of problems, and used as input for the second class. The network topology and traffic rules, on the other hand, are determined by traffic management systems and used as fixed parameters in logistics problems. The interconnection between the two classes of systems is represented in Figure 55.

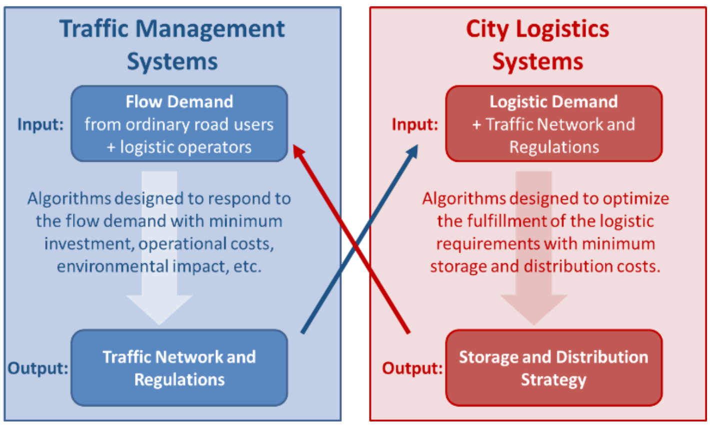


FIGURE 55
Interconnection between Traffic Management and City Logistics (Amaral et al., 2015)

An example can help elucidating how suboptimal decisions are taken by the stakeholders involved in these separate optimization processes. A traffic manager considers forbidding the access of heavy trucks to some small roads in order to reduce the congestion level. They assume that the trucks will be rerouted to other roads. But, instead, the logistics operator responsible for the trucks may simply replace them by a larger number of smaller vehicles. The congestion on the small roads becomes worse than before, and the costs for the logistics operator are also higher. It is clearly a lose-lose situation. Integrating traffic and logistical models and developing methods for the simultaneous optimization of both classes of systems constitutes an opportunity to be exploited in the city logistics framework. One possibility is to extend the formulations, which are commonly used for traffic management problems in order to explicitly take into account the participation of logistics operators (Amaral et al., 2015).

Traffic management is described in literature as a specific instance of Network Design Problems (NDP) and is usually formulated as a bi-level optimization problem. It can be expressed as

$$\min_{u} F\big(u, v(u)\big)$$

$$s.t. \begin{cases} G\big(u, v(u)\big) \leq 0 \\ v(u): v = \arg\min H(u, v) \\ \qquad\qquad s.t.\, g(u, v) \leq 0 \end{cases}$$

The upper-level objective function $F(u, v(u))$ is the total cost perceived by the traffic manager, which can include average travel times, length of traffic jams, air, noise and visual pollution, etc. This function is evaluated considering the set of control variables u which can be manipulated by the traffic manager, such as traffic regulations, network topology (e.g., by changing the traveling direction of a link from two-way to one-way), tolls, etc., and the users' response to these controls, denoted by $v(u)$. The traffic manager's freedom to set the variables u is limited by the constraints $G(u, v(u)) \leq 0$, which represent general traffic laws, budget restrictions, etc.

The lower-level function $H(u, v)$ and its related constraints $g(u, v) \leq 0$ represent the costs and restrictions which apply to the network users. The corresponding minimization problem is generally reduced to a Traffic Assignment Problem, in which all users try to minimize their travel times while respecting the traffic controls and network limitations. In order to determine the flow distribution, macroscopic traffic models consider the existence of demand rates, measured in number of vehicles per unit of time, between pairs of origin and destination points. Based on this assumption, Wardrop's first principle of route choice to calculate the flows can be applied (as in the example of the previous section).

Reducing the user behaviour to traffic assignment problems and assuming predetermined demand rates between pairs of points are the pitfalls of this approach. It overlooks the true objective and abilities of logistics operators, which intend to maximize profits rather than minimize travel times. They plan and organize their fleet based on business requirements and not only on traffic definitions. To address this oversimplification, the bi-level approach with its underlying traffic assignment model can be expanded by explicitly detaching the logistics operators from the ordinary road users, expressing their objective functions and constraints separately. A possible formulation could be:

$$\min_u F\big(u, v(u,l), l(u,v)\big)$$

$$s.t. \begin{cases} G\big(u, v(u,l), l(u,v)\big) \le 0 \\ l(u,v): l = \arg\min L(u, v^*) \\ \qquad\qquad s.t.\, g_L(u, v^*) \le 0 \\ v(u,l): v = \arg\min H(u, v, l^*) \\ \qquad\qquad s.t.\, g(u, v, l^*) \le 0 \end{cases}$$

The logistics operators' objectives and constraints are respectively represented by $L(u, v^*)$ and $g_L(u,v^*) \le 0$. They comprise the business objectives and requirements, while also being dependent on the set of control variables u and on an estimate of the traffic distribution of the ordinary road users, denoted by v^*. Examples of these functions are the ones which appear in vehicle routing and related problems. The estimate of the traffic distribution is again determined by a Traffic Assignment Problem, which has $\min H(u, v, l^*)$ as objective function and $g(u, v, l^*) \le 0$ as constraints. But now the response of the logistic operators' l^* is taken into consideration.

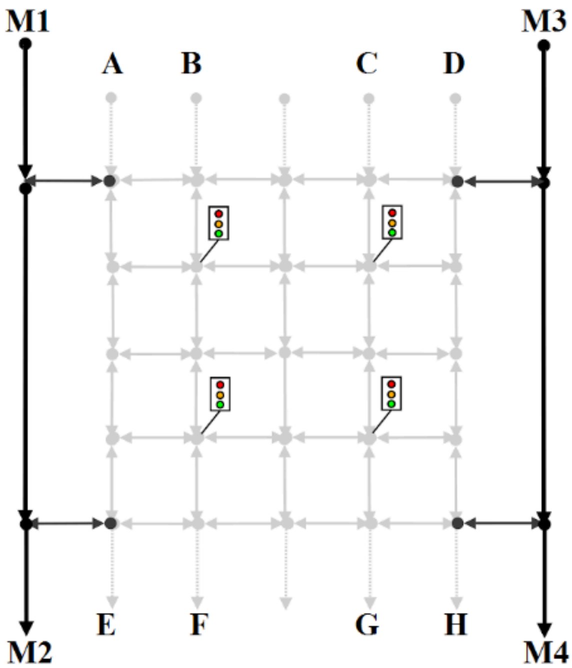
In practice, the optimization process works as follows. The traffic manager estimates the traffic flows and travel costs using the classic approach. The estimated values are used to derive the logistics operators' actions and, based on that, a new estimate of the flows and costs can be made. This process repeats until an equilibrium solution is reached. Then the traffic manager evaluates the results and manipulates the controls accordingly to predefined objectives, which may regard ordinary road users and logistic operators separately. A change on the controls possibly modifies the expected flows and costs, and, consequently, the logistics operators' decisions. A new equilibrium should be found and evaluated, and, if necessary, the controls may be readapted until the results satisfies the traffic manager's objectives or when a stopping criterion is met.

Optimality is quite hard to achieve in each of these approaches, since the stakeholders, i.e., traffic managers, ordinary road users and logistics operators, do not act cooperatively. In both cases, it can be seen as a One-Leader and Multiple-Follower Stackelberg Game, in which the traffic manager is the leader and the road users and logistics operators are the followers. Nevertheless, uncoupling logistics operators from ordinary road users in the second strategy gives the traffic manager more room to influence everyone's decisions towards a more efficient equilibrium solution. Finding compatible traffic assignment and logistical models to be used is one of the challenges arising when integrating the problems. The formulations may have to be adapted and the variables of each class of problem translated to the other class, possibly based on certain assumptions. Moreover, the computational complexity of the combined problems is undoubtedly much higher than that of the separate models, and this should not be overlooked.

Besides these technical difficulties, a managerial concern is implied in the integrated strategy: the traffic manager must have some knowledge of the logistics operators' decision-making process. Therefore, explicit cooperation between these stakeholders is highly desirable. However, depending on the performance indicators used by the traffic manager to adapt its controls, the outcome of the whole optimization process may deteriorate the results of some logistic operators, letting them worse-off than when their behavior is not anticipated. Dealing with this win-lose situation is thus an issue, which deserves attention.

An example of the described strategy is presented in (Amaral et al., 2015). The authors used the toy network depicted in Figure 56 composed of a small inner grid (light gray links) representing a fully bidirectional urban network which acts as interconnection for two surrounding motorways (black links).

FIGURE 56
Toy network used in the experiment (Amaral et al., 2015)



The link capacities are 3000 veh/h for the motorways; 1700 veh/h for all the horizontal links of the inner network; and 2000veh/h, 1800 veh/h, 1500 veh/h and 2000 veh/h for the vertical links, respectively from left to right. The Origin-Destination (O/D) demands accounted by ordinary road users are shown in Figure 57. As can be observed, off-peak and on-peak conditions were considered. The total simulation time is 2h, and the on-peak condition lasts from t=15min until t=60min. All calculations were done using time steps of 5 minutes.

FIGURE 57
Origin-Destination Matrix used in the experiment (Amaral et al., 2015)

OD Couple	M1-M2	M1-M4	M3-M4	M3-M2
Demand (off/on peak)	500/2000	500/500	500/2000	500/500
OD Couple	**A-H**	**B-F**	**C-G**	**D-E**
Demand (off/on peak)	500/2000	500/500	500/500	500/2000

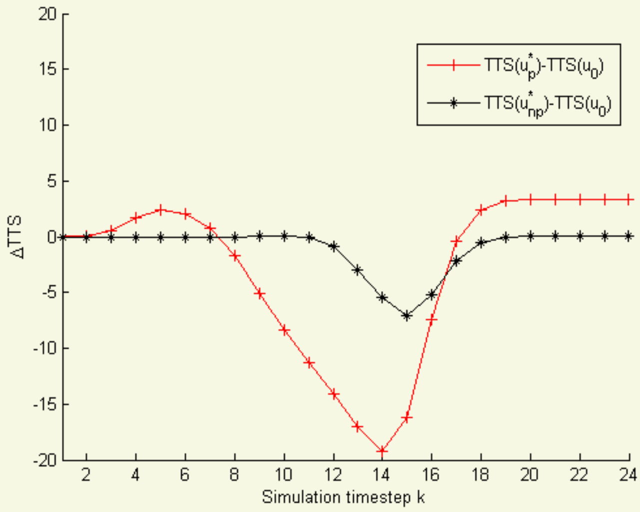
The logistics operators start their operations at the second time interval (t=5min) and, as from that moment, two operators enter the network every time interval. Each logistics operator has 10 time intervals to visit 8 customers. The last two logistics operators enter the network at t=70min, so that they can finish their operations just before the end of the simulated period. The primary goal of the logistics operators is to use the minimum number of vehicles, and their secondary goal is to minimize the total travel time of these vehicles. The customers that each logistic operators has to visit are randomly generated and located in the 25 inner network nodes. When a logistics vehicle is assigned to a link, the flow on that link is increased by one unit, and the updated flows are used to determine the routes followed by the road users and the travel times, based on a traffic assignment model.

Four traffic light controllers are deployed on the network at specific locations, as shown in Figure 57. The traffic management decision variables are the green split rates for all four intersections, assuming no all-red time. All other junctions behave according to a First Come First Served basis, where First In First Out access is ensured. The objective of the traffic manager is to minimize the total time spent in the network by all users.

The authors calculated the minimum total time spent by the ordinary road users when the logistics operators are not taken into account (i.e., using the classic optimization approach, denoted by $TTS(u^*_{np})$) and when they are (i.e., using the integrated optimization approach, denoted by $TTS(u^*_p)$). This metric was compared to the total time spent by the ordinary road users calculated for a base case in which no optimization is performed and the traffic light controllers are set such that the green split is always 50%. This base metric is denoted by $TTS(u_0)$. The results are shown in Figure 58.

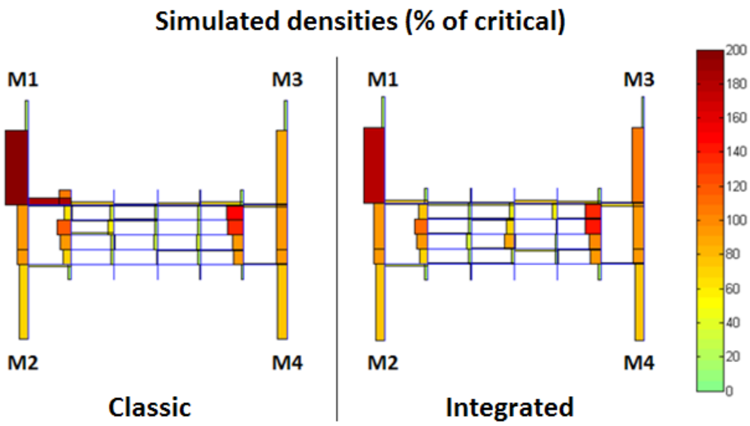
The greater negative area of the curve $TTS(u^*_p)–TTS(u_0)$ indicates the better performance when the logistics operators' behavior is anticipated. By calculating their decisions, the traffic manager is capable of driving them and also the ordinary road users to make a better use of the network, namely by using the central corridors more often. When their behavior is not anticipated, those corridors are underuti-lized, as observed in *Figure 3*. This figure shows the network link densities on the highest congested moment of the peak hour, which happens just before *t=1h*. The situations for the classic and for the integrated optimization approaches are depicted

FIGURE 58
Total Time Spent with and without anticipation of logistic operators' rerouting decisions (Amaral et al., 2015)



respectively on the left and on the right portions of the figure. The densities are superimposed on the links and characterized by width and color. The measure displayed is a percentage representing the number of vehicles assigned to the link divided by its capacity. Ideally, a measure of 100% means that the link is being utilized exactly at capacity and no congestion is happening, while any value greater than 100% implies congestion.

FIGURE 59
Network utilization with and without anticipation of logistic operators' rerouting decisions (Amaral et al., 2015)



Another interesting point to be remarked is the small increase on the values of the $TTS(u^*_p)–TTS(u_0)$ during the first time intervals. It indicates that the traffic manager can also induce the logistics operators to set earlier departure times for their vehicles in order to avoid longer delays due to peak hour congestion. This results in a small increase of the travel times in the earlier moments of the simulation, a fact that is certainly compensated by the gains on the later time intervals.

Concluding remarks

The central idea – and the main challenge – in City Logistics is the cooperation and win-win collaboration between the many and diverse stakeholders involved in mobility and delivery of goods and services in urban areas. Public administrators, traffic and infrastructure managers, manufacturers, retailers, logistics service providers and citizens must work together towards a more efficient utilization and deployment of the transportation networks in order to achieve affordable and sustainable life standards.

Unfortunately the objectives of the involved stakeholders often diverge, many strategies and solution approaches often end up being win-lose situations. These strategies should not be immediately rejected; instead ways to compensate the losing parties should be sought. Therefore, being able to estimate and monetise the gains and losses of the possible actions is absolutely necessary. Nevertheless, some relevant questions on this issue may not be possible to answer directly. For instance, how much would people be willing to pay to have less noisy streets or a cleaner environment? Political instruments and methods are thus required in order to set the goals, standards, guidelines and regulations which represent the long-term will of the population.

Another concern, which must not be underestimated, is that transportation is connected to many other economic activities, such as automotive and petrochemical industries, in an indirect but strong manner. Bearing this in mind, governments should make sur not to send out contradicting signals to the society. For example, it was very common in the last decades to stimulate production and commercialization of private cars during economic downturns in order to preserve employment rates and consumption. Tax reduction and credit supply were methods used to achieve this. This approach, however, would not match the advices of traffic and transportation experts who motivate the use of public transport.

To conclude, city logistics and mobility are among the key challenges faced by major cities around the world. The positive as well as the negative side-effects of urban logistics and mobility are expected to become more and more acute in the future. Solutions dictated by a political agenda or those imposed by the strongest stakeholder are unlikely to solve the logistics and mobility problems. The solutions that are required not only have to be Pareto-efficient, but they also need to be practical and sustainable. Multidisciplinary expertise is necessary to tackle such a multi-faceted integrated problem. This chapter proposes some operational strategies to integrate logistics and traffic management in urban areas, as initial steps towards equipping the city logistics framework with the missing tools for operationalization.

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BOX

Against sustainable mobility

on the need for irony in sustainable mobility and the democratic need for transport studies

Thomas Vanoutrive
Kobe Boussauw

Setting the scene

This dialogue about sustainable mobility starts with a discussion on the dialogue as a genre of scientific writing, it subsequently reflects on the concept of sustainable mobility and illustrates that there is no such thing as a homogeneous sustainable mobility discourse. The text argues that sustainable mobility primarily deals with questions of justice and goodness and establishes a link to social justice-inspired work. After some thoughts on irony, this contribution deals with the twofold role of transport studies. Firstly, researchers are in the position to make the normative nature of discussions on mobility more visible, and to reflect on the principles underlying transport policy. Secondly, they are able to make a profound analysis of the current transport system and its genesis.

Dialogue

Two researchers meet to discuss further their ongoing work on sustainable mobility. A enters B's office, knocks on the open door and starts the conversation.

A Good morning, what are you reading?

B Hello, you're already here, welcome. Well, I'm currently reading this book on the design of experiments[1]. It's a useful source if you want to conduct discrete choice experiments.

A Let's have a look, uhm... This part is written as a dialogue, interesting.

B Indeed, each chapter starts with a real-life situation where the authors visit a company that faces a test problem. During their conversation the problem is sketched and some potential solutions are discussed. It's an excellent way to illustrate that all this matrix algebra serves practical purposes. It also shows that the final chosen solution is the outcome of deliberation, and that some decisions taken during the research process are not as evident as suggested by the presentation of the final results in a standard research paper.

A I agree, the way in which scientific work is presented isn't neutral, but as Andrew Sayer remarked, "with only a few exceptions social scientists have paid surprisingly little attention to the fact that their knowledge is invariably presented in the form of texts".[2] Unfortunately, his appendix on academic writing does not discuss the dialogue.

B Why should he have done this? Form isn't neutral, but hey, I'm just reading a book about applied statistics. The dialogues are a plus, but why should we pay special attention to this aspect? I doubt that Plato would be lost in history if he had written in a different style.

A I don't know, but perhaps there is a more relevant question here: can we understand Plato's work without paying attention to its style, the dialogue? As Feyerabend maintains, Plato deliberately chose the dialogue.

B Feyerabend, the court jester of philosophy?

A A jester, yes, but a brilliant one. And he has written some dialogues himself. Look what he said about Plato's choice. I have it somewhere on my computer, wait a minute ... ah, here it is. According to Feyerabend, Plato 'showed much greater freedom than modern philosophers who don't even consider the problem, who get upset when serious matters are being presented in a disrespectful or in a dramatic way, and who at any rate are being controlled by editors with their own ideas about the proper shape of a philosophical (scientific, theological) sentence'.[3]
B There he is right. I remember the story of Akerlof who won the Nobel Prize in Economics in 2001, but whose most influential paper, 'the market for lemons', was rejected several times by editors. He believes that one of the reasons for rejection was the readable style which was in contrast with the 'solemnity of economic journals'.[4] But coming back to the dialogue, what are you trying to say? That writing dialogues would improve the readability of academic journals?
A That's a potential advantage, though not the essence.
B Then, what is the essential advantage of dialogues? There are other ways to link science to real life. Take for instance this book of Shaw and Docherty, each chapter starts with a story out of the life of the imaginary family Smith.[5] The effects of transport policy on their lives is illustrated by descriptions of a business trip, their summer holiday and a family visit. The inclusion of dialogues wouldn't be an improvement in terms of readability, relevance or exposition. And without denying his importance, it's fair to state that the average work of Plato is not an easy read.
A Maybe, but as the book you're reading on experiments illustrates, a dialogue can help to bridge 'the gulf between ideas and life'.[6] Note that Plato preferred oral over written dialogues, his ideal was a personal conversation and that's why he considered the dialogue, if I may quote Feyerabend again, 'the best medium for exploring difficult problems'.[7] And that's the essence, both Plato in the Phaedrus and Feyerabend see a conversation as a proper form to apply in the case of debatable things, in other words, when we deal with questions of justice and goodness.[8]
B Thanks for your philosophical reflections; can we now turn to the topic of this meeting?
A You want to talk about sustainable mobility, isn't it?
B Yes. So, can we forget about Plato for a minute?
A OK, but I'm afraid we will meet Plato again.

Sustainable mobility

B I've thought a bit about the point you made the last time we met. While we were discussing the definition of sustainable mobility, you claimed that the question 'what is sustainable mobility' should be replaced by the question 'who is sustainable mobility'.[9]
A To be precise, I claimed that it is impossible to distinguish sharply between conceptual and sociological issues when debating sustainability.
B Well, I went through some papers and books on the topic and they confirm your

point of view. According to Enoch, there are two 'transport tribes'.[10] The first is the 'supply side camp' that advocates investments in infrastructure on the basis of their 'predict and provide' philosophy. This is the traditional domain of conventional transport engineers and economists. The sustainable mobility tribe on the other hand is rooted in urban planning and related disciplines. Their preferred strategies are Transportation Demand Management or mobility management. Enoch admits that this division in two camps is a bit simple, but he observed increased levels of polarisation between the two sides.

A Nevertheless, even I know a couple of engineers who identify themselves with the 'sustainable mobility camp'.

B The existence of such converts does not contradict the existence of camps or tribes, on the contrary. But I agree that it's not just a matter of opposing academic disciplines. In an iconic paper, Banister presents sustainable mobility as an alternative paradigm, perhaps 'paradigm' provides a better description than 'tribe'.[11]

A As long as it's not seen as a scientific paradigm in the strict sense. But the fact that they present themselves as an alternative illustrates the importance of self-identification. We, the sustainable mobility camp, against them, the unsustainable lovers of concrete. However, I assume that the world is a bit more complex than that?

B Indeed, I believe that a closer look at a couple of cases enables us to better understand the diversity of opinions regarding sustainable mobility. My plan was to use a search engine to discover which organisations self-identify with 'sustainable mobility', as websites are an easily accessible source of self-images.

A But ... ?

B Even when I restrict the analysis to the URLs which contain the Dutch translation of 'sustainable mobility', 'duurzame mobiliteit', I end up with more than a thousand URLs. When grouping the URL's per website, I obtained a sample of more than four hundred websites. But the quantity of sites isn't my major concern, I'm uncertain about the data since it is virtually costless to create an URL which contains 'sustainable mobility' or a related term.

A Can you circumvent the problem by having a closer look at the links to other websites? Take some typical websites and look whether these refer to the same sites, this approach might offer a more robust view of what is considered sustainable mobility.[12]

B Interesting suggestion, give me five minutes.

A That gives me time to return these books to your faculty's library. [...]

B Ah, you're back.

I analysed ten websites so far and the results seem robust. Most of them have a link to the websites of the public transport operators, the cyclist federation and the sustainable mobility network, a network of civil society actors. Other popular sites include car sharing initiatives, the Federation for a Better Environment and the Flemish government. This can be considered the core of the Flemish network of sustainable mobility actors, we seem to move towards an ActorNetwork Theorytype of analysis.

A You can see this as an attempt to map the sustainable mobility actor-world.[13] But ANT-scholars would include a more diverse set of actants, for them railway tracks, the daily passage of bicycle commuters in front of a government building as well as a traffic accident can be part of the network. Here, we just list some organisations on the basis of their websites as a pragmatic way to define 'sustainable mobility'. It shows that alternatives to solo car use occupy a dominant position in this list. Sustainable mobility is thus a response against a car-dominated society.

B Yes, but this anti-car opposition has come in many forms, Paterson discusses no less than seven varieties.[14] A first strand focuses on technological solutions to green automobiles or to replace them by sometimes futuristic new transport technologies. Technological innovation is also proposed as a solution to problems of road safety, a second key issue in anti-car protest, next to emissions. Dependence on oil is a third problem addressed in sustainable mobility discourses, thereby emphasising the geopolitical consequences of the automobile system.

A With an obvious link to peak oil debates.

B Indeed. Oil dependence and peak oil arguments found their way in the sustainable mobility literature, also in the work of urban planners who traditionally have a more local focus.[15] How the car conquered and transformed urban space is a recurrent theme in the planning literature.[16] The deterioration of public space is a fourth protest-inducing car-related problem discussed by Paterson. The last three are more normative in nature: the obsession of society with speed, the role of the car in the reproduction of inequalities in terms of gender, class and so on, and finally, the hyper-individualistic lifestyles associated with driving.

A And why do you consider the latter approaches more normative than the discourse of the technocratic environmentalists? Despite the use of technical language and measurable indicators in many studies and reports, they contribute to a sustainable mobility myth-making process. The typical introduction of a sustainability paper, with all its references to sea level rising, tipping points and levels of CO_2 emissions, tells more about the beliefs and convictions of the authors than about the actual effects of human emissions of greenhouse gasses.

B I didn't know that you are a climate sceptic.

A I'm not. As far as I know, it seems very likely that carbon emissions will have a significant effect on climate, and that serious health problems are caused by other emissions such as particulate matter. But that's not the main message of scientific papers which belong to what Baeten calls the orthodox sustainable transport vision.[17]

B No, their main message is that we should act. Their recommendations are prescriptive, you can call that 'normative'.

A They indeed say that tough decisions have to be made since business as usual is no longer an option. But their main message is that growth is not necessarily problematic, that society can be greened without affecting the structural characteristics.[18] So far, there's little evidence that so-called sustainable mobility strategies make a better place of this world.

B Come on. Don't be cynical, several promising developments can be observed. In Belgium, as an example, quite some indicators suggest that sustainability objectives are slowly but surely achieved within the field of transport. With an average annual growth of 2.41% between 2000 and 2011, inland navigation in the Flemish region could make a nice report.[19] In 2011, sulphur emissions from inland shipping, rail and road transport have practically disappeared, but twenty, or even only ten years ago, the situation was entirely different. When looking at Belgium's federal home-to-work travel survey, we see that both public transport and bicycles have gained market share between 2005 and 2011.[20] Also, national road traffic statistics show that the number of kilometres driven per car registered in Belgium is decreasing, while the number of train passengers increased by as much as 50% between 2001 and 2010.[21]

A I agree, rail transport is on the rise and is considered by many a key element of sustainable mobility. Today, I came by train myself, but look what I found on their website when I checked the timetable. The most prominent feature is this advertisement.

B 'Straight to Brussels Airport by train. Child's play!'.[22]

A And a childlike drawing of a train circumventing a traffic jam. The rail track connects the train to the airplane. This advertisement tells you that rail is primarily seen as a travel alternative; this corresponds to the belief that the main function of public transport is to solve congestion on the road network. Moreover, it supports the view that taking a plane is a normal activity. Rail transport is heralded as one of the pillars of sustainable mobility, but promotes the most problematic mode of transport in terms of climate change impacts, the plane.

B And that's only half of the story. To increase the accessibility of Brussels airport, a new railway connection was opened in 2012, the 'Diabolo'. By the way, this was the first Public Private Partnership for the Belgian rail infrastructure provider and they won a European Rail Award for this project.[23] However, the media labelled the PPP agreement as a 'killer contract' since the private investor can force the railway company to take over the investment when passenger numbers are lower than originally anticipated. Some estimate the cost at about one billion euro. This contract is the main reason why so many trains make use of the tunnel, and why increased priority is given to trains to the airport in the most recent timetable.[24] Perhaps, the 'straight to Brussels Airport by train' advertisement should be seen in light of these discussions?

A Probably. But one thing is certain, advertisements offer an interesting entry point for transport research.

B Then you agree with Paterson, whom I referred to earlier, but his focus is on publicity for cars.[25]

A And also in the case of public transport, what is not said is just as important as what is said. Publicity generally remains silent about the social role traditionally attributed to public transport. Prestigious railway projects and attempts to attract car users might come at the expense of captive rail-travellers, mainstream sustainable mobility discourse generally devotes little attention to the social dimension of sustainability.[26]

B Despite this focus, public transport remains important for many users to be included in society.

A I agree, but when you talk about sustainable mobility, I'm afraid that more people think about the railway connection to the airport than about the diesel bus that enables an old woman to make her weekly visit to her sister.
B Which brings us back to the initial question: 'What and who is sustainable mobility?'. Following your approach, it is, among other things, a railway company which aims to improve the accessibility of an airport. What about cycling? That's far less controversial.
A I beg your pardon? I'm not against cycling, but the propaganda of many governments and universities portrays white, middle class, sporty, male employees as heroes if they cycle twenty or more kilometers to work on an expensive racing bike. Those who fulfil their environmental responsibility in a different way or aren't able to cycle for whatever reason, they have failed.[27] But let us now go back to the question what all sustainability measures have in common.
B Excellent idea, given that we still haven't found a definition of sustainable mobility. However, it's hard to find a common element in sustainable mobility indicators, there are more than a thousand of them.[28] And the environmental or climate change dimension is not present in all of them. It's also about liveability, poverty and economic viability.
A The common element is that for each indicator a higher value has either a positive or a negative normative connotation. That's also what Neuman says, sustainability can be linked to ideas of resilience, carrying capacity and diversity, but remains basically 'a Platonic idea, a category of the good'.[29]
B And so, we're back to Plato. Happy?
A I hope it's clear that sustainability, and sustainable mobility, is about questions of justice and goodness. Environmental degradation is just one side of the sustainable mobility coin, the other concerns the world we want to live in.
B Then 'sustainable' and 'good' are synonyms?
A At least in the past decades, it's time and context specific. I wanted to stress that environmental debates are not just technocratic discussions, the unjust distribution of causes and effects in space, time and along class and gender dimensions is an important aspect of the debate. And, even more important, a negative approach to sustainability which narrowly focuses on emissions and negative impacts misses the essence: it's all about the good life.
B Isn't that the point of those paternalists who wrote 'How much is enough'?[30]
A The Skidelskys? Yes, they too don't shy away from morality. But can I make a last reference to Plato and his style?
B The dialogue? I can't stop you.
A Aren't debates and dialogues the preferred way to discuss difficult things?
B That's what you said earlier.
A Isn't the dialogue, and discussion as a social activity, not the core element of democracy, as is argued by Martha Nussbaum and others?[31] Transport scientists are trained to write using technical language, but the Socratic ideal of discussion and dialogue is absent from many studies and courses on mobility.

B Correct, but the past hour I mainly heard cynical remarks from your side. A sham scientist who questions everything and all will contribute little to society. I'm sorry, but that's the truth.
A I know, but I considered it necessary to make my point.

Irony

B Well, what do we need, apart from dialogue and discussion, to make transport policy more fair, just and, ...uhm... sustainable? What's the alternative for your cynicism?
A Irony.
B Irony???
A Yes, irony is the cure for cynicism. Let us follow Jessop on this and consider transport policy as governance as reflexive self-organisation.[32] Transport policy making cannot be equated to hierarchical coordination in which the state implements a policy package to achieve fixed goals, neither is it an example of pure market exchange. And what is a crucial characteristic of governance and thus transport policy?
B Complexity? Opacity?
A Yes, but in the first place, failure. Markets and states are prone to failure as well, just like governance.
B Hey, you conceive failure as an absolute category, it's more realistic to see the spectrum between failure and success as a large grey area.
A Correct, but take for example urban planning in Belgium[33], virtually all commentators agree that the attempts to preserve open space have failed. It took decades to establish a legal framework, and even after the 1962 law was there, it took until the end of the 1970s to establish zoning plans. Moreover, these plans and the legislation have even facilitated sprawl and ribbon development.
B Yes, but house prices were kept low, homeownership is still a possibility for many households and the land use of each plot of land is known. It wasn't an absolute failure.
A But you have to admit that you consider land use planning in Belgium a failure. At least, that's what you've told me several times. There are several reasons for that; goal-displacements are likely to occur during the establishment of a bureaucratic apparatus and also for technical reasons, and the basic outline of a large-scale plan is hard to change while the world changes unpredictably. Society is not engineerable, isn't it?
B There are some limitations, and if I understand you well, I have to take an ironic stance towards governance failure.
A At the private level, irony means that you continuously put into question the way you conceive the world and the way you currently think about things.[34] At the more public level, irony is also about giving up certainty, and the ironic position involves proceeding as if success were possible while recognising the inevitability of failure.

This optimism explains why it is also called romantic irony, which stands in contrast to the paralysing pessimism of the intelligence.[35]

B Pff... that's stating the obvious: we must be both critical and enthusiastic. Is that how we will solve transport problems?

A No, being an ironist is a cure for cynicism. And irony is not obvious, I can't see the irony in all these prescriptive sustainable mobility studies which claim to know what we should, or shouldn't, do. But to answer your question, besides romantic public irony Jessop emphasises two other general principles of governance.

B And these are?

A Variety and reflexivity. Variety, or not putting all your eggs in one basket, is needed to retain flexibility in a complex and changing world. Reflexivity is about learning, but especially about the adoption of a satisficing approach. Reflexivity entails asking the question: 'which outcome is acceptable'.

B ... instead of designing a transport utopia. But should we focus on the outcome anyway? What's more important: the quality of the decision or the decision making process itself?

A Good question, given that society isn't engineerable, how decisions are taken seems to be more important.[36] As a consequence, sustainable mobility is primarily a question of participation and democracy.

Science

B This brings us to the existential question of why democracy needs transport studies?[37]

A A first role for scientists is helping to make the normative nature of discussions on mobility more visible, and to reflect on the principles underlying transport policy.

B For this, the most useful body of research seems what Farrington named 'the new narrative of accessibility'.[38] This literature builds on work in the 1970s[39] and focuses on social inclusion and the ethical dimension of transport[40]. The core idea is that access to activities and facilities is essential to participate fully in society. Access barriers can be financial or organisational in nature, but the focus of accessibility scholars is on the transport dimension. What I particularly like is their practical focus, the literature pays attention to job accessibility, access to food stores, libraries, social activities and so on. It's not an ivory tower literature, but a field of research with close ties to policy making, in particular to accessibility planning policies.[41] Such policies and studies pay attention to the daily lives of people, to the real impact of the decline of bus services, and to the transport or accessibility needs of people. To my opinion the accessibility literature tends to focus on more essential questions than studies that search for the most effective and efficient way to reduce the number of cars on our roads.[42]

A I understand you prefer to divert from mainstream discourse where the concept of demand, and not need, takes a central position.

B Yes, for accessibility scholars the just distribution of accessibility is based on the concept of need, hence, actual demand and willingness-to-pay are of minor importance. That is why the option value is considered important, even if you seldom travel by bus, the availability of an alternative or the possibility to travel have some value of their own. But to be honest, I struggle a bit with the concept of need. I do understand that the need to travel is a derived need – you need mobility in order to reach something else such as a hospital or a job location – but how much transport do we actually need? What is the basic level of accessibility someone needs to participate in society?

A It's a question without an answer, I'm afraid. Perhaps it helps us to see the accessibility discourse in a welfare state context. Some basic needs are undisputed, think of food, shelter and clothing, but discussions about needs cannot be distinguished from the process of needs interpretation.[43] When we claim that we need a bus service or a safe bicycle route, we claim a right, a right to be guaranteed by the state. Transport, in other words, is seen as a social policy problem.[44]

B Hmm ... I don't know... If accessibility needs are everything claimed to be needs...

A That's excessive relativism, some claims have more validity than others.[45] I just wanted to make clear that there is no objective list of accessibility needs, independent of context and interpretation. Conventional transport planning, however, is permeated with means-end rationality and suggestions of certainty.[46] But again, ethical questions, such as the just distribution of transport, have no answer but require public discussion and debate.

B So, it remains useful to measure how many persons have limited access to hospitals, food stores and schools?[47]

A Of course, investigating the problem is a good thing, and I prefer a problem definition based on access over one based on vehicle counts. But figures will not automatically tell you what to do, but they help in building an alternative imaginary. The accessibility discourse seems compatible with the imaginary of the grounded city.

B The grounded city?

A Just give me a second to find the manifesto... here it is.

B 'How to build a fairer city'.[48] Looks interesting.

A The authors of this manifesto propose the grounded city as an alternative to the competitive city. For them, fairness is about 'access to the foundational goods and services that all citizens should enjoy'[49], and sustainable transport is needed to guarantee this access.

B Interesting, and I agree that accessibility planning and the grounded city offer a positive project, but so far we ignored the downside of mobility: pollution, greenhouse gas emissions, traffic safety, resource depletion, ...

A ...which brings us to the environmental justice dimension of social justice inspired approaches.[50] Some groups and neighbourhoods get a disproportionate share of the burdens of transport.

B You focus on the distribution of the environmental burden, shouldn't we take the absolute levels of emissions into account too? The emissions of fifty people making one trip or one person making fifty trips are equal, but it matters whether fifty or five

hundred trips are made. Reducing the need to travel is a relevant issue.
A How much travel is enough?, to paraphrase the Skidelsky family.[51] The challenge is to develop a society where less transport is needed ...
B ... while guaranteeing access to foundational goods for everyone. Proximity seems key to achieve this goal. Less transport is needed when services, facilities and other destinations are located in proximity to origins and other destinations. That's why the 'city is the most sustainable urban form'.[52]
A It is, for urbanites living an urban lifestyle. I'm not sure whether such a lifestyle can be considered sustainable. Urbanites living in cities tend to drive less kilometres by car, but this is compensated by their airplane addiction.[53] Even if we offer the spatial conditions for sustainable living, there is no guarantee that citizens will show the desired behaviour.
B 'Desired behaviour'? Well, this sounds a bit ... I don't know ... you make me worry about the freedom left in our accessibility-based ideal. We haven't dealt with questions of freedom yet.
A And these are important questions to address. But why would the level of freedom be lower in a system based on proximity than in the present car-dominated system?
B Well, most people automatically link cars to freedom ...
A But I presume that more people are able to travel autonomously using transit, by walking or cycling. Think of children, the elderly and green widows. We've lost a lot of freedom with the rise of the car.[54] The idea that thousands of years of human evolution had one telos, one goal: becoming the world's freest animal, the human car driver, is a fiction. Think also of traffic cameras, toll gates, police controls ...
B The shrinking radius of autonomous travel by children is another well-known example. While grandfather was 'allowed to walk one mile to the woods', his grandson is only 'allowed to walk 300 yards to the end of his street'.[55] Indeed, there are reasons to doubt that becoming mass consumers of mobility has made us more free. What can I say, we still live in a capitalist society which is expansive in nature. Growth and consumption are the order of the day, whether we like it or not.
A Accordingly, a second role for science, besides debating the moral dimension of mobility, is a profound analysis of the current transport system.
B And of how the present situation came about. The car cannot be isolated from its role during the Fordist growth cycle where suburbanisation, mass consumption, increasing incomes and individualisation went hand in hand with the increasing popularity of the car as consumption item and status symbol. The rise of the system of automobility and the associated car culture is well- described, but still relevant since such self-organising systems create the conditions for their own self-expansion.[56]
A Interesting, but let me add a critical remark to this interpretation. By presenting automobility as a self-organising system, the role of agency and politics remains underexposed. The promotion of automobility is also the result of deliberate attempts to change society in a particular direction. The outcome is rarely what it was meant to be, but strategies have effects, alternative paths were possible and some relative small networks of people have been influential. Presenting the

history of transport policy as a mere cultural history misses the agency dimension and the fact that the introduction and rise of the car involved struggle and immense investments.[57]

B But the picture isn't complete without taking into account the cultural dimension. You can't understand the success of the car if you can't explain why and how millions of households took the decision to obtain a car and how this transport technology has entered the daily lives of people. This involved the development of particular lifestyles compatible with the automobile system. And I agree, marketing, government policy and power have shaped car-oriented lifestyles, but some ways of life are easier to promote than others.[58]

A I don't know, many a small thing ...

B ... has been made large by the right kind of advertising. Do you want to say that ridiculous car-oriented lifestyles have been successfully promoted: households who spend half of their incomes on luxury cars, get dressed in clothes full of logos of car manufacturers, spend their free time in their garages, ...

A I was just joking. But seriously now, isn't it interesting to see how particular technologies, such as cars and planes, have shaped society?

B It is. A discussion of the history of the twentieth century wouldn't be complete without paying attention to the role of the car. And isolating mobility from broader social contexts ...

A ... would be a travesty. This argument is applicable to the success of the automobility system, but also to the success of a particular variant of the sustainable mobility discourse. Would public transport and cycling be actively promoted in London if the advanced producer services weren't complaining about the city's transport infrastructure?[59] Can we not see sustainable mobility policy in New York as an elite project that goes hand in hand with gentrification and exclusion?[60]

B Probably not, but I still support local initiatives which promote cycling, transit, traffic calming and a more local economy.

A You're right to do so. Please, don't become a passive, cynical intellectual, but it would be too naïve to think that without altering the structure of society, compact, transit-oriented cities would solve the environmental crisis, and would be free of domination and exploitation.

B If I understand you well, I have to see the irony of my position.

A Uhm ... yes, among other things.

B And what about policy advice? Can we, as scientists, advise governments to implement sustainable mobility measures? We can play a role in improving the transport system, can't we? Doing research isn't just a hobby; researchers can help policy makers by summarising scientific evidence and by formulating policy recommendations.

A Yes and no, it depends what you mean by 'summarising'. Is this a consensus-building activity?

B To a certain extent ...

A But we concluded that there is no such thing as a homogeneous discourse on sustainable mobility.

B No ...

A Neither should this be a goal ...

B ... since the public debate you want to encourage requires diversity?

A Exactly, and when scientific work crosses the wall between Science and the State, it should be clear that recommendations are never of a 'take-it-or-leave-it' nature.

B A wall? Do you really want to work in a kind of ivory tower? I learned a lot from non-academics, we have no monopoly on knowledge.

A I agree, but the wall between Science and the State is needed to provide a free environment for scientists, remember that science needs methodological anarchism and disrespect for established conventions. Off course, researchers should leave this protected environment from time to time, and then it's up to society to decide what to do with the findings.[61] A consensus text is of no use for the subsequent broad societal debate. By this I mean a real debate, not one dominated by a limited number of powerful actors.

B Nevertheless, it's logical that scientists who investigate a problem form an opinion and actively participate in public debates as responsible citizens.[62] And that's a good thing.

A You're right, as long as scientific findings don't kill the debate. But you have to go to your meeting and I want to go to the toyshop around the corner to buy a toy car for my godchild's anniversary.

B A toy car, isn't that ironic?

A ...

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Governance and collectivity

MOBILITY GOVERNANCE IN SMART CITIES OF THE FUTURE

Enrica Papa
Dirk Lauwers

Introduction

The transport sector is at the start of a period of major change: new technologies, products and services are fundamentally changing mobility users and providers' expectations and opportunities, causing significant changes to transport systems in cities. To refer to these changed conditions, a common term used is the "smart mobility", which has become something of a buzz phrase in the planning and transport fields in the last decade (Campbell, 2013; Hollands, 2014; Jennings, 2010; Murgante and Borruso, 2013). It can be defined in line with the following realities: rise of the sharing economy, access over ownership, mobility services on-demand, the convergence of modes and types of transport, the blurring of the boundaries between public and private transport, the arrival of new entrants challenging the market and regulators to respond to a new world (Allwinkle and Cruickshank, 2011).
These modifications are reflected on both the transport demand and supply sides reshaping transport systems and fundamentally changing customers' expectations. On the supply side a system of new actors are entering the mobility system, which is seen as a business. New actors include multinational firms in the information and communication technology (ICT) sector applied to the transport sector, such as IBM, Cisco, Siemens have engaged in urban mobility initiatives conducted under the banner of the smart city, usually with the active support of the state and local administrations, but also novel entrepreneurial communities and innovative start-up firms (Rossi, 2015). On the demand side, citizens require much greater flexibility in line with the wider social trends around part-time working, working from home and more flexible journey choices. Moreover, due to new ways of working, such as remote work and virtual meetings, work-related mobility and its reliance of the office hours decrease. From more fixed mobility patterns (e.g. car ownership or long-term season tickets), we now see a trend towards the provision of access to mobility opportunities and the emergence of the sharing economy bringing a new mind-set to mobility users' expectations. The increasing diversity among travel modes, modern lifestyle is featured by increasingly multifaceted mobility means that destinations travel hours and reasons for moving varies.

A specific impact regards the 'orgware' aspect of the mobility in cities: increasing number of new global and local actors is entering the transport system. These changing conditions necessitate reflection on governance issues and of the role of public authorities in the new framework. In details new approaches, methods and tools are needed to support the development of new solutions that reflect these trends, to unlock major opportunities for businesses and to ensure that social and environmental goals remain in the planning agenda.

Indeed, after a fervent first phase in which information technology and digital data were considered the answer for making mobility more efficient, more attractive and

for increasing the quality of travel, some questions are been growing around the risks and challenges of smart mobility systems. The distance between the visionary potential that smartness is providing is too far from the reality of urban mobility in cities and in some case far for societal goals of environmental and equitable transport system. With a specific view of governance aspects, we argue in particular that two main aspects of smart mobility should be eluded: the first refers to the merely application to technology on mobility system, what we called the techno-centric aspect; the second feature is the consumer-centric aspect of smart mobility, that consider transport users only as potential consumers of a service.
Starting from this, the study critics the smart mobility approach and argues on a the need of a different approach for smart mobility, in which technologies are only one aspects of a more complex system and mobility consumers are instead active citizens, participating in shaping mobility and their city. With a view on the urgency of looking beyond technology and beyond consumer-oriented solutions, the study arguments the need for an interdisciplinary approach that could supports transition towards a "smarter mobility" for enhancing the place making and the development of vibrant cities.
Main research questions are: what are the emerging "smart mobility" issues that the governance of mobility system should address? How to face the governance challenges related to smart mobility?

This contribution does not intend to produce a radical critique of the smart mobility concept, denying a priori its utility. Our perspective is that the smart mobility is sometimes used as an evocative slogan lacking some fundamental connections with other central aspect of mobility planning. Our focus is in particular on the smart governance solution for mobility.

The chapter is organized in the following sections: section 2 provides the rationale behind the study; section 3 explores the evolution on smart mobility paradigm in the last decades analyzing in details the "techno-centric" and the "consumer-centric" aspects and analyzing the new emerging issues related to the governance of smart mobility. Section 4 proposes an integrated smart mobility governance approach. Some conclusions are finally drawn in section 5.

Beyond the smart mobility paradigm

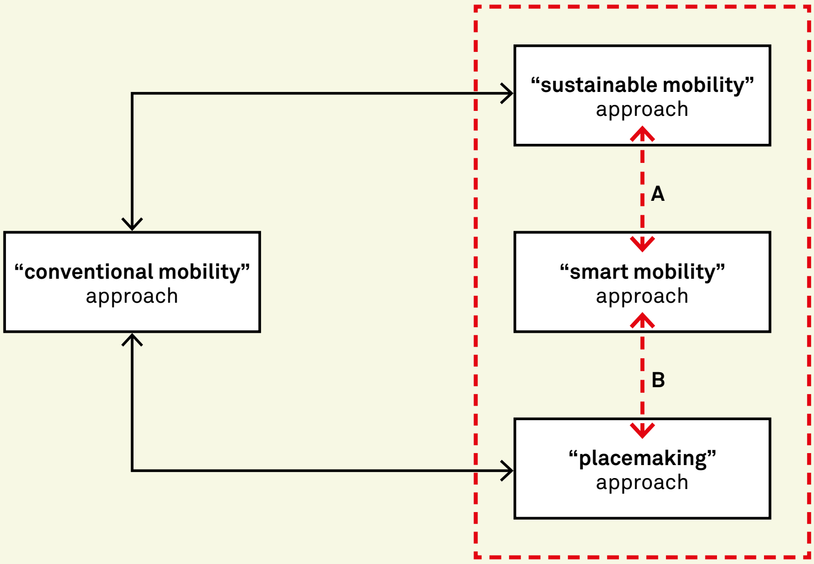
Different approaches to mobility systems and mobility planning have been developed and described within transport planning literature. The first one is defined "conventional mobility" planning and it focuses on the physical dimensions and on traffic (and in particular on the car) rather than on people: it is large in scale, rather than local, it is forecasting traffic and it is based on economic evaluation. In synthesis, the conventional approach is mostly aimed at shorting travel times, considering travel as a cost. In other words, traditional transport planning aims at improving traffic conditions; especially for motorized vehicles, and fail to adequately consider wider impacts. The "conventional mobility" paradigm could be seen as transport-based, as it maximizes travel distances by maximizing travel speed. Indeed, according to the "conventional approach", the performance of a transportation system was primarily evaluated on speed, convenience, and affordability. This approach was based on the "predict and provide" principle, meaning to predict future transport demand and provide the network for it, usually by building more roads. In other words, the lack of infrastructure capacity was countered by expanding road network that has strongly contributed to increase car use and to favor automobile-oriented improvements and had negative effect on the environment and safety.

In opposition to this, the sustainable mobility paradigm arose (Banister, 2008) which strengthens instead the links between land use and transport. It was clear that capacity of the transport system could not continue expanding. Indeed, the sustainable mobility refers to the broad subject of transport that is sustainable in the senses of social, environmental and climate aspects. The sustainable paradigm comprehends a broader range of modes, objectives, impacts, and improvement alternatives. Sustainable mobility is aimed at the ultimate goal of mobility, which is accessibility (Kennedy et al., 2005; Litman, 1998) and can be referred to as access-based, while it concentrates on creating access with the means of transport. This stems from the approach that creating access is the fundamental aim of most travel. In this sense it aims at reducing the need to travel and trip lengths and at encouraging modal shift and a greater efficiency in the transport system. In other words, the shift from conventional mobility to sustainable mobility involves moving from an idea of transport system performance, primarily evaluated based on speed, convenience, and affordability of motor vehicle travel to a more comprehensive, multimodal system of evaluation that considers a range of modes, objectives, impacts and improvement options (Litman, 2013).

Another approach to overcome the conventional mobility planning has been proposed and applied and it can be defined as the "place making" paradigm (Jones and Evans, 2012; Cervero, 2009; Gehl, 2013), born within the urban design literature and practice and applied also to the transport-planning sector. Density, diversity, design, distance to transit and destination accessibility become the key drivers in configuring the urban fabric and creating a place. According to this paradigm, the spatial and the transport systems have to be embedded first at the local scale, looking at the place making in local contexts. The attention here has been directed to the people and the places of the city and the emphasis is on the creation of quality of urban places.

Finally, a third approach has been proposed as an opposition to the "conventional" mobility planning: the smart mobility approach. With this term, academic research and industrial applications refer to the potential of optimizing existing city infrastructure, services, and urban behavior through the deployment and utilization of new technologies. The smart mobility approach, and its evolution, as described in the following section, is in fact mostly based on the application of new information

FIGURE 60
Mobility planning approaches and their missing links



technology for the innovation of transportation systems and it has been quite fashionable in urban and transport planning domains and in the policy arena in the last decade. According to some studies, the smart city and the consequent smart mobility concepts are no just limited to the diffusion of ICT, but it looks at people and community needs (Batty et al., 2014; Hemment and Townsend, 2013). Nevertheless, as explained in the following paragraphs, some important links with other aspects of mobility planning are still missing (Lauwers and Papa, 2014; Papa and Lauwers, 2015).

Starting from the distinction of the different approaches we want to provide insights on the weak or missing interrelations within them (Figure 60) and to analyze potential areas of cross borders both from in relation to specific planning goals, with have a direct impacts to governance aspects. Our main argument is that arrows A and B in Figure 60 that describe respectively the interrelations between smartness, sustainability and quality of places should be strengthen both in theory and in practice. In fact as stated by the executive director of the New Cities Foundation, the smart city (and in particular the smart mobility) seems to have lost its contact with humans: "if you type smart city on your image search engine, the first human being appears on the page number eight. The first hundred or so images are sci-fi renditions of cities that will probably never exist" (Lefevre, 2014). The same happens by searching "smart mobility" or "smart transport". In literature and in practice there is a gap between the smart approach, sustainability and place making approaches. We argue that in most case the paradigm shift is occurring directly from the "conventional mobility" approach, towards the smart mobility one, by applying new technology to transport system that instead would need better other solutions. In other words, the concept of smart transport as synonymous with innovative technological or consumer-centric solutions should go beyond this, in order to embrace citizen co-creation models for helping to drive the next generation of smarter cities. There is still a huge need of supporting the growth of broadband digital infrastructure, wireless networks, e-gov and m-gov services and Internet of things sensor networks. However, all of that smart transport systems capability should be increasingly geared towards enabling citizen co-creation and urban transport entrepreneurship.

In this general framework, in the following paragraphs we examine the links between the goals and governance aspects of smart mobility and the others: the "conventional approach", the "sustainable mobility" approach, and the "place making" approach, stressing the missing crossovers in theory and practice of the three.

The evolution of the smart mobility concept

The term smart or intelligent mobility appeared at the beginning of the Nineties in order to point out at a city with a mobility system more and more dependent on technology and on innovation. Within the "smart city", studies have defined it in many different ways (for a complete and updated list see Albino et al., 2015). Intelligent Mobility is usually defined as a way of thinking about how to connect people, places and goods across all transport modes. It is about the utilization of a combination of systems thinking, technology and data across the transport network to inform decision-making and enable behavioral change. Despite the difficulty to account for the multiple meanings attributed to the concept and the many different approaches in current urban planning literature, we focus on two main aspects, described in the following paragraphs. The first is a "techno-centric" approach based on the application of information technology to transport infrastructure, and the second one is a "consumer-centric" approach, based on the idea of providing new mobility products for transport users, considered as consumers.

The techno-centric smart mobility

The techno-centric aspect of smart mobility is characterized by a strong emphasis on the "hardware" and, namely, on the idea that ICT infrastructure represents the keystone for building up the Smart Mobility. Accordingly, it refers to the implementation of information and communications technology (ICT) in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport. As transport infrastructures have evolved over the past decades, they have become more complex and now often have deeply interwoven interdependencies on other infrastructures. For example, most large-scale infrastructure assets are increasingly relying on flows of information and other communications technologies.
According to this approach, ICT represents the keystone for building up the Smart Mobility, relates the infrastructure of smart cities to their operational functioning and planning through management, control and optimization (domain of both large and small ICT companies). Indeed ICT has played an increasingly influential role in transport systems since the 1960s, mainly in improving efficiency of operations by

being embedded in business processes. Solutions to the mobility problem are seen in technological fixes and high tech solutions, such as alternative fuels, intelligent transport systems, integration of information and communication technologies and means of transportation etc. In the face of the outlined challenges of current mobility regimes, mobility scholars tend to see potential solutions in new technologies and their combination, e.g. smart motilities systems.

With recent advances in cloud computing, along with the increasing ubiquity of mobile devices and cheaper sensors, however, the role for ICT within the transport sector has expanded dramatically and is now a source of industrial disruption, creating new linkages between economic actors and providing entry points for smaller companies as well as players from adjacent markets.

ICT is being implemented into three main ways in the transport sector (Mulligan and Olsson, 2013):

- large-scale transport system, implemented across cities in order to streamline and improve efficiencies within existing systems;
- small-scale transport system, implemented at "app" level, based on open data from cities, in order to help transport users connect with existing transport solutions in a more convenient manner;
- industrial disruption implemented on either "app" or large-scale level and disrupts the established industrial structure, either through the introduction of new players or by completely redefining the transport system itself.

ICT exploits information and communications technology, thus improving traffic flow, enhancing safety, de-creasing environmental disadvantages, generating advantageous services for car drivers, and establishing increasingly convenient multimodal mobility service use. ICT strongly contributes to an increase in the efficiency of the system. The techno-centric approach, largely widespread in the early 2000s and mainly focused on the technological aspects, provides a vision of smart mobility as capable of maximizing its efficiency thanks to a large and widespread use of ICT. Such a vision, which has been largely sustained by multinational companies, leaders in the sector of ICT manufacturing, focuses on infrastructural innovation. The techno-centric approach is still largely widespread, but even the vice-president of CISCO has recently pointed out that something should be changed. He stated indeed: "we are crossing the threshold to put internet-based tools to work in cities (….) technological devices are merely tools that can make our life better only if they are put in the hands of users who understand and can make the most of them" (Elfrink, 2012).

The consumer-centric smart mobility

The consumer-centered smart mobility is characterized by a strong emphasis on the human side and it has been largely widespread in the second half of the 2000s. According to such an approach, Intelligent Mobility combines a strong focus on putting the customer at the heart of the service offering with the requirement of integrating all transport opportunities into a whole system. Again, in this approach the user and their experience and requirements must be at the center of mobility provision.

Accordingly, the human component represents the crucial element for building up a smart mobility system: more and more widely available technologies are intended as "enabling tools", but insufficient to make "smart" an urban context, only by themselves. In practice innovations (infrastructures, vehicle and services) look at people, seen as end-consumers of a service, reflecting their individual needs. Applications furthermore are aimed at again optimizing consumer's mobility behavior through the ITCS (behavioral aspects), but without considering other more comprehensive central goals.

In other terms, while the techno centric approach is mainly focusing on the supply side, the consumer centric focuses on the demand side of transport system, but with the limit of looking at transport users as consumers of a service, than as citizens. According to this approach, changes in the transport system are taking a user-centric approach to looking at mobility opportunities for customers as part of a wider, integrated system. Indeed recent decades have seen a proliferation of small scale consumer technology such as smartphones and tablets as well as an increasing availability of cheap computational capacity in the form of cloud computing. These technologies have now reached a point where they are able to reshape industrial structures as they permit the creation of new organizational forms.

Customers are now using new and multiple channels to communicate and to keep informed. Additionally, we see a growing requirement for personalization of services. Customers are looking for ways to make their journeys easier both in planning and in undertaking them. We only need to look at the uptake of new services such as online journey planning and ticket purchasing; the use of social media to communicate with operators; and the growth of apps like Citymapper, Moovit and Waze, to see that customers have an appetite for new ideas, it is now for the transport sector to respond.

Start-up companies who are creating innovative new products and services such as Bridj's 'pop up transit' or Uber's take on taxis and lift sharing are opening up transport sector.

Information and knowledge on the agents' action space are needed to better customize the mobility service in an increasingly difference-based and dynamic world, and adapt the mobility service to the evolutionary aspects of mobility. Key to this is the pervasive theme of innovating with a focus on putting the transport system users at the center of the mobility service (Atkins, 2014).

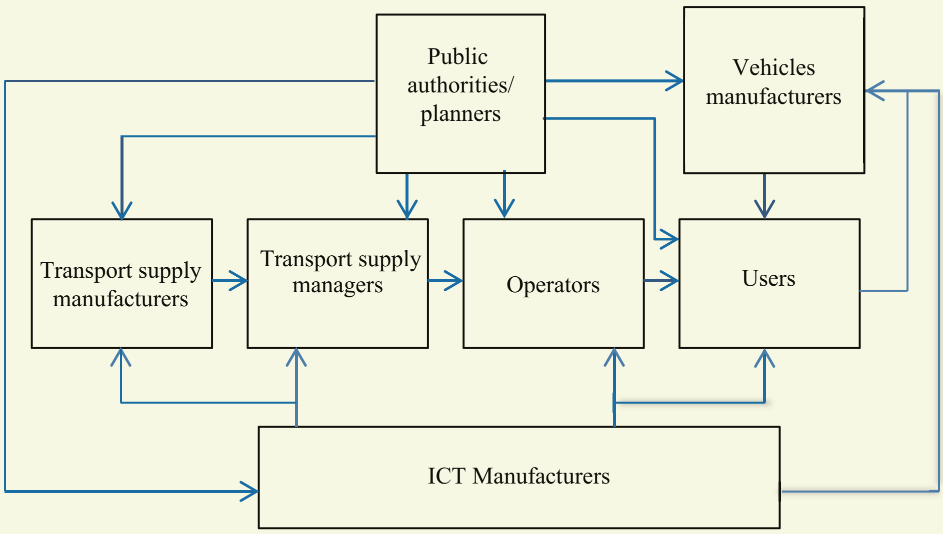
Emerging "smart mobility" governance issues

In the previous paragraphs, two different aspects of the smart mobility approach have been described and what emerge in both cases is the gap between the "smartness" and sustainability and place making aspects. The increasing part of ICT industry and the changed role of transport users into "consumers" bring a new set of issues in planning and in governance processes of mobility systems. Indeed, in both smart mobility approaches described previously, some crucial changing conditions are taking place, modifying the actual assets of decision rules (Nam and Pardo, 2011; Wachowicz and Portugali, 2012). Concerning the techno centric approach, new local and global ICT manufacturers are entering the mobility market, with the risk of losing contact with the public authorities and mobility planers. Concerning the consumer centric approach, consumers are getting into the center of the system, with the risk of the prevailing of personal goals instead that mobility planning collective goals. In both cases, the public priorities and collective urgencies are putting in a second order.

The market is evolving because of several factors interacting with each other, including technological advance, policies that governed the interaction, and the activity of market participants. In the following scheme (Figure 61), the users and ICT manufactures are embedded into the transport value chain, showing the relationships between the different actors involved in this transition. The entrance of ICT and the centrality of mobility consumers let new organizational forms to emerge also outside of industrial boundaries, challenging the traditional organization. At the same time end users are now also more deeply embedded in the transport value chain: firstly, through the capturing of an end user's private data and secondly, through the capture and analysis of an end user's behaviors. From the governance viewpoint, ICT is already having a transformational impact on the transport industry, destroying existing relationships between actors in the value chain and creating space for new entrants. Market for Intelligent Mobility is rapidly developing as customers, transport authorities, businesses and governments understand the huge potential for unlocking major opportunities. Indeed, in the last 10 years we have seen technology introduced that has either directly delivered, or enabled, significant disruption across a number of sectors. This is hugely significant to the transport sector – as customers increasingly adopt new technology, it enables new services to be developed that are bringing real benefits to customers. We can now check live bus times or buy train tickets on our phones as well as plan our journeys and keep an eye out for any issues on the transport network, such as congestion, as it arises.

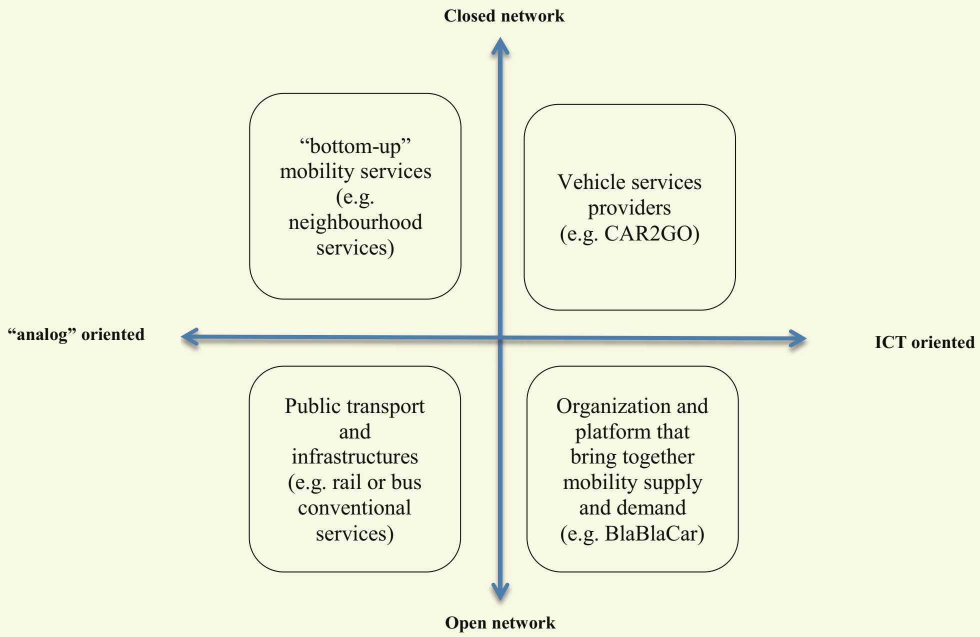
Looking again at the Figure 61, links between the actors are necessary to be stronger in order to achieve collective goals. In details, some direct links between

FIGURE 61
The system of Smart Mobility stakeholders (adapted from Mulligan, 2014)



public authorities and ICT manufacturers and from public authorities and users are necessary to assure a public regulation of some specific issue. The manner in which ICT is implemented is critical. For example, ICT can play a role in reducing congestion without building entirely new transport infrastructure, and ICT is helping provide end users more control over how they interact with transport systems. However, in both cases public authorities should have a clear role in this process.
One example of these interactions is how a route planning application can be used to prevent for example the use of a specific road in a city, according to public authorities' goals, instead that only optimization of individual travel time.
The number of players is increasing as competition between transport modes. New products and services and new operators are been introduced (Figure 62). The transformed organization of mobility services could provide users a different travel behavior and lifestyles. The service supplies of emerged service operators could be extensive enough to provide creditable level of service. This of course has direct implication on form of organization and public authorities' governance approaches.
As an example, a form of organization that it is already being tested in some cities is the so called Mobility as a Service (MaaS) (Heikkilä, 2014), based on integration of mobility modes and access to mobility rather than ownership of means of mobility: transport companies would produce services and sell them to the mobility operators in large amounts. Transport services include use of infrastructure, fleet, and data.
In this framework, some questions remain open: what is the role of all the other stakeholders and how to face the new emerging challenges of smart mobility?

FIGURE 62
Clusters of Smart Mobility services (adapted from Bos, 2015)



Towards a smarter mobility governance

The need of a new integrated approach is necessary to govern the changing situation, which should be based on the place making that a Smart Mobility have to ensure through the integration between technological and social innovation and on the capacity of cities "to create the conditions of a continuous process of learning" (Campbell, 2013).
New mobility agents for innovative mobility solutions (supplementary services, personalized on-demand services, sharing motilities and application of ICT, mobility management and time planning) implies new governance models, in relation to different providers and local and global markets, virtual and physical infrastructure, technologies, and, again, socio-institutional organizations. In this perspective, one aspect is crucial: the centrality of "citizen" (including residents, visitors and city users), business and local authorities as participants in the co-creation of improved quality of travelling and living the city, which are not just users of services, but have a specific and active role in the transition.
This approach wants to combines the previous visions, looking at smart mobility as a system capable of using ICT in an extensive and intelligent way, in order to improve the overall urban performances and, above all, the quality of life of citizens.
Among the main elements that characterize the linked approach to the Smart Mobility, it is the awareness that enhancing through ICT the performance of individual sectors does not necessarily result in the building up of a smart mobility: "a smart mobility should be viewed", indeed, "as an organic whole – as a network, as a linked system. In a smarter mobility system, attention is paid to the connections and not just to the parts" (Neirotti et al., 2014). Furthermore, it is central to consider a smart mobility as the final goal of a virtuous path aimed at improving the quality of life of citizens and based on the involvement of settled communities.

As already stated, the transport sector will radically change – existing companies will have to adapt their services and new entrants will come into the sector using new business ideas to introduce new mobility products and services; citizen will have a more active role thanks to the increasing use of smartphones and data that will empower users to enjoy better services and a better user experience by providing much greater integration across the whole system. It is a historic opportunity to rethink and reinvent government on a more open, transparent and democratic and responsive model (Townsend, 2013). Public authorities are vital in modifying the regulatory framework: by unlocking public databases and building broadband infrastructure. At the same time, bottom up initiatives civic laboratories should be stimulated to test and design local innovations.

Final Thoughts

As described in the previous sections, new 'smart mobility' governance issues are emerging. The study demonstrates also the risks of considering smart mobility from the narrow 'techno-centric' or 'consumer-centric' viewpoints. Our final thoughts want to emphasize that new smart mobility governance is necessary and it based on innovative combination of social aspects and technologies and involving cross-sectorial processes.

Concerning the vision and the governance goals, the new smarter approach should aim at place making that Smart Mobility has to ensure through the integration between technological and social innovation (Moss Kanter and Litow, 2009) and sustainability (Banister, 2008). The new approach should develop a holistic and system-level perspective on smart sustainable transport system that follows an integrative approach towards complex problems. For urban mobility are then necessary more integrated approaches that would make the best use of technology. Urban transportation requires more than technology and a new cross-disciplinary vision is necessary in order to support planning, transition and implementation of a 'smart mobility' for place making and sustainable urban mobility. The solution should extend beyond technology, but we should still value the indispensable role of it. The vision for the smart mobility of the future should integrate technologies, systems, infrastructures, and capabilities, where this innovation is a means, not an end. The transformation to smart transport system entails interactions of technological components with political, institutional and transitional components.

Concerning the governance aspects, one key element is the interactive and participatory process to commit "citizen" and not just "users" to a "smarter" mobility paradigm. The open and active involvement of people and stakeholders would be far more effective. Thus, broad coalitions should be formed to include specialists, researchers, academics, practitioners, policy makers entrepreneurs and activists in the related areas of technology, transport, land use, urban affairs, environment, public health, ecology, engineering, green modes and public transport. It is only when such coalitions form a real debate that smarter mobility can take place. The emphasis on human infrastructure highlights social learning and education. Accordingly, mobility system should start with people from the human capital side, and smart mobility governance it is about being able to function as an integral part of a larger system that also regards participation, urban and space quality, human capital, education and learning in urban environments (Siegele, 2012). The willingness to change and an acceptance of collective responsibility it is then crucial to create conditions for a continuous process of learning and innovation. Some new paths towards smarter mobility governance should aim at more cross-disciplinary, multi-actors and co-evolutionary approach (Boelens, 2009 and 2010) and at the integration between technological and social innovation. The central aspect of governance is a bottom up approach, with active involvement from every sector of the community: groups of end users, IT experts, policy/service domain experts, and public managers, coalition of business, education, government and individual citizens.

Main actions to make this approach concrete are achievable trough:

- creating the conditions of a continuous process of learning and innovation;
- broad coalitions: specialists, researchers, academics, practitioners, businesses, policy makers and activists in the related areas of technology, transport, land use, urban affairs, environment, public health, ecology, engineering, green modes and public transport;

- integrating smartness, local context, citizens, sustainability in real-life testing and experiential environments (Mobility Living Labs);
- prospective areas for Public-Private-People Partnership (PPPP) for innovative sustainable transport and mobility solutions in urban areas;
- interactive and participatory process to commit "citizen" and not just "users".

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GOVERNANCE OF MOBILE COMPLEXITY

Luuk Boelens

CO-EVOLUTIONARY MANAGEMENT TOWARDS A RESILIENT MOBILITY IN FLANDERS

Introduction

>> Recently, the Flemish administration published a decree on complex projects. This decree should allow the Flemish government to implement complex projects more quickly and efficiently. It should also improve the quality of complex projects as well as complex decision processes. Usually, these include big and disputed infrastructure projects, like the Oosterweel-link or new aviation routes for the Zaventem Airport, or highly contested environmental and spatial projects, like big shopping malls in the periphery of major cities and their expected influence on traffic congestion (Ronse et al. 2014). In order to deal with these major environmental mobility challenges, the decree drafted by the Flemish government has the following main requirements: (1) a thorough pre-consultation, (2) closer involvement of advisory bodies, (3) the combination of zoning and licensing into one step, (4) prevention and exclusion of disputes on the basis of formal requirements and (5) the designation of responsibility and accountability to a single government.

Each of these proposals would reduce the fuzziness of Belgian administrative responsibilities and would allow more opportunities for the participation of involved stake- and shareholders. However, it is also possible that this decree, with four decision phases and three decision moments, would simply add to the existing laws and procedures, eventually complicating complex decisions even further. Moreover, it is feared that it would infringe upon the equity of those decisions, thereby realizing the opposite of what was actually intended (Beyers 2014, SERV 2014). Furthermore, complex processes follow an a-linear path rather than a four-phase linear course of decisions (Boelens and De Roo, 2014). Therefore, one could even wonder if the decree would bring about the implementation of contested infrastructure projects sooner, or if it would just extend decision processes. The ongoing and ever-growing discussions about the Oosterweel- and U-place projects, with their expanding involvement of new opponents, experts, and additional stake- and shareholders, and the inclusion of more alternatives, additional studies, adaptations and extensions to the final decision would suggest that decision processes are more likely to lengthen. The present reality is dynamic and volatile, due to the ever-new insights derived from substantial augmented research and the involvement of changing views in multi-media, to the point that it wouldn't comply with the decree on complex decision-making. Thus, the key question is how to deal with these complex issues in an ongoing networked, fragmented, and empowered world.

Complex decision situations

In order to answer this question, we need to delve deeper into the underlying structure of complex decision-making. That subject has already been intensively discussed in various domains (Anderson 1999, Yaneer Bar-Yam et al. 2005, Snowden et al. 2007 Qudrat-Ullah et al. 2008, Teisman et al. 2009 etc.). From these discussions, we can see that most complex decision making proposals – such as, in this case, the Flemish legislation proposal – try to reduce complexity by selecting and categorizing issues from an infinitely chaotic and complex outer world, using an outside-in project management model, which looks for outer insights, new expertise or participatory involvement. However, these are incorporated within a demarcated and closed decision system. According to Luhmann (1997), the interior of decision systems could be regarded as zones of reduced complexity and, as such, could be 'operationally closed'; yet they also have to be regarded as fundamentally open in relation to their outer world. Society encompasses several systems (economic, political, cultural, educational, infrastructural, ideological etc.) that influence each other continuously and reciprocally. Social consistency would then have two tiers: on the one side, social systems would be islands of reduced complexity within an infinitely fuzzy world, on the other side, they would be conditioned, dependent, adaptive and co-evolutionary to their surroundings. Therefore, new insights in complexity theory and practice show that the decisions of complex projects need to be highly relational in respect to other projects, systems and their changing settings, such as shifting stakeholders and opinions. They have to be embedded in a complex management system or, better still, an interactive or even dynamic management system (Hertogh & Westerveld 2010). In other words, these kinds of dynamic systems need co-evolutionary governance (Van Assche, Beunen & Duineveld 2014) and an actor-relational approach to planning as 'undefined becoming' (Boelens & De Roo 2014) to address these complex wicked problems; that is, problems for which every solution or decision (about complex projects) would pose new problems.

Unfortunately, academics, practitioners and politicians alike too often confuse complex projects with complicated projects (Heurkens 2012; Schönwandt et al. 2013). This seems to be true of the aforementioned decree about complex decision-making. A *complicated system*, like a clock or turbo machine, is sophisticated, consisting of several parts all working together as one unit. For a specialist, it would be possible to break up the system's whole, analyse the system's parts separately, and then put it back together again without the loss of any information. This is because the relations between its parts would not change but would continue to function in a closed, static and rational way. In a *complex system,* however, this can't be the case. Each part influences the others reciprocally; all exchange (or dissipate) information with each other in accordance with specific circumstances or contexts. Taking the system apart and putting it back together again, if at all a realistic option for complex systems and their fluid behaviour, would not work because the conditional circumstances would have changed in the meantime, as the system, its parts and the context are in discontinuous flow. As such, a complex system could never be grasped as a whole,

because there are just too many interactions and too many flows and movements running through and around the system. Moreover, next to its parts, it is exactly those movements, flows, and interactions that constitute the system. In other words, a complex system exists because of its relations. Breaking up the system in an attempt to find some basic principle that governs all causes this relational information to get lost (Cilliers 1998).
In some way, this distinction between complicated and complex systems is reminiscent of Hertoch and the Westervelds' (2010) distinction between detail complexity (with its focus on many components, which all have a specific degree of interrelatedness) and dynamic complexity (which refers to living systems that evolve over time with a high degree of self-organisation and co-evolution and therefore offer only a limited, snapshot understanding and limited predictability). In that respect, complex decision-making refers to the evolving, a-linear, dynamic, contingent and situational *relations* between the elements (as in a weather system or social system), rather than the *distinct elements* themselves put together in linear, strategic, and additive ways (such as in a clockwork system) (De Roo et al. 2010, 2012). In this respect, it is awkward for the Flemish administration to mandate four additive phases of complex decision-making and expect that they will tame, solve or manage the complexity at hand. It would be no easier to plan, tame, solve or manage other complex systems, such as the weather.

Therefore, far from being fixed and predictable, complex decision-making is highly situational and co-evolving with dynamic insights and social changes in the outer world. As such, it is fundamentally different at various moments in time and space (Bovaird 2008). As said before, complex decision-making addresses wicked problems, which are defined as problems that are difficult or even impossible to solve, not only because they are usually adjoined by incomplete, contradictory, and changing requirements, but also because the effort to solve one aspect of a wicked problem often reveals or creates other problems (Rittel and Webber, 1973). In that respect, wicked problems cannot be tackled with the traditional approach in which problems are defined, analysed and solved in sequential steps. Instead, we have to learn to live with them in a complex, adaptive way, whereby, step-by-step, little solutions are proposed within an adaptive overall outline, progressing according to the labyrinth-like, a-linear steering-seeking of Niklas Luhmann's *Society of Societies* (1997).

Therefore, in this contribution I will address an alternative mode of governance in complex situations that opts to 'try and ride' such complexity, accepts it as the natural and even welcomed state of affairs, and facilitates and adapts to it instead of 'combating' it with rule, order, laws and decrees. While recognizing the importance of this realm of rule and order, we will go further to sketch a governance of complexity capable of co-evolving with a government of regulations and 'complicatedness'. Moreover, I will focus on the *governance of complex mobility systems*. While treated as an 'open system', as it is never closed or self-referential, mobility is, in fact, always relational and therefore adaptive to other activities, functions or domains in society.

First, I will describe mobility as a complex adaptive system. I will discuss the interactive domains of project and infrastructure planning, the traffic and transport market, formal and informal institutionalisations, involved stake- and shareholders, and how they are reciprocally interlinked with environmental issues, energy transition, demography, life- and mobility styles and spatial ambitions, interests and settings.
Secondly, I will delve into the evolving self-organised realms of mobility, wherein self-organisation is one of the main elements of complex systems. Here I will explore not only the emerging self-organising elements of actors of mobility – those of the civic, business and public society – but also (being mindful Actor-Network-Theory) the self-organising elements of new technologies, IT-Mobility, integrated traffic management and co-sharing organisations.
Third, I will elaborate on the elements of governance in facilitating and dealing with these emerging, self-organised features in a more resilient way. I will outline several possibilities for an environmentally engaged and socially responsible model of governance for addressing these kinds of mobile complexity. These will extend beyond the recent decree of the Flemish government towards a co-evolutionary system of structure and emergence.
Finally, I will outline an agenda for complex governance research. I will emphasise the need for an agenda of complexity, which is becoming part of the mobility (co-) evolution itself; not embedded in the ivory tower of science, but operating in the middle of real life settings in the mobile world.

Mobility as a complex adaptive system

In literature, a complex adaptive system (CAS) is defined as a 'complex macroscopic collection of relative similar, connected micro-structures, formed in order to adapt to a changing environment' (Axelrod and Cohen, 1999, Stacey, 2001). A CAS is *complex* because it consists of a dynamic network of interactions, and these relationships are not an aggregate of individual static entities. CAS is *adaptive* in that the collective behaviour mutates and co-evolves with the changing environment or the changing initiatives and evolving features of the subsystem itself (Holland, 1992, Solvit, 2012). In this way, mobility can be regarded as a complex adaptive system within the greater system or environment of society. Although some parts of the existing mobility volume can, despite the telematics revolution, still be regarded as a necessity (albeit an ongoing, lesser part, wherein one can voluntarily decide if or when the trip is made), even here the way mobility is executed is dependent on possible means, finance, personal convictions, self-esteem, relocation options etc. Mobility thus *adapts* itself to external possibilities and internal considerations, and vice versa (Schwanen 2011, Dijst, 2014). In the same way, mobility is *complex*, consisting of various volatile and changing features, which influence each other continuously, reciprocally, and in an ever-greater diversity. A recent overview study about spatial planning for urban form and sustainable transport (cf. Williams et al., 2005) concluded that the choice between compact or suburban developments is not only highly situational, but also that socio-demographic factors would be equally if not more important. All of these factors and elements matter, namely macro- and micro-economic trends, as well as socio-cultural trends, the pluralisation of lifestyles and subsequently mobility styles, the specific (possible or intended) activities during, before and after being mobile, the impact on pollution and health, as well as technological and logistic innovations, and the respective policies in question. In fact, the study concluded that researching mobility has become highly and ever more complex, whereby not only additional insights would be needed for each of the features mentioned above, but also, and especially, an understanding of the reciprocal interactions among them (Williams, 2005, 11-12).

Consequently, present day mobility needs more nuanced and sophisticated approaches and thus has moved beyond a relatively simple transport versus land-use feedback model within, if necessary, a multi-level approach (Switzer et al., 2013). More than 15 years ago, Egeter and Van Riet (1998) described the interplay between the *demand side* (socio-economic attitudes and trends) and the *supply side* of mobility (technological and infrastructural means and political strategies) wherein they distinguished between a *travel market* (with the travel volume dependent on socio-demographic factors, spatial density, diversity, telecommunication etc.), a *transport market* (which is dependent on the modal choice, system efficiencies, transport information and communication etc.) and a *traffic market* (which is dependent on traffic efficiency, infrastructure design, vehicle technology etc.). Subsequently, Lauwers and Allaert (2013) made this interplay more situational by adding the available *resources* (economic, ecologic, and spatial) versus their *impacts* on the situation itself (with respect to the added value, environment and quality of life). While each of these features can be regarded as complex adaptive systems in and of themselves, this multi-CAS model of complex adaptive mobility becomes more complex than complex, possibly even 'complex squared', with multi-dimensional and multi-perspective levels. It becomes impossible for anyone to oversee all its inter-connected features, let alone the impacts of intended proposals on each of them (if ever possible with regard to the embeddeness of those impacts in specific settings).

Nevertheless, if each of the interconnected features mentioned above is approached as an arena – that is, as a specific domain of Luhmannian 'reduced complexity' wherein intentional actors operate, each with their own ambitions, impacts and possible alliances or couplings among themselves – it would be possible to grasp these kinds of highly complex systems from the bottom up. This would also lead to the Actor Network Theories (ANT) of Callon (1986, 2009), Law (1986, 2004) and Latour (2004, 2005). A central element in ANT is the network defined by Latour (2005) as 'sets of associations between elements which are always mobile and fuzzy, going everywhere, but are specifically in need to create and maintain'. Thus, the network among actors and between those actors and their surroundings is in ANTs that are never static or given but always fluid, organic and multi-dimensional, while different elements can be involved in more than one network with different impacts, consequences and causalities. Since no one can oversee all these kinds of fuzzy and changing networks, ANT focuses on the smallest element and follows the actors themselves, their routines, ambitions, interests and traces. In other words, ANT uses a 'flat' approach instead of a pre-determined or pre-structured ontology. This idea is stretched to its upmost because a key element in ANT is that main or important actors are not only human, but also inhuman; not only a politician, businessman or inhabitant, but also old or new infrastructures, available technology or other innovative breakthroughs that could have a major impact on what is happening or not. In other words, according to ANT there exists a 'radical symmetry' between the social and the material known as the coined term 'actant'. Each of these actants could have a specific impact on spatial or, in our case, mobile developments, depending on their relations with each other and their fit within a specific time or situation. This would allow us not only to perceive complex situations from the interrelatedness of leading actors of importance (those who are willing or able to 'invest' in their surroundings, for example, for the sake of self-interest), but also to take new innovations into account that could have a major impact on the long run. Here Geels distinguishes those innovations as non-linear processes of niches, moving towards patchwork regimes and socially accepted 'landscapes' or domains; ANT identifies *'policies in the making'* along four phases of translation – problematization, interessement, enrolment, and mobilization (Callon 1986) – or four stages of 'the collective': wonderment, consultation, hierarchisation, and institution (Latour 2004).

Self organized mobilities

Whatever it may be, this feature of complex adaptive systems puts the idea of self-organization at the core of complex decision-making. Self-organization refers to the spontaneous formation of patterns or structures towards a higher or accepted social level, therefore creating a more broad impact out of the interactions between individual actors at the small, niche or local level (Heylighen, 2008). This kind of formation is a spontaneous, a-linear process, as the emerging interactions between the actors are not induced, coordinated or externally controlled by a higher power or institution, be it formal (law, rules, organisations) or informal (norms, attitudes etc.). However, this wouldn't mean that decision-making or steering becomes superfluous and without any effect. On the contrary, even (complex) decision-making or steering could have, like the other actants, a major impact on the course of those self-organizations. It is crucial, however, that it not work from the outside-in as an external power based on premeditated or pre-structured ideas about a just, good or sustainable transport. Instead, that kind of steering or complex decision-making has to evolve from within, whereby those powers and ideas about a just, good or sustainable transport have to become mutually respected, obvious and self-evident in the co-evolving actant-network assemblage itself. The crucial question, then, is how this is to be done. How could complex decision-making and steering become an obvious partner in co-evolving assemblages and, as such, shape those processes of self-organisation in a more sustainable or, better still, 'resilient' way? That question becomes even more crucial as self-organisations manifest themselves more and more, even within the highly instrumental and technologically stratified domain of civil engineering and regulatory mobility.

Due to the ongoing traffic jams and the repeated misfits of the traditional public transport systems, and as a result of climate change and the financial, economic and governance crises from 2008 onwards, this kind of self-organization has also become increasingly prominent within mobility systems. More commuters, businesses and mobility-providers are starting to organize mobility by themselves. Paradoxically, the new and elaborated means of mobile telecommunication and the all-encompassing information systems are making that organization possible. In order to develop more robust, interest-focussed, and sustainable transport systems, new waves of self-organized mobility systems pop up with an ever-growing impact. Businesses, new stakeholders, intermediaries and even local authorities and citizens increasingly initiate a wide range of projects. This has been the case in Flanders.

The Industry-bus (or I-Bus) system, for instance, is an initiative of several major companies in the Antwerp harbour area – such as. Bayer, Evonik, Ineos, Lanxess, Monsanto and Solvay, in cooperation with the Chamber of Commerce of Antwerp – working together to replace the existing public bus services with one integrated, privately-owned bus network designed as a hub with several spokes. At the moment, the system comprises some 40 bus routes moving from the outskirts of the provinces of East-Flanders, Antwerp and Flemish Brabant towards a single hub in Antwerp Harbour, from which the commuters are transported to the respective companies. Every day since 2009, some 3,000 commuters have been served in three waves working around the clock.

Likewise, *Uber,* or *PickMeUp,* is a new rider-share service where passengers use a smartphone application to connect with passing drivers who are willing to use their private vehicles for hire. Originally launched in June 2010 in San Francisco, the service is now available in 45 countries and in more than 200 cities worldwide. Although Uber has meet with growing protests and institutional barriers from regular taxi-drivers and taxi companies (for instance, in Germany, France, England, Belgium and the Netherlands, these rider-share companies are considered illegal taxicab operations), Uber can hardly be contested in traditional ways. It also expands its services to other areas, like the so-called “*BelBus-system*” and the “*Pool Van System*”. Such new applications are still evolving.

Additionally, *mobility-sharing* has reached ever-greater heights. Shared car systems like Greenwheels and Mywheels in the Netherlands and Cambio, Bolides, Tapazz and Partag in Belgium have emerged at a growing pace since the beginning of 2000. At the same time, bike-sharing systems are now operational in more than 500 cities worldwide. Local authorities themselves often initiate them; for instance, these systems exist in Brussels (Villo, since 2009), Antwerp (Velo, since 2011) and Namur (Libiavelo, since 2013) and are financed by the public budget, parking fines, or congestion charges, respectively. Additionally, public transport companies –

e.g. the NS, NMBS and De Lijn—have initiated bike-sharing systems on their own; however, these blue-bike systems are organised according to a back-to-base principal. Therefore, they are cheaper than the city bike systems (1/6th of the total cost), but are also less user-friendly. Nevertheless, city bike systems already serve some 70 to 75,000 customers in Belgium, of which 75% are also bike owners. At the moment, blue-bike is operational at approximately 50 hotspots in Flanders

Last but not least, *citizens* have also taken the mobile-issue into their own hands. For instance, since 2012, some 25 citizens in Ghent have initiated new experiments and exemplary case-projects related to sustainable transport within inner-city districts. One of the first was *'School-streets',* where citizens themselves assigned certain streets as car-free during the opening, break and closing-hours of primary schools in order to create safe zones and avoid traffic accidents. Another initiative was *'Living-streets'*, in which residents created more liveable streets according to their own interests and ideas. There is also the *Sustainable Shopping System*, *M-score* and the *Inhabitants bike-network*, wherein citizens themselves organised communal shopping for daily necessities, transportation to hospitals and leisure and sports facilities, and a network of individually owned bikes for communal use. Furthermore, not only in Ghent, but also in Antwerp, citizens, together with some hired experts, have taken matters into their own hands regarding the complex Oosterweel project mentioned above. These parties have organised broad support and arranged sufficient crowd-funding in order to promote their own alternative project: Ringland. At the moment, this idea has even gained momentum in the political domain and has thus become a major actant in the field of complex-decision making.

Consequences

In fact, each of these initiatives challenges the existing traffic and transport system in several ways.
First, each of these initiatives, in some way or another, is structured by the transition management idea, which is characterized by a multi-actor approach, learning by doing, and a span across multiple domains and levels of complexity in several spaces and times. The core of transition management starts with niche innovations in small networks and then moves throught experimenting with them towards a so-called dominant design, resulting in new 'windows of opportunities', niche stabilization and finally new markets, technologies and/or policies (Geels & Schot, 2007, Loorbach 2007, Foxon et al., 2009, Teisman et al., 2009). Nevertheless, for each of the initiatives mentioned above, it is not clear in which phase or transition they really operate. Even for the I-bus and popular bike sharing systems, it is not clear if they have really opened up new markets and/or technologies, and if they will survive in subsequent administrations with their public budget cuts or firm's policies. Therefore, it is not clear if the institutionalised traffic and transport experts can simply ignore these initiatives as merely temporary fads, or if they have to take them seriously as a new mobility feature to facilitate or explore.

Second, these initiatives present mobility planners new challenges. Planning develops a thorough and insightful knowledge of the possible impact of an initiative in space in order to propose long term strategies or governmental tactics. However, for these initiatives, not only is it unclear if they will continue or die out, but it is also uncertain how they will evolve, in which direction and/or with what kind of impact or intensity. Therefore, it is hardly possible for planners to set a fixed point in the future to integrate or facilitate the initiatives with new long-run strategies for housing, working and leisure areas, additional infrastructure measures or supporting spatial policies. Moreover, planners can hardly use and maximise the possible spatial windows of opportunity for these new, self-organised initiatives, let alone predict which new ones will arise in the future. The situation requires a new kind of *'adaptive planning approach of undefined becoming'*; an approach with which, unfortunately, planners in general, and especially traffic and transport planners, have had hardly any experience (Boelens and De Roo, 2014).

Third, although the impacts and progress of the self-organising initiatives are still unsure, they already challenge dependencies on the existing institutional pathways to their core. Take *Uber*, for instance. *Uber* is banned in Amsterdam and other cities in the Netherlands because the local governments fear a new 'war' of taxi-drivers and operators; *Uber* services are suspended in Brussels due to public court verdicts. Nevertheless, at the moment, it is still unclear how the existing laws and rules would be applied, and if these new rules and laws would ban those systems indefinitely or simply facilitate another '*Uber*-system' or other possible rider or transport sharing systems, some of which are still to be developed. However, in the meantime, in spite of these ongoing discussions *Uber* is already illegally evolving in practice, even in banned city-areas like Amsterdam (De Volkskrant 12th of October 2014). As a result, taxi operators are already sharpening their blades, watching the developments with suspicion, and Brussels Airlines has already withdrawn their free *Uber-Vouchers* for Brussels proper, fearing the actions of the official taxi-drivers in and around the Zaventem Airport.

Last but not least, although they have hardly matured, these initiatives are already putting a heavy burden on available budgets. The Villo system in Brussels, for instance, is financed by the existing budget for public space maintenance, the one in Antwerp by parking ticket revenues, and the municipality of Ghent is deliberating on whether to incorporate 'Leefstraten' as a core project in its municipal spatial policy, which would require extra funding. Each of these initiatives therefore competes with the existing mobility programmes and results in a financial shift from institution-alized projects towards new ones. It induces heavy debates and comparisons between all kinds of preliminary ideas and windows of opportunity, especially in times of neo-liberal budget-cuts; some even fear hidden-savings because when, after a while, those new ideas and opportunities prove to be unstable or inefficient, authorities will simply skip finance altogether. Moreover, even when those self-organised projects prove to be robust and sustainable, they are institutionalized and included in the existing governmental and political path dependencies through financing at a very premature phase, possibly not allowing for the expansion of all its (self-organising) potentialities. As such, these innovative policies could even turn to the reverse, limiting all real innovation from the bottom-up (Boonstra and Boelens, 2011).

As a result, actual public policies for traffic and transport are highly fuzzy or even obsolete. Official documents – like the Flemish Government Policy on Mobility and Public Works 2014-2019 – hardly deals with these new and ongoing self-organizations in traffic and public transport. In general, these initiatives are treated casually; at best, they are approached pragmatically, with neo-liberal jumps from project to project without any general idea about their ongoing complexity, which is in essence characterised by the features of self-organization. In fact, the current laws in the Netherlands and Flanders regarding complex projects don't treat them as complex systems as such. At best, they are approached as complicated systems, with a focus on more efficient management and cost and time reduction. New approaches are needed to exploit the new windows of opportunity of self-organization, which will go beyond the realms of strategic, goal-oriented planning.

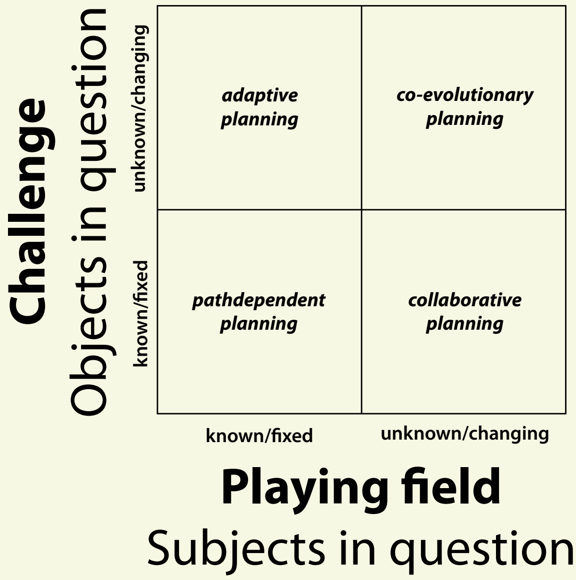
New approaches

As a result, the search for new approaches is receiving growing attention in theory and practice alike (Hillier 2008, Boelens 2009, Urhahn 2010, De Roo et al. 2010, 2012, Moulaert et al. 2013, Rydin 2014, Rauws 2015, Boonstra 2015). However, despite the growing international attention on planning for complex systems, experimentation with planning tactics of complexity in real life remains scarce since structuralist strategic planning is still the mainstream in planning theory and practice. Within this kind of ontology, politicians, planners, cooperating actors and others tenaciously cling to the idea of *strategic* planning, whereby strategic targets need to be met over time and, if necessary, in subsequent phases through several sub-stations of pre-, mid- and post evaluations, or by implementing them co-productively with various stake- and shareholders. These kinds of approaches deal with real life, which can be modelled, steered or guided in a certain direction over time. Although these approaches could be useful in fixed contexts, *complex* systems are much more a-linear, fuzzy, multi-dimensional, and unpredictable, and therefore undefined, than these strategic points, which can be set and maintained on a fixed timeline. Instead, complex questions and challenges need a more *tactical* approach than a strategic one, focusing on the various mutual reinforcing, dissipative decisions and activities, while realising that in complex settings decisions and activities could go several ways and are highly situational and fluid over time, without the ability to predict, let alone direct or plan them (Boelens 2010).

Furthermore, we become increasingly aware that there are not one but several grades of complexity. We distinguish at least four, based on the fuzziness of the context or the playing field versus the object or planning problem in question (Hertogh &

Westerveld 2010, Boelens 2015, Verbeek & Boelens 2015, Terryn, Boelens & Pisman 2015, Boelens & Goethals 2015).

FIGURE 63



In the bottom-left field of figure 63, planners encounter a relatively fixed playing field made up of the so-called *'usual suspects'*, with a relatively *'closed'*, well-known object of planning. Here a path-dependent, procedural planning model could succeed, whereby each decision would be evaluated in pre-, mid- and post evaluations and redirected, if necessary, towards the overall strategic end goals.

However, these types of planning situations are increasingly rare in our (physical and thematic) cross-bordered, volatile and networked society. More and more, there are also situations in the bottom-right field of figure 63, where, although the object of planning is still more or less clear or well-known over a longer period of time, the number of involved actors is growing or even changing (due to empowerment, contingent settings or other drivers) and therefore requires a kind of participatory or collaborative planning.

There are also situations in the top left field of figure 63, wherein the (leading or involved) stake- and shareholders – both the actively involved and passively interested, or the 'drivers' and the 'pushers' – need to solve a fixed or well-known problem or planning challenge, like those in the bottom-right corner of the matrix. However, because the object of planning is so new, innovative or interrelated, the possible solutions, including ideas on how to get there, could change dramatically over time. Here an adaptive planning is needed to navigate through an ocean of changing winds, currents and waves towards the intended goals.

Furthermore, there also appears to be a growing number of situations in the top right field of figure 63, wherein neither the involved actors nor the precise challenges or objects of planning are clear, fixed or 'closed'. Here planners encounter an ever-growing state of fuzziness, contingency and complexity, which can only be 'solved' by becoming an integral part of the planning process itself, co-evolving with the changing contexts and objects of planning themselves. In this context, major planning challenges can only be encountered step-by-step by *'trying to ride the issue itself'*, while neither the specific object nor the (courses of the) involved stake- and shareholders are clear in advance. This co-evolution between evolving objects and evolving subjects could lead anywhere, although it is hoped it will move towards a more resilient assemblage in the long run, creating a system that is robust and strong enough to survive socio-economic and/or socio-ecologic hazards over time. It is precisely that 'ambition' that could become the predominant intermediary task of co-evolutionary planners who work with complex situations seeking to translate them to more resilient systems able to cope with high levels of contingency.

Explaining and translating these ideas of varying degrees of complexity to meet the new challenges of mobility planning would lead to the following examples:
The bottom-left field would represent the traditional and present *degree on complex mobility projects*. It would refer to path-dependent, procedural planning, wherein brown and green papers would be followed by white policy documents, including several phases of participation by invited (mediated) actors, in pre-, mid- and post-evaluations, and would move towards (adapted, if necessary) implementation and/or the iteration of the process all over again.
The bottom-right field would be representative of the *Oosterweel-project,* wherein the object of mobile planning remains mostly fixed over time (closing the Ring of Antwerp as a solution for ongoing traffic jams), but the involved actors from BAM, via Straten Generaal, Ademloos, Ringland etc. have changed and are still changing enormously, including the involved interests and resulting actions; here a mediating planning model is needed.
The top-left field of the matrix would refer to a situation like the *Lab of Troy project* in Ghent. Unlike the Oosterweel project, here the involved actors are more or less clear (engaged inhabitants, the Ghent Climate Trust and the local administration), while the initiatives of mobile planning are still highly unclear and could go in several ways. Each of the initiatives (*Living Streets, Sustainable Shopping System, M-score, Inhabitants bike-network, etc.)* needs to be translated into a more resilient form, a process that could change them massively. Accordingly, the process would require a kind of adaptive mobile planning.
The top-right field represents a mix of all the self-organising processes described above, especially those dealing with shared, digital and emerging cooperative solutions of mobile complexity. This field requires an inclusionary planning attitude that would become a part of the evolving ideas and therefore could be considered co-evolutionary.

Therefore, the future of complex settings drives towards not a single but rather a multi-planar attitude of mobility planning. In addition to path dependent, procedural planning approaches and collaborative and adaptive ones, planners increasingly need to cope with 'full-settings of complexity', or in other words, co-evolutionary planning ideas of self-structured becoming. Like evolutionary theories, these ideas of co-evolution are rooted in general Darwinism with its notions of heritage, fitness, survival of the fittest, mutation and variety. However, they also go beyond these classic evolutionary concepts to the point that groups of organisms are evolving not only by themselves in specific biotic circumstances, but also changing in explicit circumstances through reciprocal selective interaction with other related organisms, contexts or systems (Ehrlich and Raven 1964). As such, over time and space, subjects and objects dissipatively and continuously influence each other, co-evolving towards a new and, if possible, more resilient state. (Durrant and Ward, 2011). As stated before, here the dissipative arrangements between the species or elements and their settings or contexts become more crucial than the evolution of the elements themselves. In other words, within co-evolutionary approaches, the networks or evolving assemblages between the elements become the main focus for receiving useful insights or coping with complexity.

Mobile Living Labs

Whereas procedural (Faludi, 1986), mediating and collaborative (Innes, 1995, Healey, 1997) adaptive planning approaches (Ovink et al., 2011) have been sufficiently described elsewhere, this kind of co-evolutionary planning remains highly untouched. Therefore, there is a call to give these ideas of co-evolution increasing attention (AESOP 2014). This is especially true as those full settings of complexity with fuzzy emerging undefined objects placed within changing settings of stake-and shareholders gain increasing importance in mobile planning systems. Therefore, there is a growing plea for further experimentation with those ‘full complex questions’ in theory and practice in order to enhance the conditions of co-evolutionary planning. The platform of this experimentation refers mainly to the idea of Mobile Living Labs, whereby planners, politicians, entrepreneurs and civilians alike become equivalent partners in order to negotiate and test new solutions for complex mobility patterns (Boelens & De Roo 2014).

These Living Labs are real-life testing and experimental environments for user-driven information (Desouza 2013, 2014). Originally grounded in technologically driven innovations, which embrace urban regions as testbeds where experimentation and dissipative innovation can be tested before putting new technology on the market, Living Labs have expanded across administrative, social, economic and infrastructural issues. As such, Living Labs also involve crowdsourcing ideas and actively engage citizens, businesses and public administrations in the experimentation and solution development (www.openlivinglabs.eu). In this emerging field of Living Labs, Planning or Mobile Living Labs are immensely scarce; one could even claim non-existent. Therefore, we have proposed to create two Planning Living Labs in the Flemish Government’s *Policy Research Centre on Spatial Development 2012–2015*, in order to develop co-evolutionary resilient planning tactics for the Flemish peri-urban situation: one for polycentricity as a guiding concept for analysis and future planning, and one for resilience as a guiding concept for analysis and future planning. Here we will discuss the first, which is focused on latent sustainable translations of the N16 corridor between the municipalities of Temse and Willebroek. This Planning Living Lab is connected not only to the evolving PhD-research within the Policy Research Centre itself, but also to the evolving Master programme of Urban and Regional Planning at Ghent University. Thus, this Planning Living Lab serves as a quadruple helix between scientific, civic, business and public interests, not only serving co-evolutionary translations on the ground, but also serving the possible scientific and educational renewal of planners' foundations towards undefined becoming. In discussing this idea of a Peri-Urban Living Lab with the involved businesses, civic interest groups, municipalities and other (intermediary) organisations, we soon discovered that a growing interest evolved in and among several issues, ranging from sustainable energy transition to food production, healthcare and mobility issues, all working in close reference to each other. A great majority of the stake- and shareholders was willing to experiment with the idea of the Peri-Urban Living Lab for these issues, agreeing that they could not execute the new transition challenges alone and needed mutual collaboration. Therefore, the Living Lab was initiated in February 2014, with a rough focus on mobility and energy transition and the aim to evolve to more resilient assemblages in these areas. A Living Lab coordinator was adopted, a mutual 'curratorium' installed, the Policy Research on polynuclearity was focused on N16 and master studios and theses were prepared, all with the aim of *'trying to ride the issue'* without knowing beforehand how, where or even when it would end.

Discussion – towards a balanced planning tactic-strategy of complex mobility

Currently, the actant-relational lab is still ongoing, and it is still unsure if the stakeholders will come to an agreement and subsequent implementation with the help of their complex surroundings (multi-level governments, citizens, their shareholders, other actants etc.). The proposals are still fragile and could fail or move in another direction. Nevertheless, some preliminary conclusions can already be drawn.

First, we can conclude that the actant-relational approach is promising for the governance of complex mobile settings, but it needs further elaboration. The alternative, top-down, deterministic strategic planning approach – be it technological, rational comprehensive, participatory or collaborative – is no longer tenable in situations where complexity has replaced complicatedness, and where objects and subjects change their numbers and insights regularly (see diagram 1) and thus have become highly situational in time and space. Defining specific long-term strategic goals, and breaking them down into several consecutive, manageable project-decisions of reduced complexity (albeit with feedback loops) – which is at the moment the typical way of dealing with complex projects and has subsequently inspired the Flemish law on complex projects – is no longer operational in a world that has become highly fragmented, volatile, a-linear and contingent, moving in various, fuzzy ways. Instead, we need in these complex settings of changing objects and subjects a type of co-evolutionary approach where evolving projects and changing surroundings influence each other reciprocally; the process must become intentional, but also highly undefined.

Second, although these complex processes are, to a certain degree, undefined and (co-evolutionary) self-reliant, this wouldn't mean that they can't be moved or facilitated in a certain direction. As said before, this would require a radical turn in managerial orientation. Instead of working from the outside-in and acting as a neutral referee or objective researcher (if at all possible), for the sake of some predetermined idea for a good, just or sustainable society, the manager, governor, planner or researcher needs to become an integrated, common and respected part of the evolving, self-organising assemblage. While complex projects and their co-evolving processes are highly situational, this kind of 'process-included-position' needs to be repeatedly invented and maintained. Moreover, to tackle possible objections to such an inclusive and highly involved perspective, governors, professional planners, complex managers etc. would have to do more than simply follow or propose their own professional intentions. On the contrary, we still need to distinguish within these self-reliant processes of complexity the various moments or, better still, attitudes of undefined becoming: problematisation, interessement, enrolment and mobilisation. Each of these moments or attitudes of assembling would require specific intermediary actions from the planner, manager, governor or other actor in order to move or facilitate complex self-reliant processes between and among the involved actants/surroundings: fundamental research about trends, impacts and possibilities, seducing actants towards what-if scenarios, path-creation towards new possibilities, and institutionalisation of, if necessary, new and embedded frames.

Third, in her study about self-organisations, Boonstra (2015) distinguishes at least three intentionalities for including steering professionals from the bottom-up. These are composed of an intriguing mix of planning tactics and strategies of undefined becoming. The first is *'interfering for a change'*, based on tactics that open up. It is an intentionality that focuses on how things could be made better, according to the actors involved, including the professional planner himself. What is considered 'better' is not a given truth or a fixed optimum, as is the case in strategic or comprehensive rational planning, but rather something that is contextual, situational and thus constructed within the assemblage itself over time and space. This intentionality has been the main professional driver for the mobile living lab described above. According to Boonstra, the second intentionality would be *'networking for a fit'*. This would function with a navigating strategy whereby the association of complex processes would be gradually strengthened, expanded and made robust not only in terms of the (number and ambitions of the) actors involved, but also in respect to their surroundings. The third intentionality would be *'assembling to maintain'*, a structured coupling tactic focused on the maintenance, homogeneity

and coherence of the actor-network, which would, in the end, provide resources as well as a restraint on the heterogeneity of complex processes. Boonstra concludes that in planning processes of complexity and/or self-organization, the case is often 'either or'; however, she proposes a real multi-planar strategy, tactic and focus. Therefore, the agenda of mobile complexity would be multidimensional with several focus points for governmental planners and policies: one to open up 'social mobile capital' and one to institutionalise networks for matching and maintaining
the interactions among all the mobile initiatives. The result is an inspiring actor-relational agenda for a sustainable future.

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Adaptive Mobility

This book sketches a new, future research and policy agenda for mobility planning in Flanders, and therewith for suburban, horizontal metropolises in general. It departs from evolving investigations, researches and lines of thought at several departments of Ghent University (coordinated within the Network for Sustainable Mobility Research; IDM) and tries to further materialize this into a resilient agenda for tomorrow. These attempts start from different views about the interaction between society, space and mobility; driven by radical transitions (disruptions) from the traditional to more complex, a-linear approaches. This transition is characterized by three major challenges:

– From generic towards situational approaches of the demand side of the travel market;
– From hard and stable to smart adaptive approaches within the transport and traffic market;
– From top-down strategies towards structural couplings and coevolution in the mobility market.

The first challenge (**SOCIETY AND SPACE**) deals with situational travel behaviour in respect to changing settings of accessibility, lifestyles, and their interaction with society, health and space; and drives towards an urgent need for a better understanding of 'soft' factors such as personal attitudes and lifestyles.

The second challenge (**TECHNOLOGY AND INDIVIDUAL TRAVEL**) deals with the ongoing use of new technological means, including shared mobility and interactive design to facilitate these increasing individual demands; and drives towards a better understanding and policy processing of the ongoing use of new technological means that pervades daily life and allows us to construct connected mobility and interactive design to facilitate increasing individual demands.

The third challenge (**GOVERNANCE AND COLLECTIVITY**) deals with adaptive, actor-relational approaches of mobility, in changing settings of formal and informal initiatives in mobility planning; and drives towards a better understanding of the complexity of decision making and the adaptive, collaborative or co-evolutionary 'governance' of complex mobility situations.

This book elaborates on each of these challenges with state-of-the art research executed at Ghent University. However each of these challenges needs also to be taken together towards a mutual adaptive, co-evolutionary agenda for sustainable mobility. Society and space, technology and big data and governance of common pools are three main drivers for resilient change, and need to be integrated in order to translate towards efficient, embedded and decisive mobility policies.

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