9th International Sustainability Transitions Conference: Reconfiguring Consumption and Production Systems

Manchester, UK, June 11-14, 2018

Full Paper

Spatial patterns of transitions in the mobility sector: applying the concept of service regimes and sectoral regimes to anticipate changes in urban and rural transport systems

Track: theoretical contributions to transition frameworks

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1. Introduction

In this paper we want to highlight the relevance of the spatial context for a transition of the mobility regime and we suggest an approach to support the analysis, anticipation and governance of such processes. We use examples for the mobility sector in Germany to illustrate our concept.

Decarbonsing transport is of utmost importance if ambitious targets for combating climate should be achieved – the share in transport related Greenhouse Gas Emissions (GHG) emission on the overall GHG emission in Europe is about 30%. Over the last decades no real progress was made in terms of reducing overall GHG emissions from the transport sector (EEA 2017). Technical and organizational innovations are considered as essential for achieving such progress. It is therefore crucial to accelerate innovations and its diffusion to achieve significant progress in this field (Geels et al. 2017). It is important to find entry points for policies to support such acceleration. Further it is often argued that a sustainable transition of the mobility sector needs to go beyond a pure substitution of "old" technologies (e.g. Internal Combustion Engines) by "new" ones (e.g. electric mobility) but has to include a modal shift away from private car usage (Schippl et al. 2018). Such a modal shift means a change in modal choice of the users.

There are many technical and non-technical dynamics observable that are about to transform the transport system. Electric mobility is starting to substitute internal combustion engines, but also more fundamental changes to the way transport is organized are likely to come. Many observers see various variants of "mobility-on-demand" service (sharing schemes, apps, platforms) as enabler for less car dominated, “seamless” mobility systems. And, even more, the advent of the driverless car technology is supposed to come as a revolution for transport systems. There is a broad agreement that changes are likely to come, but it is far from clear how these changes will look like, what impacts they have on sustainability of the mobility system and how they can or should be influenced by governance. In the last years many studies on sustainable transitions in mobility sector have been published to help answering these questions (Geels et al 2012; Banister 2008). However, the relevance of spatial contexts for such transition processes seems to be underexplored (Schippl and von Wirth 2018).

Transport system is not a homogenous regime. There are huge differences between rural and urban areas. This is of particular importance in Germany, since only 30% of the Germans live in cities with more than 100.000 inhabitants, about 44% live in small and medium sized urban areas and about 26% live in even less densified areas (DLR, infas, 2010). In urban agglomerations there a many alternatives to car transport, which is less the case in smaller towns. But there are also huge differences between urban areas. For example, in the City of Stuttgart, only 7% of the trips are done by bicycles whereas in Karlsruhe the share in cycling is around 25%. In some larger cities far more than 50% of the inner urban trips are done by non-car modes (for example in Karlsruhe only 30% of the trips are done by private cars).

Against this backdrop it appears to be not really sufficient for many challenges, if the transport system is considered as one regime. This is in particular insufficient if potential development trajectories in different spatial settings have to be assessed. In such cases, arguing that transport is dominated by cars and treating the other options such as public transport or cycling as niches is not a fully satisfying solution. Public transport is usually operated since decades and dominated by well established, actually incumbent organizations. In many larger cities in Germany cycling as well does not really show the character of niches since it is well established since decades, it often has its own infrastructure and modal shares between 20% and 30% are not an exemption in Germany. The idea of subaltern regimes (Geels and Kemp 2012) takes such facts into account; however, in this paper we will suggest a slightly different terminology to capture the huge variety of different services that make up the sociotechnical system of mobility. Against this backdrop, we argue, that the concept of regimes needs to take this spatial characteristics more into account when it is used for anticipating, assessing and governing future developments in a – presumably - fast changing transport system.

In order to better cope with the spatially highly different assemblages of infrastructures and services that make up the transport system in different regions we propose to apply a concept that has recently been introduced by van Welie et al. (2017) for the sanitation sector in Nairobi. Here, in sociotechnical regime a level of service provision is differentiated from the level of the sector. Service regimes are understood as a “specific institutionalized combination of technologies, user routines and organizational forms for providing the service”. Sectoral regime can be understood as “the broader economic or societal realms (or organizational fields) that cover a societal function such as mobility. We assume that the approach is able to capture spatial differences and to better understand spatially sensitive regimes dynamics. We illustrate this by the example of an urban and a rural area.

Therefore, with this paper we want to explore to what extent the concept of service regimes and sectoral regimes may provide a useful heuristic to anticipate future developments in the transport system and to identify entry points for the governance of the system. We assume that the concept is able to provide a more fine-grained but not too complex framework for analysis. Transport is a complex web of infrastructures, service and societal interests. It is difficult to have a cross cutting perspective that takes different modes into account but still provides a systematically developed framework. We further assume that an under-represented key factor for the design and performance of the transport system of the future, that will strongly be driven by digitalization and related developments, is the degree in alignment or misalignment between services in the transport sector. Furthermore, this is a key-parameter for the differences between urban and rural transport systems and their potential development trajectories. As will be shown, the degree in alignment or misalignment is at the very heart of the concept of service regimes and sectoral regimes.

The paper is organized as follows: In section 2 we further highlight the need to work with a more spatially sensitive, fine-grained framework in the mobility sector. In section 3 we introduce the service regimes of the transport sector and their core dimensions. Section 4 has a closer look at the sectoral level. The relevance of alignment and misalignment of service regimes for the quality of the sectoral regime is highlighted. In section 5 it is illustrated that very different dynamics of alignment and misalignment may emerge if technical or organizational innovations (electric mobility, self-driving cars) are starting to coevolve with spatially different version of the mobility sector. Conclusions are drawn in section 6.

2. Conceptual background

The concept of the socio-technical regime is usually at the center of transition research. Such regimes are coined by the highly institutionalized set of formal and informal rules, habits, beliefs and norms in a certain field (Fuenfschilling and Truffer, 2014; Geels, 2002). For understanding transitions of socio-technical regimes processes of alignment or misalignment in the institutional settings of regime are crucial. The idea of the regime proved well to be able to integrate factors and actors of rather different natures into a concept of strong explanatory power. It helps to shed light on drivers of change and it helps to understand how stability can persist in highly complex socio-technical configurations. However, the spatial dimension has rather been neglected so far (Schippl and von Wirth 2018). Usually, regimes appear as a spatially rather homogenous conglomerate. In particular in case of spatially highly sensitive infrastructures, such as transport and (renewable) energies, such a homogenous understanding does not seem to fully exploit the potential of the regime concept. Over the last years, scholars pointed at this conceptual deficit (see Coenen et al. 2012; Hansen and Coenen, 2015; Murphy, 2015; Van Welie M.J. et al., 2017). For example Truffer and Coenen (2012) state a lack of spatial perspectives in transition research and innovation studies.

Figure 1 illustrates that in particular the transport system shows highly different mixtures of infrastructures, user interfaces and services in the different spatial settings. Transport, in particular urban transport, is a highly complex socio-technical system. Its design and its development trajectories are shaped by the co-evolutionary interactions between rather different elements, such as infrastructures, technologies, political regulations, broader institutional settings and the versatile interests, preferences and attitudes of different actor groups including users (Geels et al., 2012; Truffer et al. 2017; Puhe and Schippl, 2014). Cars are one element of these systems, in particular in urban regions, other options such as public transport, cycling and walking are at least as important as cars. The functioning of urban transport regimes is indispensable without these options. A transport system based only on private cars would lead to a collapse of the system at least in urban areas and heavily increase its negative impacts on human health, the environment and waste of space. For that reasons ideas about the fully car-friendly city have been abandoned some decades ago in most cities.

Figure 1 shows the transport systems in the city center of two larger German cities, Freiburg and Heidelberg, and of two villages in the surroundings of these cities. The differences between the rural and the inner urban transport system are quite obvious. The urban system consists of various elements such as roads, bus lanes and stops, trams with tracks and stops, interchanges between different lines, but also cycle lanes and pedestrian areas. It is a rather heterogeneous complex of infrastructures which are more or less linked with each other. In rural areas, not surprisingly, the situation is much simpler. Transport infrastructure consists mainly of roads and parking areas, some sidewalks can be seen as well.

	
Mixture of serive regimes in an urban area. Example: City Center of Freiburg, Germany	**Mixture of serive regimes in urban area. Example: City Center of Heidelberg, Germany**
	
Car as dominating service regime in a rural area. Example: Center of the Village of Freiamt, wider region of Freiburg	**Car as dominating service regime in a rural area. Example: Center of the village of Gaiberg, close to Heidelberg**

Figure 1: Examples of urban and rural transport regimes (all pictures from google earth)

It can further be argued that future development pathways in the two environments have to start from very different presuppositions and have different plausible end points. A well aligned, “seamless” mobility system is one vision that is prominently discussed for urban areas, usually in context with processes of digitalization (UITP 2018). In car dominated rural areas, there usually is far less potential to achieve seamlessness across various modes, since public transport and options for car-sharing are by far rarer; in some regions finding a Taxi in the night can become a difficult task.

In order to better cope with the spatially different assemblages of services that make up the transport system, in our contribution we propose to apply a concept that has recently been introduced by van Welie et al. (2017) for the sanitation sector in Nairobi. Here, in a sociotechnical regime the level of service provision (service regime) is distinguished from the level of the sectoral regime. Service regimes are understood as a "specific institutionalized combination of technologies, user routines and organizational forms for providing the service". Sectoral regimes can be understood as "the broader economic or societal realms (or organizational fields) that cover a societal function such as mobility". A sectoral regime can be populated by different service regimes (private cars, public transport cycling etc.).

Following van Welie et al. 2017 and Fuenfschilling and Truffer 2014 we argue that such multifaceted sectoral fields like the transport sector are shaped by different, sometimes competing institutional logics. Each service regime is characterized by its specific institutional settings, including norms, regulations, taken for granted assumptions, user routines, ways of doing things, and/or practices. Which institutional logics dominate the mobility sector in a geographical unit, what kind of combination of service regimes emerge and how they are interlinked and aligned is spatially highly sensitive.

Service regimes follow their own institutional logics, which might be very distinct and different from each other, in particular in rural areas. On the other hand, a process of alignment between different service regimes is visible in larger urban areas, where first steps are undertaken to stronger integrate different forms of public transport, taxies, car-sharing and cycling and to a certain extent also private car usage (e.g. park and ride; car-pooling). In smaller cities, public transport is less developed and for many citizens not considered as an alternative to car transport. In such regions we have much more fragmented mobility sectors. Different service regimes may exist, but are much more difficult to align.

We assume that the ability of the transport system to fulfill its various societal functions strongly depends on the degree in alignment and misalignment on the service and on the sectoral level. On the service level, the alignment between the core dimensions of the different service regimes is important. On the sectoral level, the alignment between service regimes is crucial for the performance of the overall system.

3. Service regime in the transport sector

Service regimes can be described along certain core dimensions that shape their character and their performance. Structuring the complex network of options in the transport sector is a difficult task. Besides clearly delineated modes such as private cars or bicycles, in particular in the field of car sharing there are many hybrid forms range from car rental to ridership with privately owned cars. We see the following service regimes a distinct enough to build a category on their own:

1. Private Cars, user-driven
2. Public Transport
3. Not owned cars, user-driven (car-sharing, car-rental, etc.)
4. Taxis, Ridesharing – driver comes with the service
5. Cycling (owned bike and bike rental, always self-driven by users)

6. Walking

The overall aim of any transport system is to provide mobility for its uses. Therefore we put a user perspective at the forefront for the delineation of the service regimes. As regards the categories 3 and 4, for the users is it relevant if he books a car that he has to drive himself or if he just books a ride and the car is driving by another person. This does not apply to the same extent for cycling, since here the user is always the driver. We do not count the recently emerging platforms and apps for booking and payment of transport services as an own service regime, at least not in the transport system that we see today. We see these as different kinds of services since they do not bring the user directly from A to B. As will be explained in the next chapter, we allocate such multimodal platforms and apps directly to the sectoral level.

The strength and the stability of the service regime depend on the degree in alignment of its core dimensions. Alignment can be assumed when the technical settings, the interests of different groups as well a broader societal expectations or targets converge to a high degree. To give some examples for misalignment:

- Cycling in urban areas is not well aligned if there are no cycle path and if cycling is just seen by the majority of society as a disturbance to car traffic flows;
- Personal mobility based on older diesel cars is not well aligned with regulations about and societal interests in human health in dense agglomerations;
- Public transport in rural areas is not well aligned with user interests in flexible mobility and frequent services.

The service regimes are characterized and can be delineated by several interlinked core dimensions (van Welie et al. 2017). These dimensions are developed, shaped and reproduced by the interplay of infrastructures and technologies, practices and needs on side of the users, the service provides with their business models and regulators with their missions and visions. Users and service provides have their specific interests and needs. Users want to be able to move through their social networks (Axhausen 2008, Urry 2003), providers need viable business models. Regulators have to balance between the interests of both, taking wider societal interests into account. The overall societal meaning of different service sectors is crucial for how this balance is negotiated (is there a right to have “unrestricted” car usage; to what extent is decarbonisaton a societal priority?). This general social meaning of the different service regimes is expressed by cognitive and normative institutions. Regulations try to reflect and to balance between general societal interests. General societal interests are to provide reliable, affordable, convenient but also environmental friendly and healthy mobility. There are trade-offs between these targets that may differ between service regimes.

Based on these reflections we see the following core dimensions as particular relevant for mapping the internal alignment or misalignment in a service regime in the transport sector:

- Technologies and infrastructures are the basic elements of the respective service regime, the hardware, the physical infrastructure, urban design, etc.
- Organizational mode/arrangements refer to the way the service is organized and how the user interfaces are designed; it includes the preconditions/constraints of providing the service and the interests of service providers in viable business models;

- User interest and expectations refer to the interest of the users to have access to functioning, reliable, affordable, safe and convenient mobility; to be capable of arranging their individually desired social networks;
- User requirements refer to the skills, knowledge or competencies that are required to use a certain service;
- Planning practices and public financing refers to the formal planning guidelines and regulations but also to informal taken-for-granted assumption and rules of thumb that guided, for example, the car-euphoric planning period in the 1950'ties and 1960'ties;
- Societal meaning; general societal interests in and wider societal connotations with a service regime, for example "sustainability", "health", or "freedom", "climate change", and others.

Table 1 summarizes how these core dimensions unfold.

	Private Car (PC)	Public Transport (PT)	Taxi and Ride-Sharing (RS)	Sharing-schemes and car rental	Cycling	Walking
Infrastruc-tures and technologies	Capacities on roads and parking spaces, stations garages	Road capacities stops, partly on separated infrastructure	Car-Infrastructure and dedicated taxi areas RS needs to be organized	Car Infrastructure, Service need to be organized ; second car may facilitate private sharing	Cycle lanes and facilities for safe and convenient parking	Safe and convenient walkways
Organisat-ional mode and user interfaces	Users buys the car; nearly always and everywhere usable but restrictions in terms of congestions, parking space, environmental zones, city maut	PT provider offers service, user pay for trips, user is driven, time tables Digital info and payment possible	Taxis: Operator owns the vehicles; user is passenger, Can be called nearly always and everywhere - but only for shorter trips (costs) RS-operator brings driver and user together via App / Platform	Car provided by operator; users drives Availability depends on the density; so far mainly in larger cities available Access via app	Usually privately owned and maintained, sharing also possible In principle always and everywhere usable for shorter trips; weather as critical factor	Free usage, In principle always and everywhere usable for short trips; weather as critical factor
Mode specific user interests and expectations	Good traffic flow and parking close to destination	High frequencies, reliability, easy access to booking, info and payment	Taxi: often avoided because of costs RS: reliability, easy access to info, booking and payment	High frequencies, reliability, easy access to booking, info and payment	safe and convenient cycle routes	safe and convenient walkways
Mode specific user requirements	Be able to finance car and driving license	Finance tickets, understand the system, e.g. time-tables, tariffs etc. Some flexibility	Be able to finance taxi rides; trust in RS	Understand the system, trust, some flexibility	Finance bike, physical skills, weather,	Physical skills, weather,
Regulators practices	Dependence on public funding, planning and regulations Find balance between the car usage and livable cities	Strong dependence on public funding, planning and regulations Strengthen the competitiveness of the system	Organizing licenses and taxi infrastructures	Strengthen competitiveness; in Germany with car-sharing law	Public funding, planning and regulations important Allocate resources to infrastructures for cyclist	Public funding, planning and regulations crucial Planning to extent walking networks and pedestrian areas;
Social meaning	Freedom, status, but also impacts on health and environment	Pragmatic user motivations, Only usable for certain destination at certain times	Expensive, exclusive, for special situations only Ride-Sharing sounds innovative	Innovative but only in certain areas available; extra-parking for CS not always accepted	Flexible and clean, problem of safety, weather and sweating - may be exhausting	Flexible but may be exhausting

Table 1: core dimensions of service regimes

In terms of internal alignment in the service regimes the differences between rural and urban areas are quite obvious (see table 2).

	Private Car (PC)	Public Transport (PT)	Taxi and Ride-Sharing (RS)	Sharing-schemes and car rental	Cycling	Walking
Alignment in urban areas	Not perfect because of congestion, lack of parking, pollution	Is able to transport large amounts of people; does not always fit with individual needs	Always and everywhere available; alignments with user needs limited by costs	High alignment if service is well developed and if access is easy – but this is not always the case	Alignment depends on infrastructures, weather and physical condition of users	Allows for access to several things ; Infrastructure available and mostly well aligned; sometimes too crowded
Alignment in rural areas	Strong alignment and highly institutionalized; drawback that ICE is not sustainable	No real alignment since service operates not frequent enough and does not meet user needs	No real alignment since taxi not always available everywhere; high costs reduce availability	No-weak alignment since service is usually not available or only in a basic variant	Often no cycle lanes; car may be dominating and fast; safety concerns	Only for shorter distances, many things not accessible; enough space for sidewalks available

Table 2: internal alignment of service regimes in rural and urban transport systems

4. Sectoral regimes: alignment and misalignment of service regimes

Coming back to the definition of van Welie et al. (2017), sectoral regimes can be understood as "the broader economic or societal realms (or organizational fields) that cover a societal function such as mobility".

On that basis it can be argued that a sectoral regime in a certain area and at a certain point in time consists of the service regimes it is encompassing. The quality of the single service regimes strongly depends on the internal alignment of their core dimensions. But what is also very crucial for the overall quality of the sectoral regime, for its ability to cover the societal function of mobility, is the degree in and kind of alignment between service regimes. A high degree in alignment means that the service systems do not obstruct each other; in the ideal case they are synergetic.

The sectoral level therefore is more than the pure addition of service regimes. It contributes significantly to the alignment or misalignment between service regimes and affects the internal configuration of the latter. In particular in urban areas a service regime is not isolated from the other service regime. Alignment and misalignment between the services is a question of how the interfaces between them are designed. We see three different categories of interfaces or interrelations that can be distinguished:

- Technical/Infrastructural interfaces: In particular in urban areas all modes compete for space, as it is illustrated in the pictures for Heidelberg and Freiburg (figure 1). But this point refers as well to infrastructures that are designed to provide a smooth and convenient interface between two service regimes such as bike and ride facilities that allow for a high degree in alignment between the service regimes of public transport and private cars.
- Organizational interfaces: This can be services such as integrated ticketing that allow using one ticket for trips with different operators or any kind of smart cars that may enable access to the service regimes of public transport, car-sharing and taxis.
- Institutional interfaces: This can be related to integrative planning paradigms such as, for example, flexible and seamless mobility as an official goal in transport planning. It refers as

well to the more hidden competition for resources in the different planning departments, where decisions have to be taken about the allocation of financial resources and planning capacities to the different service regimes.

These categories help to illustrate the variety in interfaces between service regimes. In reality, most interfaces show elements of all three categories, but may mainly be determined by one of them. For example the option to take a bike in the train can be framed as a technical interface, but it is also an organizational interface since the train ride or the bike needs to be paid for. It may also be institutional, if administrations push towards its realization since it is seen a beneficial for sustainable transport. Further, it is quite obvious that service regimes permanently compete in a way about different resources (road space, public attention, planning capacities, investments etc.). This multifaceted nature of interfaces and interrelations between service regimes underpins the sociotechnical character of the sectoral regimes. Institutional and technical factors co-evolve also on the sectoral level.

Innovations explicitly addressing these interfaces can also take place at the sectoral. Indication for such innovations on the sectoral level can be found in all three fields:

- A simple but efficient example are bicycle racks at train stations. A more innovative approach are bike trailers at long-distance busses.
- A good example for organizational innovations are multimodal platforms or apps that provide information and allow for booking and payment for different service regimes. A good example is the platform Moovel that allows for booking and payment of public transport, car2go, myTaxi and trains in some German Cities (see https://www.moovel.com/de/en). There is also a close connection to the regime of car ownership since Moovel started as a brand of Daimler Financial Services
- A good example for a relative new development in the institutional dimension is the decreasing interest of younger adults in some urban areas in car ownership (Puhe and Schippl 2014). As one amongst several triggers for this development some observers point at a more general trends towards an on-demand culture, where things are just ordered when needed and not necessarily possessed (Truffer et al. 2017)

Based on different kinds of alignment in and between service regimes van Welie et al. (2017) identify four typologies of sectoral regimes in the sanitation sector in Nairobi.

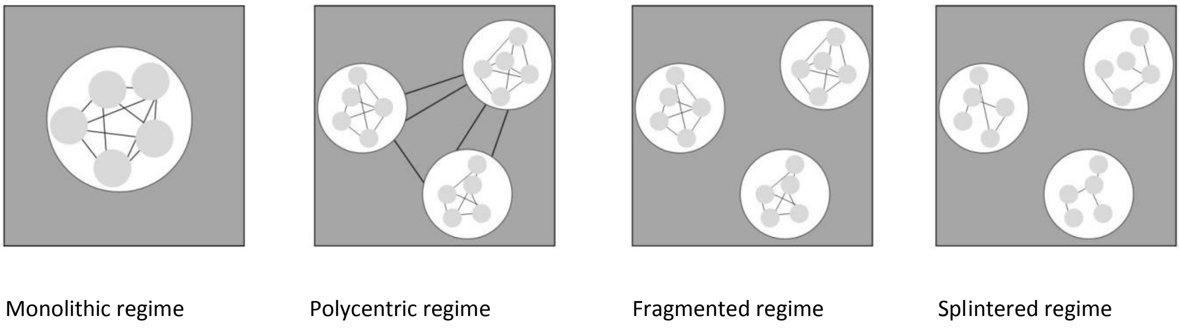

Figure 2: Four typologies of sectoral regimes - sectoral regime (grey square), service regimes (white circles), dimensions of service regimes (grey circles), alignments (lines). Adopted from van Welie et al. 2017

In the transport sector, the differences between rural and urban areas in our examples can be mapped with a similar scheme, highlighting the relevance of alignment in and between service regimes. As it is illustrated in figure 3, a polycentric sectoral system is typical for many urban areas. In rural areas we use the term monocentric regime to describe the strongly car dominated sectoral regimes that can be found there.

It may well be that one service regime is clearly dominating the sectoral regime, such as the car regime in rural areas. The majority of trips in smaller towns are definitely done by car; if one looks at the kilometers driven (instead of the number of trips) the dominance of car transport is getting even more extreme.

One service regime might also dominate and frame the dominant institutional logics in a sector. This has been the case for the service regimes of cars at least over a period of several decades. In many European countries in the 1960s and, to some extent, in the 1970s, the leading paradigm for urban transport was to create a city optimised for motorised individual transport with broad roads and parking spaces. Public transport was considered old fashioned and, in many cities, tramway lines were removed. As a key element of the car regime, the combination of oil-based fuels and internal combustion engines became a central backbone of modern transport systems in particular in advanced economies around the globe. For Germany, motorized transport has a particular significance because of the outstanding importance of the automotive branch in the country. Some of the most successful global car companies are based in Germany, many of them are well-known for their products in the high-end segment.

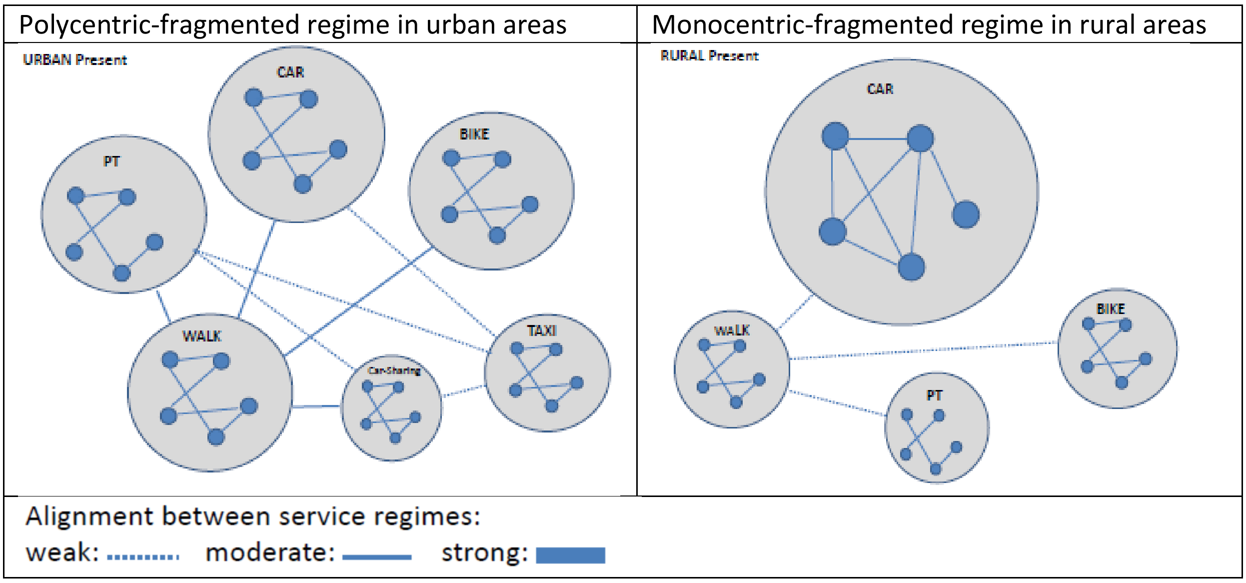

Figure 3: Illustrative examples for service regimes in rural and in urban areas.

In the last decades the situation has clearly changed. Sustainable transport is now high on the agenda in urban transport planning (Banister 2008; Schippl and Puhe 2012). It is usually linked with concept of fostering public transport, cycling and walking, in order to induce a modal shift away from private car usage. In some cities remarkable success could be achieved, for example in Karlsruhe less than 40% of the trips are done by car and regarding cycling there is the outstanding example of the City of Copenhagen that aims at achieving 50% modal share for cycling.

Ideas of sustainable development or combating climate change are clearly linked to wider societal targets and not only rooted in the mobility sector or in one of its service regimes. Any sectoral regime is embedded in a broader societal context that co-determines the institutional settings in sector.

The sectoral level encompasses different services regimes, but it is more than the pure addition of single service regimes. The interfaces between service regimes are strongly influenced by the sectoral level with its infrastructural, organizational and institutional settings of cross-cutting nature. These interfaces determine alignment and misalignment in the mobility sector and, thus, are of utmost importance for the overall quality and also sustainability of a sectoral regime. Transitions in the mobility sector manifest themselves mainly on the sectoral level and have to take into account changes in alignment along the interfaces between different service regimes.

Of course, this statement is based on understanding a transition of the transport sector as broader, far-reaching change in the technical and institutional settings of the sector. It goes beyond a pure substitution of old technologies by new technologies (e.g. “dirty” diesel to “clean” diesel) and sees changes in modal choice at the user side as a constitutive factor of transitions (see Schippl et al. 2018). A transition means that changes in the transport patterns of the users take place as well, usually in form of a modal shift away from private car usage if it is a sustainable transition. Such changes in users’ modal choice imply that new developments and its impacts are not restricted to one service regime, but affect the composition and alignment of service regimes on the sectoral level at least to a “significant” extent.

5. Alignment in and between service regimes of sustainable mobility futures

The concept developed above can now be used to better understand and anticipate the impacts of innovations on future development pathways of the mobility sector in different spatial settings. We use two examples of two innovations that come with clear transformative potentials for the mobility sector.

5.1 Electric mobility:

With this example we illustrate commonalities and differences between urban areas and less densified areas in Germany which support or hamper the diffusion of electric mobility. The diffusion of battery electric vehicles (BEV) is an important topic in the debates about a more sustainable transport system in Germany (Schippl, 2012). But the spatial dimension is usually not well integrated in such debates. In many visions or scenarios, electric vehicles are framed as an element of highly advanced mobility systems in smart cities of the future. The concept of smart cities encompasses developments and ideas which are based on the rapidly increasing digitalization of urban processes which make cities more intelligent and at the same time more sustainable. This alignment of different service regimes to a seamless web of mobility options is central part of such visions.

Interestingly, data about the first private owners of BEVs in Germany illustrate that only about 22% live in these larger urban areas which are expected to be transformed into smart cities in the future (Frenzel et al., 2015). The majority of the early adopters live in other spatial settings or even in the ‘dull’ countryside. First analysis by the authors of data for Germany (data from Kraftfahrtbundesamt) for the year 2017 indicate that large agglomerations have received relatively more registrations in the last two years, but the less densified areas are still responsible for a significant share.

It is important to note that in Germany only about 30% of the population lives in cities with more than 100,000 inhabitants. Efficient strategies for decarbonising transport can not only focus on this regions. A large part of the population lives in mid-sized cities and about 27% live in rural areas with a density of less than 150 inhabitants/km². However, there are several important transport-related commonalities between these three different spatial categories. For example, the number of daily driven kilometers is not too different with 38 km in larger cities, 40 km in medium-sized cities and 42 km in rural areas (Infas and DLR, 2010). On the other hand, the car dependencies are higher in less densified regions. So far electric vehicles are relatively often used by families as a second car (Frenzel et al., 2015). The number of households with more than two persons is also higher in less densified areas than in larger cities. Another advantage of less densified areas is that more citizens have a private parking lot there, often on their own property. This facilitates the installation of private charging points.

For the anticipation of future diffusion patters of BEVs we need to take into account that the transport system is not at all static (Truffer, Schippl and Fleischer, 2017). A number of trends or dynamics are expected to change the transport system in the future, many of them actually fit with the smart city paradigm. For example, digitalization is improving the internal alignment of public transport, sharing schemes, ride-sharing and taxis since access to information as well as booking and payment are getting easier. Furthermore and as often envisioned in smart city concepts, it is expected that the alignment between this service regimes will be improved if they can be booked and payed via one platform or apps. Some of these trends are also relevant for less densified areas, but clearly to a far lesser extent.

In terms of internal alignment of particular interest are car-sharing schemes. They show strong growth rates in terms of usage and number of cars, mainly in larger cities in Germany. Free-floating car-sharing schemes have experienced heavy growth rates in Germany over the last decades and in the meantime they have more registered users than the traditional station-based schemes. However, the free-floating schemes are only available in 12 large German cities, reaching about 10 million people (BCS, 2018). Of particular interest for our analyses is that about 10% of the car-sharing vehicles are electric vehicles (BCS, 2018). Even if many of these still belong to pilot projects, they are in daily usage on the roads. The internal alignment of the service regime which we called “sharing-schemes and car rental” may be strengthened since BEVs should support the societal legitimization of sharing-schemes by enabling zero-emission-mobility, at least at the place of operation. Further, in case of stricter access regulation because of air pollution, BEVs may legalize the usage of car sharing cars in inner city areas.

Another observations which is mainly focused on urban areas is that several studies point at a decreasing interest in car-ownership amongst younger adults in urban agglomerations (Puhe and Schippl, 2014) REF, Compared to the same aged group about ten or twenty years ago, a growing group of younger adults seems to be more open for car-sharing, for public transport and for multimodality in general (what does not mean that this applies to the entire group young adults). If this trend continues it will further contribute to alignment in and also between these regimes and weaken the alignment in the private car regime. Multi- and intermodal approaches may increase market shares on the sectoral level in larger urban areas, which would mean that a modal shift away from private cars takes place.

Against this background, it becomes obvious that different socio-technical development trajectories will have to be distinguished for different spatial categories: one pathway where BEVs are mainly adopted as second or third vehicles in households with more than two persons in less densified areas and a second one where BEVs are mainly embedded in car-sharing concepts in larger urban agglomerations. The first trajectory would rather be a substitution of an old technology (Internal Combustion Engines, ICE) with a new one (electric vehicles), whereas the second pathway would imply a significant change in alignment in urban sectoral mobility regimes.

Figure 4 shows the composition of and alignment between service regimes in the two pathways.

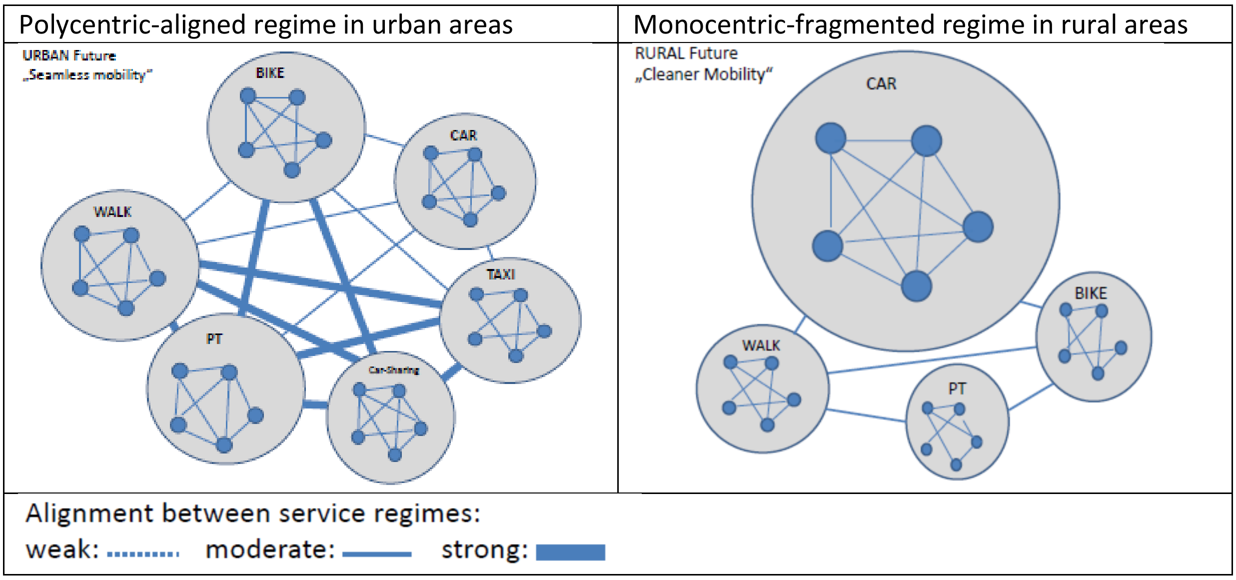

Figure 4: BEVs in an urban and a rural development trajectory towards sustainable mobility futures

In the rural trajectory we still have a monocentric sectoral regime and the degree in alignment between the service regimes is not affected significantly by the diffusion of BEVs. The relative position of the car might get somewhat strengthened, since internal alignment might be slightly improved because electric cars fit better with societal expectations towards environmental friendly cars. But no significant change in mobility patterns can be expected, it is just that users are buying a different kind of cars. In the service regime of public transport internal alignment is often rather poor in rural areas. Public transport is costly for operators and mobility patterns are strongly individualized. There are clashes between user expectations towards frequent services and the interests of public transport operators in viable business models. Alignment between car regimes and public transport may be improved somewhat by park and ride facilities and other measures. But it seems to be of particular importance to accelerate electrification of cars in rural areas. In the short- to middle term this strategy appears to be the most effective way for achieving a better alignment between users’ needs to have access to flexible mobility on the one hand and the societal interests in sustainable mobility on the other hand.

In the urban trajectory a further co-evolution of BEVs with many other factors is likely, including increased car-sharing usage which means changes in mobility behaviour or mobility patterns respectively. In the mid-to long term this trajectory can lead to a multimodal, "seamless" sectoral regime, as it is often envisioned in ideas about sustainable urban mobility futures. Personal owned cars only play a minor role, cycling is strengthened and better aligned internally, and in particular the service regimes of public transport, sharing, taxis and walking are very well aligned. Electrification of cars is desirable and may contribute to the attractiveness and acceptability of electric sharing schemes and, thus to the internal alignment of sharing schemes. But the changes in alignment between service regimes are actually the most important developments in terms of sustainability.

It can be stated that e-cars are not entering a homogenous car regime or mobility regime. The diffusion of electric vehicles needs to be understood in the context of a region's overall transport system. The new technology's degree of disruptiveness depends on the dynamics in alignment in and between service regimes in different spatial settings. Apparently the groups of early adopters are quite different in urban and in less densified areas. In larger urban agglomerations car-sharing schemes play a crucial role whereas in less-densified areas family men seem to dominate. It seems likely that spatially sensitive governance strategies will are useful to take greater account of these different development trajectories (Schippl and von Wirth 2018). Imaginable are, for example, sspecial subsidies for car sharing schemes or higher subsidies for the purchase of electric vehicles in rural areas and lower ones in urban areas where many alternatives to cars are available.

5.2. Self-driving vehicles

Automated driving is a key topic in the debates on the future of mobility. Different degrees in automation are distinguished that range from already established driver-assistance systems to fully autonomous, self-driving cars (see SAE 2014). It is widely acknowledged that this technology comes with a huge transformative potential for the mobility system and maybe also for land-use patterns (UITP 2017). Far less agreement exists amongst experts, however, about which degree in automation will be commercialized at which point in time and in which regions (Schippl et al. 2018).

In the following we limit our analysis to self-driving cars (Level 5 in terminology of SAE 2014) for reasons of simplification and because it is sufficient for our purpose of illustrating the concept introduced above. Also in this case, it can be shown that different dynamics in internal and external alignment can be mapped. If and to what extent self-driving cars will contribute to sustainable development in the transport depends mainly on processes alignment and misalignment. The basic question is whether individual transport is strengthened by self-driving cars or if, in contrast, self-driving vehicles will mainly be used for collective forms or transport.

For both development pathways, individual or collective transport, self –reinforcing dynamics are plausible that could lead to lock-ins in a positive or in a negative sense from a sustainability perspective. In urban areas it is often argued that because of reduced capacities on roads political regulations are likely which will support collective transport. For example EBB (2017) argues that driverless robo-taxis may complement the public transport system. This could be understood as an extension of the public transport system and as a better alignment of its core dimension with user needs, since a more flexible service can be expected. Further it may strongly contribute to alignment in urban areas by offering affordable and flexible last-mile options and support for institutional logics that strive for a seamless mobility sector. The better the alternatives to private cars are aligned, the more likely it is that further political regulations are promoted and accepted by politicians and by the public. A development is imaginable that successively reduces car usage. In particular for commuters solutions would be needed, that better align services in the rural and in the urban mobility sector.

For rural areas as well, new forms of collective transport are discussed which may strengthen the alignment in the sectoral regime (Bernhart et al. 2018). As for urban areas, the idea is that pubic transport may become more adapted to the user needs, however, to what extent such services would be financially viable is difficult to tell from today's point of view. A development may set in, as it is sketched in figure 4 with collective transport extending its services and increasing its market shares. The more attractive the system is the more users it will have and the more promising it may be to further extend it. Organizational alignment with the taxi or the sharing regime is imaginable and may contribute to such a development. However, it is hardly imaginable that the dominance of the car regime is broken since it is too well aligned with user needs. Further, increasing accessibility may motivate more citizens to move out of the city and lead to urban sprawl with the negative consequences of traveling longer distances and waste of space.

On the other hand, in particular in rural areas, self-reinforcing dynamics are also imaginable which strengthen the alignment of the car regime and led to misalignment of public transport and other alternatives to cars. The relative attractiveness of the public transport system could be weakened, which could in turn reduce the economic viability of the system. Services might be reduced and the alignment with user expectations about frequent services might be further weakened: Consequences are fewer customers, less viability, again less alignment and so on. The fragmentation of the system might increase by this self-reinforcing process which is strengthening internal and external misalignment.

Such an erosion of public transport is less likely in urban areas, since public transport regimes are needed to move large amounts of people and the system are usually well aligned there. However, a negative development is not impossible if corresponding policy measures are no take. Policies may be needed early on to prevent the development of a negative trajectory. Individualized transport based on self-driving cars may reduce the attractiveness of urban areas, since they will be dominated even more by cars. Rural regimes could gain in attractiveness, since it is here where the internal alignment of the car regime may benefit the most from making drivers to passenger. Sprawl and more traffic might be the consequences.

The reflections above illustrate well that self-driving cars will surely change the patter of alignment on both, the service and the sectoral level in the one or in the other direction. There is a window of opportunity to make urban transport and to a certain extent also rural transport more sustainable when self-driving cars will be commercialized. But policy measure to prevent negative and to support positive developments will definitely be needed to make use of this window (UITP 2017; Schippl et al. 2018).

6. Conclusive remarks

The approach helps to understand that transitions in the mobility sector depend on how the different service regimes develop individually and on how the alignment between the regimes develops. It helps to illustrate the differences between processes in urban and rural environment. In particular in urban environments, better alignment between service regimes is crucial to achieve more sustainability and to combat climate change. In rural areas it is more the alignment of core dimensions in the car regimes that paves the way towards more sustainability.

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