Land-use and transport planning – a field of complex cause-impact relationships

Thoughts on transport growth, greenhouse gas emissions and the built environment

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Abstract: The notion of integrated land-use and transport planning is linked to hopes that it may be possible to reverse the traffic-inducing effects of interactions between the built environment and transport, and to use planning interventions in land-use and transport provision to effectively contribute to the reduction of transport-related greenhouse gas emissions. However, the targeted design of mixed-use and compact structures on the local and regional level is superimposed by societal and spatial trends that make large-scale mobility politically desirable or necessary. Against this background, the aforementioned hopes appear clearly exaggerated. Written from a German, at times also a wider European perspective, this paper develops the following argument. Land-use and transport are indeed interrelated, but the historical transport growth we face is mainly driven by other societal factors, such as economic growth, the spatial division of labour, large-scale societal integration, and gender equity. In addition, the effects of land-use on transport are uncertain due to limited knowledge on cause-impact relationships. Even in cases where cause and impact can be established, the impact of planning is limited. We conclude that the scope of integrated land-use and transport planning on the local level should not be overestimated so as to avoid false hopes and corresponding failures. This type of planning can hardly be justified by arguments related to the prevention of carbon dioxide emissions, but is useful in pursuing other urban development goals, such as ensuring accessibility without the use of cars, providing a healthy and livable environment, and – to a lesser extent – shifting travel to other modes and, indeed, reducing it overall. Local and regional land-use and transport planning should be justified by realistic and achievable goals, while at the same time highlighting that it has little effect on the general increase in distances travelled and associated greenhouse gas emissions. Conversely, we conclude that the necessary reduction of emissions within the transport sector must be tackled by interventions on the national and supranational levels, rather than expecting or demanding success from largely ineffective, more local interventions and the actors involved with them.

Keywords: Transport growth, peak travel, urban development, land-use planning, climate protection, transport planning

1 Introduction

Since the Second World War transport developments over the world have been characterised by a marked increase in both passenger and freight transport, especially that involving cars and trucks. In Germany passenger travel distances have increased from an average of 9 km (1950) to 42 km/person*day (2015), i.e. by a factor of 4.7, while distances covered by private motor vehicle transport have increased from 1.8 to 31.5 km, i.e. by a factor of 18. The growth in road freight transport has been even greater, from 286 to 5,646 tonne-kilometre per inhabitant, i.e. by a factor of almost 20 (BMVI, 2017, authors' calculations). This increase in transport occurred as part of a complex process of social and spatialchanges.

Debates on cause-impact relationships between space and transport play a significant role in the planning discourse. Discussion refers to two issues: On the one hand, to improved accessibility (especially in terms of improvements in infrastructure and the growing number of cars) as a driver of dispersed, low density and less mixed urban development . On the other hand, to the same type of urban development has been identified as a driver of road construction , growing car ownership, and increases in the distances travelled.

Integrated land-use and transport planning seems to offer some hope of reversing the hitherto traffic-inducing nature of this interaction (Cervero, 2003) so that planning interventions in land-use structures and transport provision could lead to a reduction in distances travelled (traffic reduction) (Moriarty, 2016; Cervero and Duncan, 2006) and cause a modal shift from car transport to more environmentally friendly modes (Boarnet, 2011; Ewing and Cervero, 2010; Holz-Rau et al., 2014; Naess, 2011). However, this discussion tends to understate societal drivers of transport trends that are particularly relevant to climate change (e.g. economic growth, globalisation, educational expansion, emancipation). It is expected that such societal developments will encourage a continued increase in distances travelled and a rise in long-distance trips (ranging from long-distance commuting to private or business intercontinental travel). Although research into these topics is increasing, such developments have thus far received little consideration from either academia or planning.

Against the background of such societal trends and the connected growth in transport, it seems overly optimistic to believe that spatial planning concepts on the municipal and regional levels (summarised as the 'local level' in the following) could achieve any notable reduction in transport-related greenhouse gas emissions. We therefore address three principal questions in this paper:

1. Are changes in spatial and transport structures primarily determined by interactions between the two or are other, possibly more powerful, drivers involved?
2. Even if such interventions should be effective, is it actually likely that they will be implemented?
3. Can the coordinated planning of land use and transport influence transport demand so that transport-related climate emissions are notably reduced?

The paper does not report on original empirical findings but uses the theoretical and empirical literature to set out and support our position. There is a lively debate about the role the built environment plays in reducing travel and associated carbon emissions and other negative externalities (see Stevens, 2017, and the array of comments in the same issue raised by this paper). This discussion tends to rely on empirical relationships while less emphasis is placed on the feasibility of the proposed concepts or on the responsible stakeholders (but see Banister, 1998; Curtis, 2008; Silva et al., 2017). Our contribution is to consider the three questions posed above in concert.

Section 2 presents a view that is widely represented in the planning discourse and that focuses on the interactions between spatial structures and transport in modelling efforts and empirical research. In this context, spatial structure generally refers to the spatial distribution and densities of land uses that function as the origins and destinations of trips. We use the term built environment to refer to this (Ewing and Cervero, 2010; Cao, 2014). We also speak of integrated land-use and transport planning. This ranges from regulating land uses and densities to transport infrastructure and travel demand management. Together land-use and transport planning are important elements of more general spatial planning. This discussion is primarily related to the local level, in line with the jurisdictions for land-use planning in Germany. Our perspective is situated in the German planning system, but may hold to a large extent for other countries organised along decentralised lines with a government-led (rather than market-driven) planning system.

In Section 3 we question the usual conclusions drawn from the models and empirical findings presented in Section 2. We look more closely at (1) the lack of causality, (2) the lack of temporal stability of the links investigated and (3) the difficulty of influencing the causes.

The notion of interactions between the built environment and transport has a strong empirical foundation but tends to ignore other dominant societal changes that influence spatial and transport development. We discuss various components of social change in Section 4. They take place outside the field of intervention of land-use and transport planning to a great extent. These trends lead to the extension of activity spaces within which people undertake daily and long-distance travel. This is similarly true for freight traffic, the consideration of which is beyond the scope of this paper.

In Section 5 we conclude that planning discussions clearly overestimate the effectiveness of interventions affecting the built environment. This limits hopes attached to local land-use and transport planning concepts for traffic reduction.

Two points should be emphasised. Firstly, this paper does not embrace political science approaches such as actor or discourse analysis, even though the interests, discourses and power of numerous groups of actors are undoubtedly of great relevance for land-use and transport planning and policy. Indeed, it is worth noting that policy studies point out the link between the capitalist economy, fuel consumption and transport growth (Castells, 1996/1998; Huber, 2009; Schwedes, 2017).

Secondly, we focus here on arguments concerning transport volumes (distances travelled) and thus on strategies for reducing transport; the use of transport modes (modal shift strategy) is given less attention. Modal shift concepts may indeed have some success (Schwanen et al., 2004; Spears et al., 2016; Christiansen et al., 2017), but they remain marginal in face of the volume of total growth and the reductions necessary for *effective climate protection*. To date growth in transport has been accompanied by a strong increase in modes with high emissions of CO_2 per capita and kilometre travelled. We also do not discuss the potential of new technologies and services such as automated driving or sharing systems as their potentials (and risks, in terms of demand increase) are largely unclear to date.

2 Interrelationships between the built environment and transport

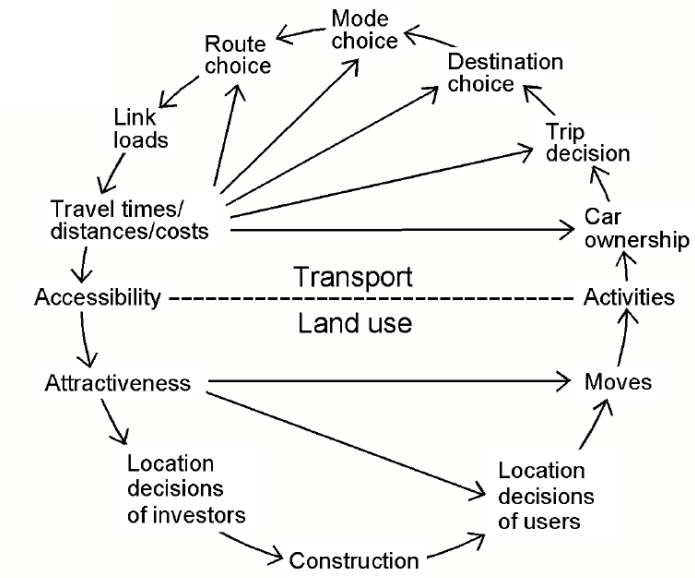
2.1 Theoretical understanding

Urban development and transport have always been closely related. The historical growth of cities typically occurred in parallel to improvements in transport, as transport and urban geography point out (Rodrigue et al., 2009). The private car offered many people a chance to

escape the confines of the city. For many years urban and transport planning followed the model of light, air and sunshine (Athens Charter) and accompanied and supported increases in cars and trucks by developing road networks and low-density housing on the edges of cities. The car facilitated this movement to the outskirts of the city and simultaneously impacted negatively on urban living conditions. Kutter (1975) describes this process of spatial and transport development (which was accompanied or even encouraged by planning) as a vicious circle. Newman and Kenworthy (1999) as well as Mattioli (2014) highlight the self-reinforcing dynamics of car dependence that go along with the spatial developments associated with increasing car use. Wegener (2004) defines a model of these interactions as a feedback cycle of land use and transport (Figure 1), and critically emphasises the development impulses that proceed from improved accessibility (extension of transport infrastructure, sinking transport costs).

The basis of this cycle is the observation that there is little variation in travel time budgets in passenger transport in the long term (Szalai, 1972; Metz, 2004; Stopher et al., 2016), averaging a little over an hour per person per day in developed countries. However, since the first empirical investigation (Szalai 1972) increasing car ownership and the extension of transport infrastructure have led to a massive acceleration in travel. This is not used for savings in the time spent travelling but rather for expanding activity spaces while maintaining largely constant travel times (or possibly slightly increasing them, Mokhtarian and Chen, 2004). This is also termed induced (or generated) travel (see special issue in disP, Axhausen, 2012). The consistency of travel time budgets is associated with a steady expansion of search spaces in line with improved accessibility.

Figure 1: The land-use transport feedback cycle (source: Wegener 2004)



Within a relatively fixed travel time budget, acceleration thus opens up new options on the demand side, i.e. in terms of place of residence, work, leisure time and shopping. Simultaneously, new possibilities for concentration and dispersion emerge on the supply side, e.g. the development of large-scale retail facilities at non-integrated sites, the development of housing or industrial estates in the surroundings of cities. Such developments can, however, lead to a decline in accessibility for people without a car (social exclusion, see Holz-Rau, 2006; Lucas, 2012). The constant travel time budget thus forms the chief basis of the logic of transport in Wegener's feedback cycle (2004).

Notwithstanding multiple developments in modelling with increasing complexity (see Acheampong and Silva, 2015, for an overview), two points can be taken from the feedback cycle and Kutter's (1975) vicious circle with reference to the era of private motorisation.

Firstly, the increasing availability of private cars extends the spatial options for both private and business location decisions. This potential is used by private households and private and public institutions, leading to more traffic, especially more car traffic.

Secondly, this process is accompanied by the extension of transport infrastructure catering for increasing demand ('predict and provide') and the development of housing, employment and other land uses at transport-intensive, car-dependent locations. These developments are based on planning or policy decisions, more precisely on the implementation of plans, which often deviates from the original plans (Banister, 1998; Curtis, 2008; Silva et al., 2017). Impacts on transport, as far as they exist, are caused by implementation rather than the decisions themselves.

The models thus link land-use planning – or, more precisely, its modified implementation – with transport planning and transport demand. However, this understanding of spatial development and transport growth appears too focused on planning to be realistic. Other societal processes that influence spatial and transport development largely remain unconsidered. Economic development, specialisation on the labour market, the convergence of gender roles and other trends influence spatial and transport development, and indeed in some instances vice versa (see Sections 3 and 4).

2.1 The built environment and travel behaviour – empirical findings

Numerous studies have contributed detailed knowledge of interactions between land-use structures and transport. The fundamental findings are largely similar in different countries. It seems that mode choice and distance travelled differ significantly between residents of different spatial contexts (Holz-Rau, 1997; Ewing and Cervero, 2010; Boarnet, 2011; Naess, 2011; Stevens, 2017). This is demonstrated below using a number of studies from Germany, primarily undertaken by the authors of this paper. Categorising municipalities according to their population roughly captures differences in urbanity and transport systems. The findings are not to be understood as one-way causal relations (see Sections 3 and 4).

1. Residents of large cities travel shorter distances on everyday trips than residents of smaller municipalities. The range varies from 27 km/person/day in cities with over a million inhabitants to 40 km/person/day in municipalities with less than 5,000 inhabitants (Holz-Rau et al., 2014).
2. Within cities the average daily distance covered by residents increases with distance from the centre. Thus a somewhat older investigation in Berlin found that the average distance covered by residents of inner-city neighbourhoods was 11 km/day while that covered by those living on the edge of the city was 20 km/day (Holz-Rau, 1997, 54). Similar results were found in Cologne (Holz-Rau et al., 1999). The average distances travelled by residents of neighbourhoods with sub-centres tended to display secondary minimums, but the differences from the centre to the periphery continued to dominate.
3. Within cities the average daily distances covered by residents of neighbourhoods with mixed land use and/or high density are lower than those in districts with homogeneous land use and/or low densities (Holz-Rau et al., 1999). It should be noted that the land-use structure of the neighbourhood and its position in the city are usually related to one another.
4. Residents of municipalities and neighbourhoods in which daily distances are below average use the car less often. They more often walk and/or use a bicycle and public transport (Holz-Rau et al., 2014). Linked to this, car ownership rates are typically lower, and this in turn affects mode choice (Van Acker et al., 2014; Konrad, 2015).

5. Accessibility on different scales may lead to competition (Handy, 1992; Naess, 2011, no research known for Germany). The transport-reducing effects of an excellent local supply of retail facilities and services are often offset by well-accessible large-scale facilities on the regional scale.

3 Critical questions

In land-use and transport planning the findings noted in Section 2 are often ‘translated’ into concepts of urban development, for instance neo-traditional development, new urbanism and transit-oriented development in the USA (Boarnet, 2011) or the compact city and the city of short distances in Europe or Germany (Jenks et al., 1997; Holz-Rau et al.; 1999; Schwanen et al., 2004; Naess, 2011). Such concepts represent a paradigm change from the earlier adaptive planning approach towards integrated land-use and transport planning, which attempts to influence travel behaviour through the ‘backdoor’ of spatial structure (‘urban design planning’). However, even the transport models critically discussed above cast doubt on the notion that such effects can be transferred in space and time.

When such findings are seen in the light of Kutter’s (1975) vicious circle of transport planning or Wegener’s (2004) feedback cycle a number of questions arise: Can these cycles be reversed, halted or at least slowed by planning and policy? Can integrated land-use and transport planning help reduce travel distances (and car use), and thus reduce traffic? Can planning support the emergence of 'virtuous circles' (Jackson, 2011)?

In order that transport planning result in the reduction (or modal shift) of traffic it is necessary that at least the following conditions be fulfilled:

- Causality of relationships: The variations in travel behaviour observed in different built environments must be based on causal relationships. Without this causality, changes in the built environment cannot be effectively targeted.
- Temporal stability of relationships: These causal relationships must be stable over time, otherwise the expected effects may not actually occur in the future. The process character of cause-impact relationships cannot be identified in cross-sectional analyses.
- Influenceability of causes: It must be possible to influence the causes of the causal relationships – politically, structurally and financially. Otherwise no impact can be achieved even if the causal relationships are understood.

Simple consideration and empirical findings show that these three conditions are not met. The following discussion is intended to help deterministic and incorrect conclusions to be avoided and to instead clarify the complexity of the causal chains involved.

3.1 Causality of relationships

The spatial differences found in everyday travel have various causes, and only some are related to the built environment. These include:

Firstly, population structure. The population structure differs between various spatial contexts. Levels of education and income are usually higher in cities (Goebel and Gornig, 2014, for Germany) than in smaller municipalities, even though the picture is much more nuanced on the neighbourhood level. As higher incomes and educational levels are linked to longer distances in everyday travel, they also contribute to differences between spatial contexts. However, multivariate analyses that simultaneously consider social and spatial factors still tend to show more limited but nonetheless clear spatial variations in travel. In the cases of income and education the variations in travel distances and car use may even tend to increase once the higher levels of income and education in cities are taken into account.

Secondly, complex cause-impact chains. Spatial variations reflect complex cause-effect chains, but not direct causal links between the built environment and transport demand. Of relevance here are self-selection processes, which have in recent years been the subject of much investigation in relation to decisions on residential location (Cao, 2014, and other papers in the same issue, Scheiner, 2009), but also affect destination choices (place of employment, shopping trips, etc.). This implies that particular lifestyles and mobility styles concentrate at correspondingly suitable residential locations (and destinations).

If, for the sake of the argument, we surmise (Holz-Rau, 1997, 38f.; see Chatman, 2014, for an example concerning pedestrians) that the population may be divided into those with an affinity for public transport and those who are averse to it, it can be assumed that those with an affinity frequently reside in locations with adequate public transport. If public transport were improved in locations where only those who are public transport averse live, then such an improvement would have much less effect than a comparison between the two populations would suggest. What is more, it can be assumed that there is not only a direct relationship between residential location and mode use but also links, for instance, to trip distance, time of travel and other trip characteristics.

Thirdly, functional dependence between over- and undersupplied areas (centre and periphery). Commuting distances undertaken by the inhabitants of cities are on average shorter than those undertaken by residents of smaller municipalities (Elldér, 2014; Einig and Pütz, 2007, 88). As well as self-selection – those who dislike commuting prefer to live in the city – the surplus centrality of the cities plays a role here (Johnson 1971, 158). In cities, particularly in the inner cities, there are more jobs than resident labour, and retail supplies and educational facilities are greater than what is required by the residential population. In contrast, on the urban edges the labour pool is larger than the number of jobs and the retail facilities and (secondary) schools cannot satisfy local demand. Here there is indeed a causal relationship between the built environment and travel demand (distance and, in some cases, mode choice). Compensating for this surplus centrality (i.e. attracting more workplaces, schools, retail to undersupplied areas, in whatever way that may be possible) would thus lead not only to decreases in distances travelled in the previously undersupplied locations, but also to increases in distances travelled in the locations with surpluses. This is equally true for all activities, as ‘transport-efficient’ locations are also characterised by a surplus in the supply of shops, schools, cinemas etc. The potential for reducing traffic is in any case significantly less than is suggested by the difference revealed by cross-sectional analysis. This is empirically demonstrated by the fact that panel studies ‘tend to show much smaller effects than the vast number of cross-sectional studies, which examine *differences* in travel behavior between places with *different* land-use patterns’ (Van Wee and Handy, 2016, 19). The type of analysis that looks at the travel behaviour of residents in an area without taking into account the behaviour of those attracted by the area divides a functional region into sub-areas that are not able to function individually. Inner-cities cannot function without their catchment areas and suburbs cannot function without the city centre. Each region (at least) should therefore be analysed as an entity (Boarnet, 2011).

3.2 The problem of timeframes

Notwithstanding a tremendous increase in longitudinal analysis in the past two decades, most travel behaviour studies are cross-sectional (Boarnet, 2011). This can lead to spatial effects being misjudged, as the example of suburbanisation demonstrates. Three points may be highlighted.

Firstly, residents of smaller outlying municipalities travel further on average than the population of larger outlying municipalities (Kagermeier, 1997; Motzkus 2002, 112ff; Siedentop et al., 2005, 95ff). The obvious interpretation is that much of what enables transport-efficient everyday life is

not found in smaller municipalities. The usual planning corollary is that if suburbanisation were concentrated in the larger outlying municipalities, transport would be reduced (see discussion of the concept of ‘decentralised concentration’ in Siedentop et al., 2005, 42ff; Holden and Norland, 2005). These differences in travel can be traced primarily to commuting (Geier et al., 2001). However, differentiating between long-term and new residents shows that there is little difference between the types of municipalities in terms of the commuting levels of new residents. Those who move from the inner city to the suburbs tend to continue to work in the inner city (Geier et al., 2001; Bauer et al., 2005; Scheiner 2009, 162ff). As the proportion of new residents is much higher in the smaller outlying municipalities than in the larger ones, the population of the smaller municipalities travel further distances than the population of the larger municipalities. Therefore, diverting suburbanisation to the larger municipalities may not significantly reduce travel in suburbia as a whole, at least not in terms of commuting, which is particularly relevant for the differences in distances travelled. Modal changes towards public transport may be achieved (although see discussion on the behaviour of those averse to public transport above). Of course, the larger outlying municipalities are more efficient in terms of shopping and school trips. However, for the total balance of distances travelled this consideration is less pertinent (in Germany, trips to education account for 3.5% of distances, shopping trips for 15.9%, BMVI, 2017, 225).

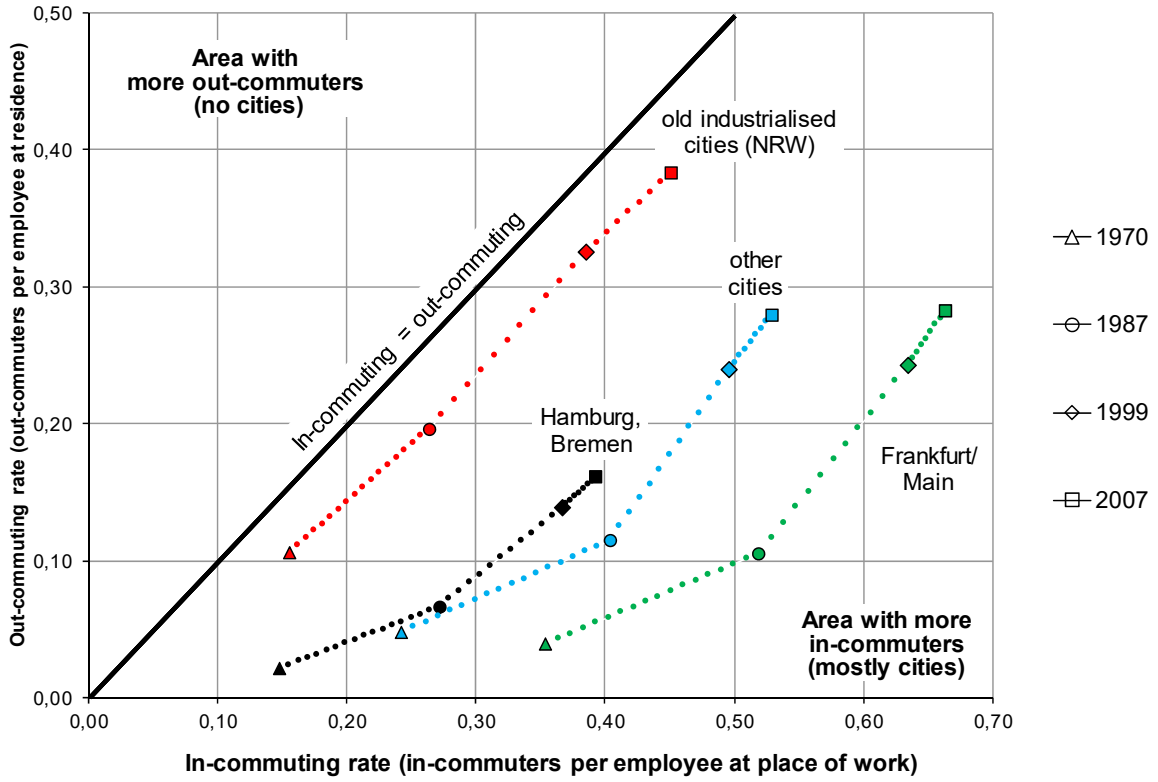
Secondly, transformation processes are also easily missed in cross-sectional analyses. This is illustrated by Germany-wide statistics on commuting covering 1970 to 2007. Over this period commuting into and out of German cities (former West German states) increased distinctly, most strongly in the years between 1987 and 1999 (Figure 2). This is true for rates of both in-commuting and out-commuting, for the latter particularly more recently. A role has been played by the suburbanisation of housing and jobs, but also by decreases in the stability and security of jobs. The process is more influenced by increasing car ownership, general decreases in the impedance of distance and – perhaps most significantly – changes on the labour market (specialisation, temporary contracts…) than by the distribution of jobs and housing in space. This is demonstrated by the fact that the necessity to commute (based on the regional distribution of housing and jobs) has scarcely increased (Guth et al., 2012). Such developments can also be described as the decoupling of travel behaviour from the local built environment (Holz-Rau, 1997) or excess commuting (Guth et al., 2012; Suzuki and Lee, 2012).

Thirdly, spatial differences in travel behaviour are not stable over time. In 2008 the shortest daily distances in Germany were found in the largest cities and the highest in the smallest municipalities (see above). However, in earlier surveys (former West Germany) the minimum distance was found in medium-sized cities while the population of the large cities as well as that of smaller municipalities travelled further distances (Table 1). Since the first German national travel survey in 1976 average distances in the smaller municipalities have increased most, while in cities with over a million inhabitants they have not increased at all. Thus the minimum has gradually shifted from smaller cities to those with over a million inhabitants while at the same time overall distances have distinctly increased. Extrapolating into the past suggests that in the 1950s and 1960s travel distances were actually the highest in cities with over a million inhabitants and the lowest in the smallest municipalities. Car ownership rates were extremely high in many cities in West Germany in the 1950s and 1960s, while in rural areas they were below average (Scheiner, 2012). Taken overall, one may argue that urban lifestyles were more travel intensive in the first half of the 20th century, while in the second half rural areas were gradually linked with urban areas, i.e. rural life became 'more urban'. Massive transport growth occurred in both types of areas as well as in the emerging suburban areas, and it was stronger in the latter than in the regional cores. Change was driven by catch-up motorisation in the countryside and changes in

economic structure. In 1960 much of the labour force of the smaller municipalities was still employed in agriculture. Trips to work were short and usually restricted to the municipality of residence. The decline of agriculture led to a rapid increase in commuting into the cities. Furthermore, labour specialisation has increased. Increasing career expectations led to difficulties to find a suitable job even in larger municipalities. This is intensified by increases in the number of dual-income households.

Overall this implies that reversing Wegener's (2004) feedback cycle would not take us back to the original transport structures. The settlement structures of the past would be utilised in a distinctly more transport-intensive fashion today than they used to be.

Figure 2: Rates of in- and out-commuting in German cities (old West German states, authors' analysis of the censuses of 1970 and 1987 and statistics from the Bundesanstalt für Arbeit 1999 and 2007)



Old industrialised cities NRW	Other cities	The spacing of the points represents the mean annual change between the years 1970, 1987, 1999 and 2007.
Bochum, Dortmund Duisburg, Essen, Wuppertal	Bielefeld, Bonn, Düsseldorf, Hannover, Köln, Mannheim, München, Nürnberg, Stuttgart	Closely spaced = little increase Wider spacing = greater increase

3.3 The influenceability of causes

Transport developments cannot be successfully managed by just identifying (spatial structural) causes. It must also be possible to influence these causes in a targeted manner. This is not always feasible. We give three examples.

Fistly, the distinctly lower daily distances travelled by the population of the (inner) cities result from the surplus of central-place functions. A region cannot, however, consist only of inner cities. Using differences between the travel behaviour of residents of the inner city and residents of the suburbs as a basis for concluding that traffic can be reduced is therefore to misjudge the

importance of the spatial division of tasks within regions. Even if causal relations exist, it does not necessarily mean they can be instrumentalised in order to reduce transport.

Table 1: Average distances in everyday travel over time (km/person*year, minima in bold) (Authors' analysis of KONTIV 1976, 1982 and 1989 and MiD 2002 and 2008)

Municipality size [a]	1976	1982	1989 [b]	2002	2008
< 5,000 inh	10,150	11,876	12,937	13,539	15,485
5- <20,000 inh	9,730	11,414	12,260	13,246	14,120
20- <50,000 inh.	**8,614**	11,394	11,304	11,637	13,424
50- <100,000 inh.		**9,752**	11,293	11,294	12,883
100- <500,000 inh.	8,978	10,597	10,872	11,969	12,430
500,000 - <1 million inh.	9,270	10,522	**10,740**	**10,087**	12,754
>= 1 million inh.		11,690		11,591	**10,961**
Total	9,329	11,066	11,520	12,363	13,558

[a] The municipal size categories are not identical in all surveys. The boundaries between categories thus differ between individual years.

[b] Due to the survey method used, the original 1989 values are somewhat lower than the values of the other surveys. They have thus been increased by a factor of 1.21. This value corresponds plausibly with the overall average of the series. This has no effect on the comparison of the means of municipal size classes.

Secondly, the planning concepts of different sectors often compete with one another. Although suburbanisation is sometimes viewed as being related to transport disadvantage (Delbosc and Currie, 2011; Li et al., in print), suburban developments eased pressure on the urban housing market. The relocation of businesses to the edge of the city, especially those in the manufacturing sector, simultaneously improved their profitability and inner-city living conditions. In this way potential was released in the inner cities and regions for the increasing demand for living space and for tertiary and quaternary jobs, sometimes at sites with excellent public transportation links. In most cities a reversal of this trend would be impossible to realise while maintaining tolerable densities, especially in light of high standards for production, distribution and housing space (see Herfert and Osterhage, 2012; Rink and Banzhaf, 2011). Such a reversal could in any case not be justified solely on the grounds of potential reductions in transport because it would conflict with other sustainability goals (Moriarty, 2016).

Thirdly, there also does not seem to be much political support for concepts that increase the friction of distance, for reducing the capacity of major road networks as a whole, or for drastically increasing the cost of transport by car. Though some major cities have implemented restrictive policies such as capacity limitations in parking or the road network (e.g., Vienna, Paris) or price regulations (London, Stockholm), we are not aware of any city that has done so on the scale of a region as a whole or even on the level of long-distance transport. Furthermore, social processes that affect the field of transport tend to develop considerable momentum and are very difficult to control through policy (Rammler, 2001). In certain cases where it would be possible to intervene, the relevant processes are viewed positively rather than negatively despite their traffic-inducing effects. They are correspondingly supported by policy. This is particularly true of decision-making processes on the German national and EU scales, which tend to be primarily concerned not with visions of integrated planning but rather with economic growth and infrastructure provision, and

which therefore target and promote exchanges of goods (freight transport) and labour (private transport).

The increase in distances travelled has been a dominant trend in transport in recent decades, but this cannot be adequately explained by reference to changes in the built environment, even though links between the two exist. The extension of activity spaces is primarily connected to other aspects of social change (Section 4). The majority of these processes are, however, beyond the scope of urban and regional planning and are generally welcomed as representing 'social progress'. The reversal of these developments thus hardly seems an appropriate option for reducing transport.

4 Social change and transport

Social change in recent decades has been described using numerous key concepts such as modernisation, individualisation and globalisation (for the transport context see Castells, 1996/1998; Rammler, 2001; Canzler et al., 2008; Scheiner 2009). In principle, the most important sub-processes all act in the same direction: that of increasing volumes of traffic, extending activity spaces in private transport and increasing areas of interlinkages in freight and business transport (Axhausen, 2007). We discuss four trends, focusing on private transport We include consideration of long-distance trips here for two reasons:

1. Long-distance transport accounts for over 50% of the greenhouse gas emissions of private transport (for Germany Aamaas et al., 2013; for Helsinki Ottelin et al., 2014). Consideration of the contribution of the transport sector to reducing greenhouse gas emissions should therefore include this growing area of travel. Even if intervention in the local built environment cannot be justified by the possibility of influencing long-distance travel, such travel is relevant in terms of judging the overall effectiveness of intervention. This is particularly true as long-distance travel is increasing, especially long-distance commuting (Pütz 2015, 14f), which leads to an ever-greater proportion of trips and distances (and thus greenhouse gas emissions) being excluded from urban transport analyses.
2. At the same time the inhabitants of the cities, transport-efficient though they may be in everyday life, are particularly active in long-distance travel (Holden and Norland, 2005; Ottelin et al., 2014; Holz-Rau et al., 2014). In terms of self-selection affecting population and economy, this is an indication of socio-spatial configurations that can only be correctly interpreted by analysing overall travel. This is also true of the current and at times jubilant debate about the ecological advantages of decreasing car use among young adults. Completely different conclusions may be drawn if this group are found to be particularly active long-distance travellers (Frändberg, 2009).

Owing to the data available, the following results are based primarily on cross-sectional analyses despite the dangers of misinterpretation (Section 2). However, similar findings have been reported in numerous investigations at different points in time in different countries (Holz-Rau, 1997; Schwanen et al, 2004; Scheiner, 2009; Ewing and Cervero, 2010; Naess, 2011; Elldér, 2014; van Wee and Handy, 2016) and within Germany in the different waves of the KONTIV/MiD surveys (Konrad, 2015). We are also unaware of theoretical concerns about the interrelationships discussed.

4.1 Higher incomes = more cars and longer distances

In both daily and long-distance trips household income is clearly linked to travel distance and modal choice. Our own multivariate analysis shows the difference between the highest and lowest income categories (upper and lower 10%) to be 3,500 km/person*year in daily travel and 7,700 km/person*year in long-distance travel (Holz-Rau et al., 2014, 498) with an average of

12,500 resp. 7,700 km/person*year (ibid., 500). These differences are seen particularly with trips by car and plane (Reichert and Holz-Rau, 2014). It follows that longer-term increases in wealth are associated with an increase in distances travelled (Dargay, 2007), in everyday travel especially by private car and in long-distance travel especially by plane. A review of the literature on income elasticities suggests a demand-income elasticity of 0.4 in the short term and 1.0 in the long term for vehicle ownership and fuel consumption (Goodwin et al., 2004). Fouquet (2012) finds similarly strong income elasticity (0.8) for passenger transport in the UK. Such findings challenge the idea of decoupling economic growth from transport growth, although this is the focus of much research (Garceau et al., 2014).

More detailed consideration reveals at least three different aspects to this phenomenon:

- The increase in income and/or purchasing power opens up financial options for private car ownership and driving. It is a precondition for the extension of daily activity spaces and holiday travel.
- Increases in income result from general rises in earnings but also from an increase in more highly qualified occupations, which are linked to more frequent business travel.
- Simultaneous reductions in the cost of flying allow more business and private trips to be made by plane, and thus to be made over longer distances.
- The reductions in transport costs over time also refer to the costs of driving. Even though average real incomes have remained fairly stable over the past twenty years in Germany and other countries, unit car transport costs (purchase and operation) have declined considerably in the long term (Frei, 2005).

It thus seems that increases in income have contributed and continue to contribute to increasing travel distances in daily travel and long-distance trips.

4.2 Higher education and increased specialisation = greater distances

Almost parallel findings have been reported concerning level of education (taking income effects into consideration). Thus per year those with a university degree cover 1,700 km more in everyday travel and 7,200 km more in long-distance travel than those with a secondary-modern school leaving certificate or with no school qualifications (Holz-Rau et al, 2014, 498). Higher educational qualifications are linked to more specialisation in the labour market and thus a lower density of suitable jobs and, frequently, longer trips to work.

Language skills tend to improve with higher education, providing the competence and an incentive to travel abroad, and in addition stays abroad have themselves become an integral element of life courses and lifestyles especially among higher educated younger generations (Frändberg, 2014; Luzecka, 2016). There are many indications that such periods spent abroad lead to private globalisation in the form of further private visits and a higher degree of international career mobility (Frändberg and Vilhelmson, 2003; Frei et al., 2009). This contributes to a considerable increase in long-distance travel. For instance, from a snowball sampling survey in Switzerland (Kowald and Axhausen, 2012) it can be seen that an average respondent has about 1.1 private leisure contact persons in the distance range of 100-1,000 km with whom (s)he makes personal contact 12-13 times per year on average. Even in the >1,000 km distance range 0.28 contact persons are reported, with personal meetings averaging 10-11 times per year.

Higher education and parallel specialisation on the labour market are linked to greater distances in daily and long-distance travel. Thus the expansion of education seems likely to have contributed to and continue to contribute to increases in the distances covered in daily and long-distance travel.

4.3 Increasing equality for women = more cars and longer distances

Increases in private car ownership in recent decades are overproportionately due to increased car ownership of women. In the younger cohorts there are hardly any gender differences in car availability, distances travelled or car use between men and women in similar employment (Konrad, 2015). At the same time the numbers of women in gainful employment have increased significantly. For both men and women, being employed is connected with greater distances travelled and greater car use (Konrad, 2015). Differences in long-distance travel that still exist can be traced to higher levels of business travel among men, which is an indication of the different professional profiles of men and women (Holz-Rau et al., 2014, 497ff.).

Furthermore it is more difficult for households with two earners to find a residential location that minimises household commuting distance. No matter how commuting is split between partners in a couple – the men usually have longer commuter trips than the women – it is more difficult for dual-income households to coordinate place of work and place of residence in a travel-efficient manner than for one-income households, even though empirical results are inconsistent (Sultana, 2005; Surprenant-Legault et al., 2013).

The gender convergence in travelling in the younger cohorts has largely involved women's travel increasing to the higher level of men's (Beckmann et al., 2005; Frändberg and Vilhelmson, 2011; Konrad, 2015). It is only in the last decade that a few countries have seen some indications of a reduction in car use and a decline in the daily distances travelled among young men (Kuhnimhof et al., 2012; Frändberg and Vilhelmson, 2011). There has been no investigation to date of whether distances travelled have declined if long-distance travel is included, but this seems unlikely.

Overall changes in gender relations are linked to increasing employment levels and car ownership among women. Both lead to an increase in daily distances travelled and car use.

4.4 Virtualisation, multi-localisation and equal-status partnerships = greater distances

Today, telecommunications allow long-distance private and professional networks to be more easily created and maintained than even a few years ago, e.g. among young adults and their contacts from a period of study abroad. This is also a condition for the increase in many forms of multi-local living that are associated with spatial exchange over long distances ('living apart together' couples, children commuting between parents, long-distance commuter marriages, etc., Hesse and Scheiner, 2007; Dittrich-Wesbuer et al., 2015).

Forming partnerships in conditions of limited spatial impedance and larger, sometimes virtual search areas – via online dating sites – promotes homogeneity of status between couples and the 'matching' of couples over greater distances. Simultaneously, social polarisation is considerably strengthened at the household level (Blossfeld and Timm, 2003).

It should be noted that there is much discussion about the potential effects of information and communication technologies (ICT) substituteing for physical travel. While the impacts of ICT are still largely ambiguous (Circella, 2017), aggregate (Choo and Mokhtarian, 2007) as well as disaggregate (Lee et al., 2017) analysis suggests that 'virtual travel' and physical travel may well be complementary forms.

Virtual interaction that helps maintain social contacts and the extension of search spaces for personal relationships lead to greater distances being covered, especially in long-distance commuting and weekend travel.

5 Conclusion and outlook

Transport and spatial development form a mutually determining process, described in the planning discourse as a feedback cycle or vicious circle. Wegener's feedback cycle (2004) and similar models emphasise the mutual interrelations of land-use and transport decisions and development, and thus the importance of land-use and transport planning. This is also true of transport models in which variations in travel behaviour between specific types of built environment are used as the basis for transport prognoses and impact assessments. Utilising the current state of knowledge, the following conclusions can be drawn.

While it is supposed that integrated land-use and transport planning has the potential to reduce transport, important pre-conditions have not been met, particularly concerning the planning of the built environment and quantification in transport models. There is a lack of methodologically robust evidence for the causality of relations and little knowledge about the temporal stability of observed relationships. Additionally, planning has limited scope to influence the supposed causes:

- Differences in travel behaviour between different types of built environment are linked to self-selection processes and spatial variations in population structures. The categories of built environment used for analysis break up interconnected spatial units in a region, even though such units can only function together as a whole.
- The spatial differences in travel behaviour are not stable over time and are strongly influenced by societal change. Analyses based on temporal cross-sections can lead to spatial variations in travel behaviour being divorced from the processes by which they emerged and hence to false interpretations. Actually, increases in transport over time are of greater significance than spatial differences at any given moment.
- Various processes of societal change lead to increases in transport volumes. At the present time this is particularly true of long-distance travel, which is often ignored by transport research (see for exceptions Holden and Linnerud, 2011; Holz-Rau et al., 2014), and of freight transport, which is not considered in this paper.
- Important factors that we generally regard as social progress – economic growth and wealth, increasing gender equality and the expansion of education, globalisation and travel – lead to the extension of regional, trans-regional and worldwide interactions. Although especially growth trends have been heavily contested by environmentalists since the beginning of the ecological movement in the 1970s under the term 'limits to growth', they are generally welcomed by mainstream society – and in some cases even by an ecologically oriented academia – and promoted by policy.

The lower (but still high) level of car use among younger adults and growth in the populations of cities have been interpreted by some mobility researchers as signs of a transformation in transport (peak car, peak travel, Millard-Ball and Schipper, 2011; Kuhnimhof et al., 2012; Van Wee, 2015), but there are reasons for a more 'pessimistic' interpretation.

Firstly, young adults may be particularly active in long-distance travel and may thus contribute an above-average amount to transport-related greenhouse gas emissions, despite low levels of car use. For people particularly involved in long-distance travel with multiple places of residence, changing places of work, and extensive social and professional networks, flexible options such as car sharing are more suitable than owning their own car. Low levels of car use among young adults can thus also indicate the expansion of activity spaces beyond the limits of the car – as one of our students once put it: 'We don't have our own cars because cars can't fly' (Björn Vetter). Future investigations in this field should thus not be restricted to daily trips but should include long-distance travel and developments such as the increasing multi-locality of both residence and work.

Secondly, in many regions the growth of the cores is associated with the simultaneous growth of surrounding municipalities, which are characterised by transport-intensive daily travel. In Germany, reurbanisation has been accompanied by a loss of population in suburbia primarily in the eastern German states (Herfert and Osterhage, 2012), so that this phenomenon is relevant mainly in those urban regions where there is attractive and affordable housing space available in the cores. Focusing on reurbanisation detracts attention from the population growth of the transport-intensive and car-dependent areas at the edges. The increasing importance of agglomerations overall can be linked to a further rise in transport volumes, despite the growing number of residents in the cores.

Thirdly, it is important from a transport perspective whether the travel behaviour of the 'reurbanites' is similar to the behaviour that has so far been characteristic of the population of the (inner) cities. We suspect that the urge to move into the (inner) cities may be a reflection of the multi-locality that is connected to highly qualified dual-income households, the time-consuming long-distance commuting between major cities (Pütz 2015, 8f), the increased importance of long-distance (private and business) trips. The growing centres are usually especially well integrated in long-distance transport networks and the individuals living there are particularly active in long-distance travel.

We suggest that transport growth continues, but it is increasingly realised in fields where the car is irrelevant. This conforms with growth forecasts for the US (Schäfer, 2017). The areas where this growth is strongest are the agglomerations, both their centres and their peripheries, and namely those regions that started from the lowest levels in the past, resulting in convergence between regions (Abe and Kato, 2018). The current processes of reurbanisation (more accurately described as the growth of the agglomerations overall) and the lower levels of car use among young adults are linked to continued increases in transport volumes and are not necessarily the beginning of travel decline, as the peak travel debate suggests (Millard-Ball and Schipper, 2011). Car use may decline somewhat in this process but transport volumes overall and thus greenhouse gas emissions will continue to rise due to increases in long-distance trips.

Verifying this hypothesis on the dynamics of society, space and transport requires further theoretical and empirical work, referring for instance to the concept of the network society (Castells, 1996/1998) and including consideration of preferences, lifestyles and multi-local living, as well as the role of large-scale accessibilities, and more. Besides increasingly detailed social categorisation it may also be useful to perform more spatially aggregated analysis to ask whether there may be not only urban sub-areas but also entire regions that are organised in a more transport-efficient or more transport-intensive way. What is more, while transport studies are characterised by excessive travel behaviour analysis and modelling, there is less research on the rationales, preferences and actions of stakeholders and organisations. More studies on policies – especially those that can potentially result in large reductions in GHG emissions – may thus be warranted in the future.

Our view suggests a shifting of priorities in discussions about the contribution made to climate protection by integrated land-use and transport planning, which can only be briefly outlined here. We do not doubt that the sustainable development of cities and regions requires integrated land-use and transport planning that follows the idea of mixed-use and compact structures. However, it is unhelpful to offer erroneous justifications for such an approach and to pursue unrealistic goals. Transport planning is today characterised by extremely broadly defined, unclear and nebulous objectives (Taylor und Morris, 2015). This obstructs successful local-level planning and can actually damage climate protection as failures only become apparent after a long period of time has elapsed. The reduction of CO_2 emissions should not be more than a secondary goal for local-level integrated land-use and transport planning, because the most important opportunities for intervention are on the

national and supra-national levels. Integrated land-use and transport planning should rather focus on providing:

- high quality of life in cities and regions,
- social inclusion and participation for all,
- traffic safety – with the prospect of no traffic fatalities ('vision zero'),
- a healthy environment – avoiding negative impacts on health caused by traffic noise and other transport-induced emissions,
- communicative and lively public spaces,
- low costs for the general public (including that of the future) and for socially disadvantaged groups.

In order to achieve these goals, it is necessary not only to focus on improving the provision of desirable transport modes (pull strategies), but also to increase restrictions on undesirable modes (push strategies), e.g. parking space restrictions (Petrunoff et al., 2015), which requires studying the role of street spaces and parking rather than just land-use along the roads (Manville, 2017). This is clearly more controversial than simply improving transport provision (perhaps even in parallel for all transport modes).

The following strategies should continue to be pursued, but oriented towards realistic goals and addressed to the relevant actors and levels:

- Ensuring accessibility without the use of cars through integrated land-use and transport planning with barrier-free transport provision, with local opportunities for activity, and with options for location choices on the local level that avoid structural car dependency.
- Rendering transport more environmentally compatible (safer, quieter, less emissions...) in order to limit damage and improve quality especially by using policy frameworks on the national and supra-national levels (paying particular attention to air traffic), by enforcing CO_2 compensation payments or significantly increased fuel costs, and by local transport planning measures related to local impacts.
- Modal shift to achieve the goals of local land-use and transport planning (e.g. urbanity and quality of urban life through the reduction of road transport, increased cycling and walking) and also as a side effect of measures intended to improve accessibility. Arguing that this may make only a limited contribution to climate protection is in line with the existing debate on the link between land-use and transport, where there seems to be broad agreement that the magnitude of the effects of the built environment on travel is not very substantial (Stevens, 2017, and other papers in the same issue).
- The reduction of transport (and car ownership) in the longer term could be supported by considerable rises in fuel costs, if this was possible to implement (which we think unlikely)[1]. Acceptance of drastic price increases may be enhanced by benefits elsewhere.

[1] The effects of distinctly more expensive fuel taxes (or other costs) can be varied and are, for instance, dependent on the concrete use made of the additional payments received. Adaptations in behaviour need not be limited to transport demand. They can, as indeed desired, promote the success of fuel-efficient technology. They can also, however, lead to a reduction in spending outside the field of transport (e.g. shopping for cheaper goods, abandoning private pension plans) or – similarly dependent on the use to which the funds are put – also to changes in economic performance. Estimating the effects on travel behaviour and transport-induced CO_2 emissions is very complex and, we believe, not reliably predictable, espcially for strong increases. Overall, however, we view the lack and unpredictability of social and political acceptance of such a measure as a more important barrier.

> In this sense land-use planning may improve acceptance by providing destinations in close proximity, thus ensuring there are options for coping with increasing travel costs. The well-known path dependencies in travel behaviour suggest that beneficial experience may well contribute to the emergence of 'virtuous circles'. However, these are likely to emerge very slowly, while from the perspective of climate mitigation there is little time.

Integrated land-use and transport planning, implementing the idea of a mixed-use, compact 'European city', no doubt has an important contribution to make towards creating more lively, liveable and functional towns and regions. Within the urban areas this may also lead to modal shifts or a limited reduction in distances travelled. However, while this is welcome, it is hardly relevant in light of the magnitude of the reductions in CO_2 emissions necessary. Hence, the focus must be on other approaches and actors.

Achieving notable reductions in CO_2 emissions in the transport sector is primarily the task of the national and supra-national levels even though a lack of political will makes transport "a roadblock to the world's efforts to mitigate climate change" (Creutzig et al., 2015). Motivated by 1980's forest dieback, the German federal government and the EU have successfully shown how traffic emissions can be reduced: through the use of effective regulatory limits for car manufacturers (despite recent fraudulent practices connected with measurements of exhaust emissions). This success, however, does not include CO_2. A further step should involve binding carbon offsetting (compensation payments) for all passenger and freight carriers. The income derived from such payments could be used for the effective reduction of equal amounts of CO_2 emissions in other fields. In order to be fair, the amount to be paid per unit needs to be linked to the cost of emission reduction in these other fields and thus increases as the potentials become exhausted. Still the issue of fairness between fields remains to be discussed.

Last, but not least, we want to remind readers that this paper was written from a European, more specifically a German, perspective. Any evaluation of what is to be expected in terms of climate change mitigation in transport needs to take into account other regions, most notably strongly car-dependent nations such as the US, Canada and Australia, and fast-growing emerging economies such as China, India and many in the Global South. In these latter countries it is as yet largely unclear which models of urbanisation and general spatial development will be followed once economic wealth reaches a higher level: US-type sprawl, European compactness and mixed-use, or something else (IPCC, 2014). Their future paths may strongly affect their levels of car use and daily travel distances, although at the same time it is very likely that these economies will be integrated into global links with high levels of business and private long-distance travel just like Western countries.

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