

Motorways and urban development in Denmark

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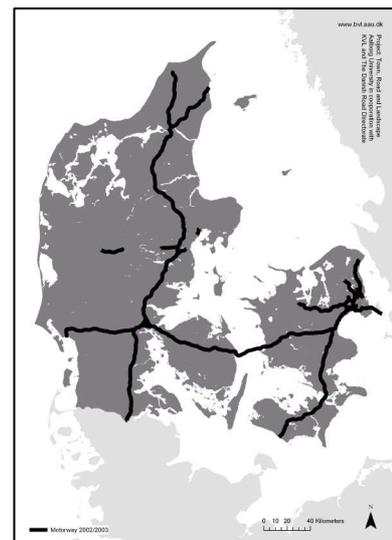
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Background

As of 1 January 2004, the Danish motorway network has a length of some 1,014 km (The public motorway network has a total length of 973 km and Sund & Bælt Holding A/S' motorways make up an additional 41 km). The motorways make up just 1.40 percent of the Danish road network, yet at the same time currently handle about 22 % (2004) of road traffic activity in Denmark. This is due both to the geographical location of the motorways as the connecting element between the key areas of urban development in Denmark and the development of road traffic, which is in turn derived from the economic and technological development in Denmark as a whole. Despite this, the motorway network's significance for urban development in more general terms has never been the subject of serious public discussion in a national Danish context. The formal reason for this is that an overall plan for the layout and development of the Danish motorway network has never been discussed at a political level, nor has it been adopted by the Danish parliament (*Folketing*), although a draft of an overall plan drawn up by Danish Road Directorate existed as long ago as 1962 (Jørgensen, 2001). At present, Denmark is in the paradoxical situation that the country has a well-developed, cohesive motorway network, that has gradually developed from numerous ad hoc decisions on the individual road segments. The conception of motorways as connections between pre-existing urban entities – together with an approach to road planning that is largely based on “predict and provide” – means that there has never been an all-encompassing discussion of the overall physical structural consequences of the motorway network for urban development.

Figure 1: The Danish motorway network by October 2003



The origins of the Danish motorway network

With the “Report on Copenhagen’s traffic routes as preliminary work for Copenhagen’s regional development plan”, the connection between road construction and urban development was discussed on the modern city’s terms in 1927 in the Danish architecture and planning periodical *Architekten*. As one of a number of proposals, the report suggested that the road regulations applicable at the time be deviated from and replaced by a wide road profile of 34 metres with two carriageways (width 6.5 m) running in opposite directions separated by a tramline zone (width 9.0 m). This road width was to be used to handle the traffic on the major approach roads to Copenhagen. The option of having roads as the exclusive domain of motorcars was also considered in the report, but it was concluded that such a need did not exist in Denmark at that time.

The road in question was not a motorway in the sense of the later definition, but a type of road that was designed to solve the problems that continued urban development and growth in society in general were expected to create

in urban areas. It was exactly this type of road that was being considered in connection with the planning concerning the development of London organised around “the Greater London Arterial Conference (1913-16)” (Architekten, 1927), and indeed one of the main conclusions of this work was that physical planning (division into urban and rural zones) should take place prior to the planning and realisation of infrastructural investments in order to prevent uncontrolled urban growth around this infrastructure and thereby devalue the value of these investments.

The first major presentation of the idea of a cohesive motorway network in Denmark appeared in 1936/1937 in two publications on the initiative of three major Danish engineering companies. As inspiration for the commencement of the development of a cohesive motorway network in Denmark in 1936. Inspiration came from a number of European projects, e.g. the construction of the first motorway in Europe (the autostrada from Milan to Varese in Italy from 1924) (Jørgensen, 2001) as well as motorways constructed subsequently in Germany, the Netherlands and France (Christiani & Nielsen et al., 1936; Christiani & Nielsen et al., 1937).

The basis for the location and routing of the cohesive Danish motorway network in the publications was rooted in a number of considerations that could be boiled down to an assertion that the construction of a cohesive motorway network would be closely linked to a more “*complete and rational exploitation of (“investment in”, ed.) motor-driven vehicles*”, which again was assumed to be a prerequisite for continued economic growth in Denmark (Christiani & Nielsen et al., 1936, p. 15). The proposal was therefore also naturally based on linking the biggest cities in Denmark on Zealand and Funen, as well as the cities on Jutland’s east coast. The motorway’s effect on urban development in Denmark was not explicitly discussed in the publication from 1936, besides some remarks on which cities that should be linked to the network and whether one or two entrance points would be necessary depending on the size of the city (Christiani and Nielsen et al., 1937). The proposal was not well received by the country’s urban- and traffic planners, who judged that such a network was unnecessary and a waste of limited resources. This did not mean, however, that motorways should not be built – but the opinion was that such a solution could be used where there were particular problems and needs. Indeed work commenced on Denmark’s first stretch of motorway north of the capital Copenhagen as early as in 1938 (notably the section was not part of the 1936/1937 proposal). Due to the Second World War and a general shortage of materials this first section of motorway did not open until 1956, and it was quickly followed by a number of other stretches of motorway that characteristically routed traffic around busy areas (e.g. Lyngby by-pass, Randers by-pass) or acted as approaches to the new ferry berths on what was without doubt Denmark’s most important domestic ferry route - the Great Belt crossing - linking east and west Denmark.

It was not until 1960 (Humlum, 1960) that the arguments for the location of a cohesive motorway network in Denmark, and thereby the arguments for where and why motorways in Denmark were to be built, were seriously questioned. This occurred with reference to the idea of the establishment of “*the central Jutland motorway*” (Humlum, 1961, p. 5), which in this case was based on the assertion: “*that the construction of a cohesive motorway network will have crucial value for the future development of our society, its manufacturing, export and entire economic and social standard*” (Humlum, 1966, p. 145).

Although there was not any actual disagreement with regard to this assertion, disagreement did exist as to whether the construction of the motorways should take place with a view to safe to promote development in western Jutland and a new comprehensive plan for the location of centres for urban growth - or whether the road should be built in the densely populated eastern part of Jutland where the roads already carried by far the largest traffic flows (Bendtsen, 1960; Jørgensen, 2001). Inspiration for Humlum’s idea can possibly be traced to Germany, where the first sections of the motorway network in the 1930s were planned and realised based on the same considerations. The solution led to problems in creating connections between existing towns and the motorways, and was therefore abandoned (Bendtsen, 1960). In 1962 the Humlum proposal was discussed in a report from the Danish Road Directorate, which, with reference to a historical outline of the basis for development in Jutland, recommended an eastern route. (Danish Road Directorate, 1962). With the highway planning committees’ “Outline for Road Planning for the period 1975-90” a final proposal was presented for the location of the cohesive motorway network (Highway Planning Committees, 1975), which as of 2004 has largely been realised. The central argument for this proposal stemmed from the spatial planning committee secretariat’s work from 1969, (not completed in 1975, however) (Highway Planning Committees, 1975) and revolved around the desire to connect the biggest cities in Denmark. The content of the proposal was directly derived from wishes put forward by the labour ministry at the time via the so-called perspective planning work (Perspective planning 1970-1985, 1971). The Danish towns were incorporated into a five-part hierarchical structure consisting of “*provincial centres, regional centres, major area centres and local centres*” inspired by Walter Christaller’s service centre theory (Matthiessen, 1985; Illeris et al., 1973). It was proposed that these centres be served by a corresponding functional hierarchy of road types, characterised by the accessibility they provided. The highest level was thus made up of cities with motorways that ensured accessibility between the largest provincial centres and to other countries (Highway Planning Committees, 1975). The argumentation for a cohesive motorway network is thus closely related to the “*service centre theory*” and thus implicitly the existence of a stable hierarchical urban system derived from “*the consumers’ demand for low transport costs*” (Matthiessen, 1985).

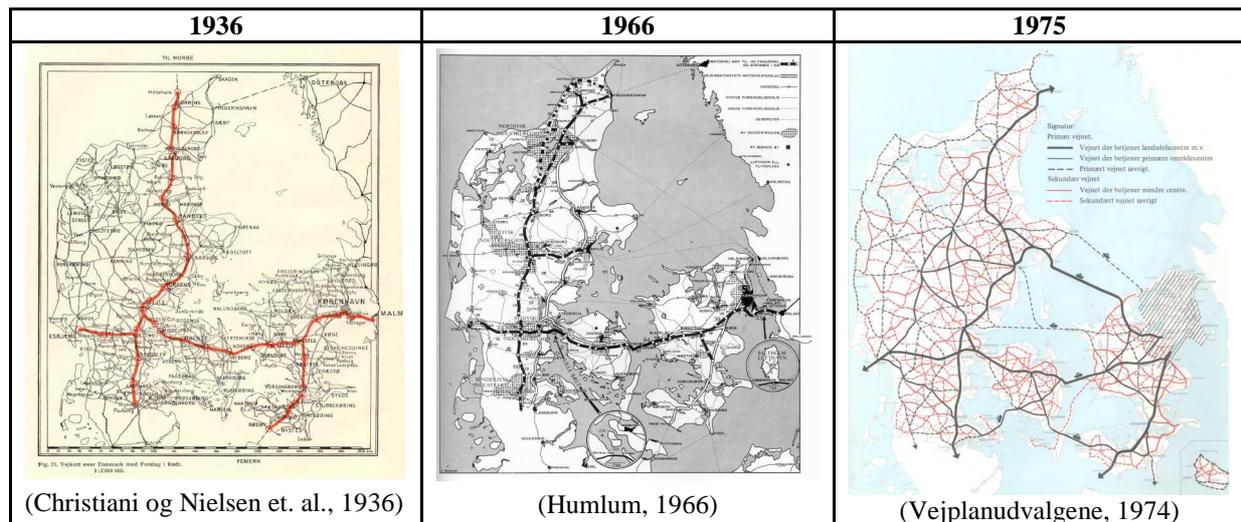


Figure 2. Proposals for a Danish motorway network.

The concept of the urban pattern and the idea concerning division into zones, and thereby the importance of physical planning, was retained in spite of the fact that during the 1960s, it was registered on the part of, for example, the Spatial Planning Department that the development of infrastructure, also drove forward the transformation of Denmark (Spatial Planning Department, 1970). It was not until the 1990s that alternatives to the image of an urban hierarchy linked with infrastructure was included in national planning documents (Spatial Planning Department, 1996). One of the development alternatives was designated a “linear city”, which was based on, and geographically identical to, the structure of the motorway network as it appears today. At present the Danish urban pattern and urban hierarchy seems to be undergoing significant change with concentration of population and workplaces in the largest urban centres on the east coast of Jutland and in the capital area (Christoffersen, 2003). Further the continued development of mobility and transport infrastructure renders the idea of an urban hierarchy irrelevant in many instances.

What was neither generally discussed at the time nor since in connection with the planning and construction of the Danish motorways is that the nature of the problem with regard to “motorways and urban development” is not static, but dynamic. The motorways have contributed to the transformation of the functional interdependencies within the country and have been used by municipalities and business as sites for urban development. The development in interaction patterns and the urban development alongside the motorways gradually causes the traffic on the motorways to change character, and thus the motorway goes from being a place where traffic flows at a relatively high average speed (+80 km/h) to a place where the traffic flows at much lower average speeds (Anders Nyvig, 1963). In other words, the very idea and importance of the motorway as a rapid transit connection is diluted. This problem is briefly outlined in a number of Danish publications, e.g. (Danish Road Directorate, 1996), (Danish Road Directorate, 1999) and (Spatial Planning Department, 2000). Internationally there are a number of classical publications that discuss the physical consequences of the dynamic development that the connection between “motorways and urban development” creates. Fore instance Robert Venturi (1977) discusses the development alongside the roads from the viewpoint of the drivers visual experience. Tunnard and Pushkarev (1963) discusses the new types of urban development that takes place alongside motorways in the rural-urban fringe.

Analyses of 20 years of urban development alongside the motorways

In this section a number of the project’s preliminary results for urban development and commuting over the last 20 years are presented. The final analyses will be published in fall 2005, but the data presented provides a good basis for pointing out a number of trends and discussing the significance of the motorway in terms of development.

Data and methods

The general idea from the offspring of the project has been to employ the recent improvements in the availability of disaggregate geodata derived from public registers to analyse changes around the motorway network in a before and after perspective. The paper’s analyses of the developments around the motorway network have been performed on the basis of the data retrieved from the Danish Building and Dwelling Register (BBR), the register-based labour force statistics (RAS), and GIS-based planning data from the years 1982/1992/2002 -

combined with text studies of a number of planning documents retrieved from municipal, county and central government institutions.

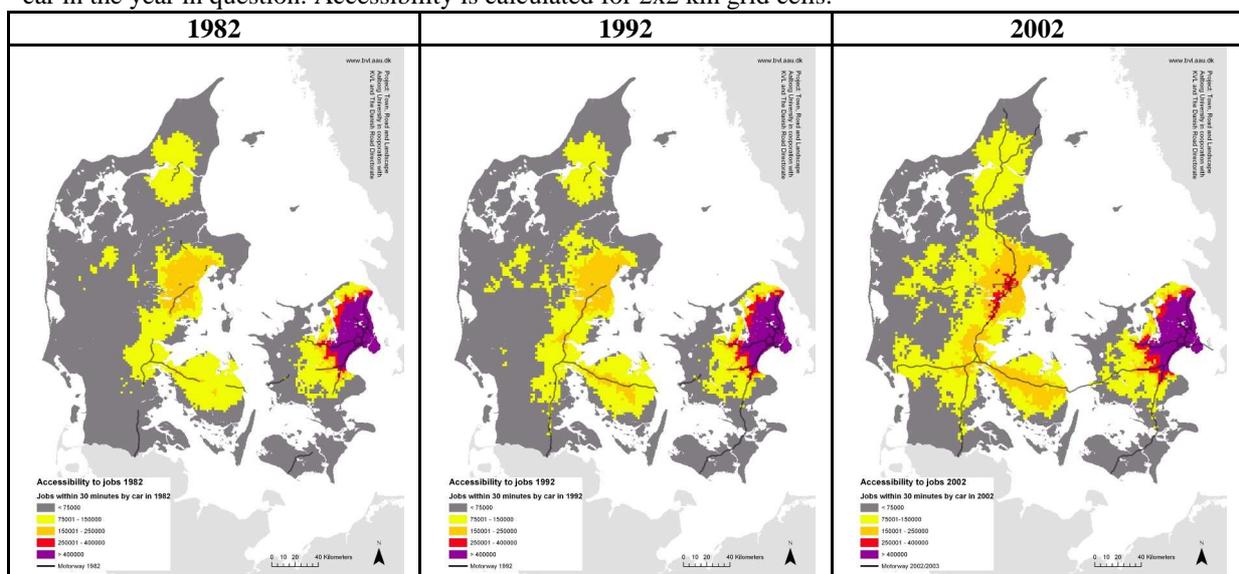
The Danish Building and Dwelling Register contains information on all buildings, including year of construction, volume, primary use and geographical location (address coordinates). The register-based labour force statistics contain information on residence and places of employment for the entire labour force from 1982 up to the present day. The Building and Dwelling Register's information has been utilised to follow the development in the geographical location of buildings during the last 20 years. Similarly, the register-based labour force statistics have been utilised to illuminate changes in commuting patterns and employment location from 1982 to 2002.

There are of course a number of challenges to be faced when analysing the significance of the motorway network for urban development and patterns of interaction. This applies in particular to the causality and contrafacticity issue, i.e. the question of to which degree the motorway is the reason behind the actual development and what the development would have been had the motorway not been built. Since motorways are often constructed between densely populated areas and/or where the development in traffic is particularly marked, it is likely that these areas generally have other conditions for development than areas without motorways. Based on the assumption that this problem is fundamentally insoluble and that the development trends so realised are in themselves of significant interest in terms of planning, a form of analysis has been chosen in which urban development and commuting patterns are by way of introduction sought described more generally. These general analyses, which in the majority of cases are presented as different "maps of Denmark", are followed up by more specific analyses of aspects such as the built-up area's relation to the motorway on a small scale, and, in other parts of the project, statistical analyses of commuting patterns, demand induction and interviews with business enterprises with regard to the decision-making process prior to establishment adjacent to the motorway. Through this approach the project aims to describe the development context in which the motorway is located and to focus on specific forms of development that occurs in conjunction with the motorway network.

Accessibility

A significant direct effect of the construction of the motorway network is the reduction in journey times and the resulting development in accessibility by car. Based on the project's focus on urban development, the development in accessibility is compiled as a cumulative measure of accessibility that must be assumed to describe the transport-economic benefits in the individual areas in question.

Figure 3: Development in accessibility calculated as the number of jobs that can be reached within 30 minutes by car in the year in question. Accessibility is calculated for 2x2 km grid cells.



In concrete terms the number of places of employment that can be reached within 30 minutes by car is used as an indicator. Journey times are based on driving at permitted speeds. In order to recreate the network with permitted speeds as the basis for the analyses for 1992 and 1982, a backdating of the road network in 2000 is carried out. Such a backdating does of course not provide the complete picture, but takes into account the motorways, major road projects, the Great Belt Bridge, crossing times for ferries and changes in speed limits.

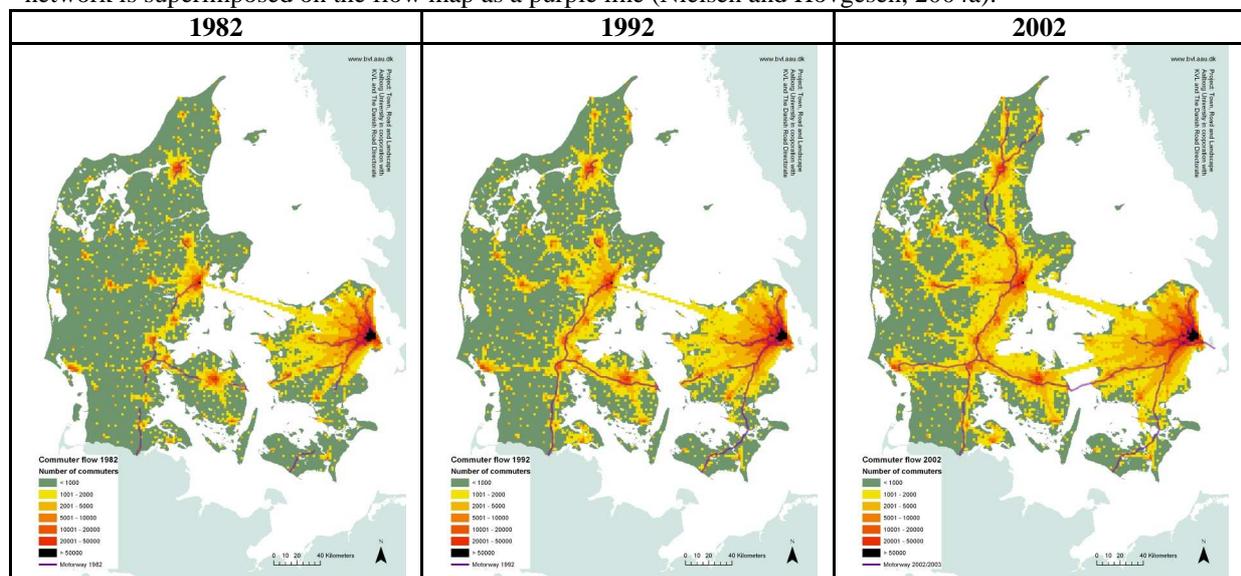
The maps (figure 3) clearly show how the extension of the motorway network makes its mark in the form of increased accessibility to places of employment in the areas in which motorways are built. The greatest

development in accessibility can be seen in East Jutland, where the majority of motorways have been constructed during the last 20 years.

Development in commuting

Commuting can be regarded as the project's indicator for the development in patterns of interaction. In this case, calculations of commuting based on the register-based labour force statistics have the advantage that historical data can be acquired. Figure 4 illustrates the development in commuting between parishes calculated as flow – in the sense of the number of commuters that begin, end or pass through (as the crow flies) given areas. The map thus shows which areas are functionally integrated or more or less central on the basis of movement between the home and the place of employment (Nielsen and Hovgesen, 2004c).

Figure 4: Development in commuting illustrated as flows. The term flow here refers to passage, start or end points for commuters enumerated on the basis of straight lines drawn between the home and parish in which the place of employment is located. The flow is summarised on a 2x2 km grid, and the maps show the number of commuters according to the same absolute scale for all three years. The parallel development of the motorway network is superimposed on the flow map as a purple line (Nielsen and Hovgesen, 2004a).



There has been considerable development throughout the period, and the maps demonstrate a tendency that indicates that commuting is generally on the increase, and that this has resulted in the previously somewhat isolated surrounding areas being incorporated into larger functional regions to an increasing extent. Development has been particularly marked in East Jutland, where the “belt” of cities from Randers via Århus to Odense in 2002 is beginning to resemble a functionally integrated polycentric urban region. The growth in commuting primarily takes place alongside the established infrastructure corridors.

The growth in commuting in absolute figures can be used to indicate whether there has been an erosion of the central urban districts' dominance, whether the creation of corridors is taking place, and where, due to the high level of absolute growth in commuting, the corridors between the established urban centres are “reaching out” to the commuting build up within existing cities. This appears to be the case. In all the biggest cities there are visible holes in the development in commuting in the historical inner cities. A “doughnut effect” – or in any case an erosion of the central urban districts' dominance can thus be traced as a trend in development. However, the effect is local and the urban centres are already major commuting destinations. Tendencies towards corridors “reaching out to” or overlapping the largest areas of urban development due to the development in “commuter flows” are particularly visible around Århus (Randers-Århus-Horsens-Vejle) and around Copenhagen (Hillerød-CPH-Ringsted/Køge), cf. (Nielsen and Hovgesen, 2004c). The fact that the development in commuting follows the motorway network is due in part to historical reasons. Statistical analyses of the material, however, point to the fact that access to the motorway – taking historical trends into account - has significance for the commuting pattern both through the reduction of journey times and through an infrastructure bias that is articulated by the fact that greater numbers commute to the major urban centres from residential areas that are situated close to a motorway junction (3 km) and that commuting distances are greater in the case of places of employment that lie close to a motorway junction (3 km) (Nielsen and Hovgesen, 2004b). Furthermore, the greatest growth is in the long commuting journeys between starting points and destinations that have been connected by a motorway between 1982 and 2002.

Development of built-up areas

By way of introduction, the project focuses on a survey of the general development features within the location of building and construction and employment, with the proviso that it is both difficult to point to direct effects of the development of infrastructure and that in any case an infrastructure effect will probably be found within, or perhaps in spite of, one or more macro trends.

Importance has been attached to getting under the skin of the standard – geo-statistically somewhat arbitrary – administrative divisions in the project’s surveys. The maps of non-residential building in figure 5 utilise building data from the Danish Building and Dwelling Register of address coordinates combined with a smoothing function whereby the result provides area statistics without fixed area boundaries.

In general, non-residential building takes place around the largest cities – i.e. in particular in East Jutland and on Zealand. There appear to be tendencies towards continuous areas of growth along the infrastructure corridors in East Jutland (the so-called “Triangle Area”) and between Kolding and Århus.

Another way of approaching the relationship between built-up areas and the motorway – highlighting change within the areas close to the motorway - is a “simplistic” compilation of how buildings are distributed when taking the road as the reference point. Figure 6 illustrates the relationship between a zone’s proportion of non-residential building mass in 1992 and the proportion of growth between 1992 and 2002 for zone widths of 100 metres. There is a very clear connection to the distance from the motorway, such that zones up to 1 km from the road have a relatively large share of the growth. These zones will therefore make up a greater proportion of the non-residential building mass in the future.

The figure is for the whole of Denmark, and thus cuts across a large number of different contexts that also have great importance for the location of buildings and built-up areas. If the data is divided into sub-areas, it can be seen, for example, that the coherence is weakest in the Copenhagen region, where the motorway network is older and the sites alongside the roads are often already fully developed. The coherence is greatest around the major provincial cities and in the rural municipalities – i.e. at places where the motorways were built most recently and where there is plenty of space to establish new built-up areas alongside the motorways.

Figure 5: Location of non-residential building between 1992 and 2002. Based on the location of new buildings in combination with a kernel density function.

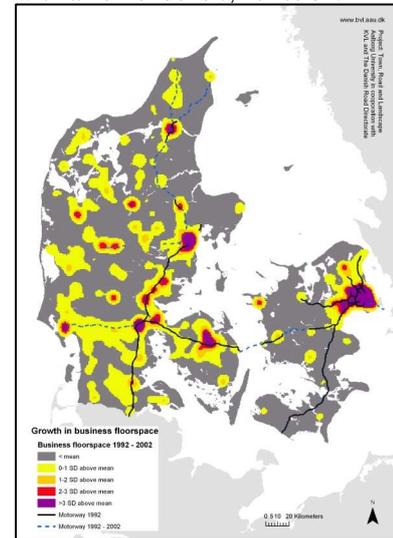
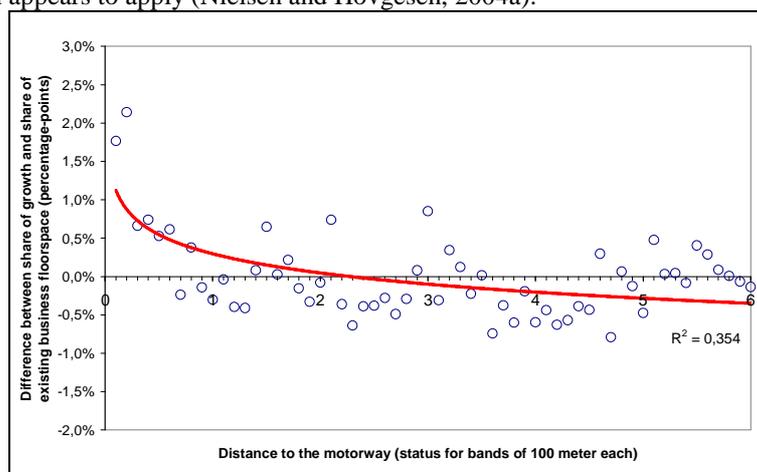


Figure 6: The difference between the proportion of industrial floor space in 1992 and the growth in floor space between 1992 and 2002 - calculated for each zone of 100 m (up to 6 km from the motorway). The dotted line is a logarithmic regression superimposed on the figure to illustrate the connection between growth and distance to the motorway which appears to apply (Nielsen and Hovgesen, 2004a).



It should be emphasised that this is a conclusion concerning the importance of the motorway on a small scale, where urban development gradually alters asymmetrically in the direction of the motorway – and with a partial dissolution of the traditional “market town form” as a result. Interviews suggest that business enterprises and local authorities share the responsibility for this development. A large number of local authorities have previously laid out large areas between the town and the motorway and have thereby paved the way for the development that has later taken place. A lot of enterprises also demand such locations, however, which in some

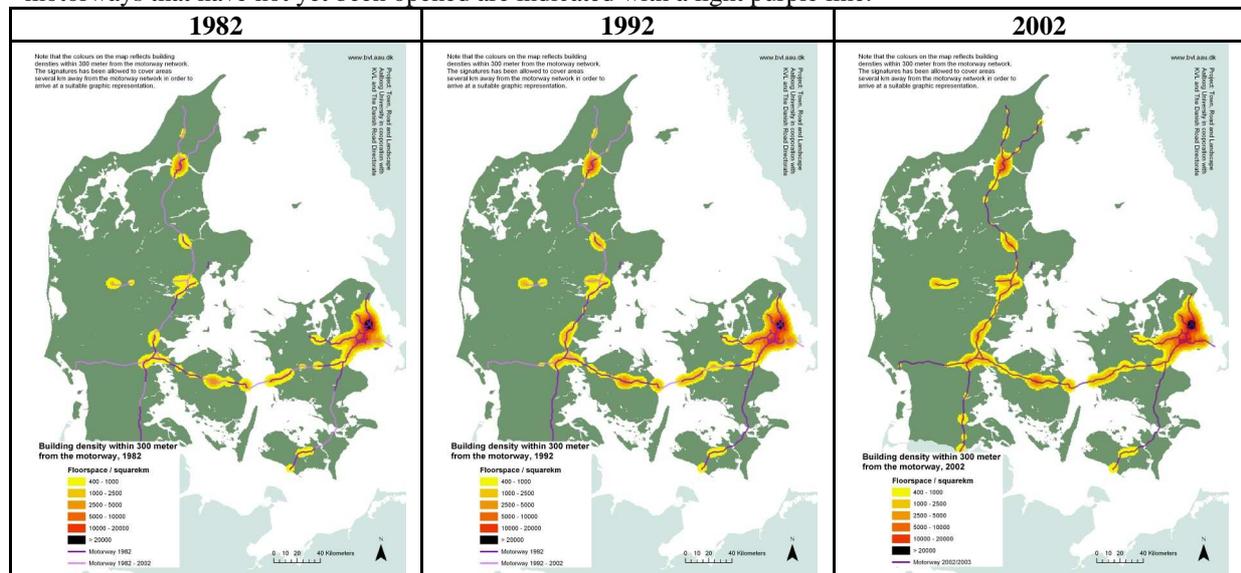
cases has meant that the laying out of areas carried out by local authorities has had problems meeting the demand for sites close to the motorway.

The motorways neighbors

Since the question of the future layout and use of the highway corridors is a considerable element of the project, there has been particular focus on that part of the building mass that has been placed in the highway corridor and in many areas will be visible to road users on the road. For pragmatic reasons, a zone of 300 metres on each side of the central reservation is used to define the road's "neighbours". The maps in figure 7 illustrate the intensity of the building mass within 300 metres of the motorway. It is the distance to the 2003 motorway that determines whether the area is included in the survey. The building mass is retrieved from the Danish Building and Dwelling Register with address coordinates (all types of buildings are included here).

It can be seen that there has been a growth in building intensity in the motorway corridors, both in the corridors where the road has been built during the period, and at a number of places where the road already existed in 1982. Overall, it is particularly in areas where the motorway is laid out in the vicinity of existing urban areas, close to exits and where there is the heaviest traffic that the intensity of built-up areas within 300 metres of the motorway is greatest.

Figure 7. Building intensities within 300 metres of the motorway completed by the end of 2003. Built-up areas are shown as kernel densities based on normally distributed smoothing over 3 km and summarised on a 1x1 km grid. The completed motorways for the years in question are shown with a dark purple line – whilst the motorways that have not yet been opened are indicated with a light purple line.



In other words, it appears that existing urban areas expand to include areas adjacent to the motorway whenever possible. The significance of the volume of traffic should in this context not only be understood as being significant in itself, but also as an expression of the fact that the places where there is a large volume of traffic are located centrally in the Danish urban system. There are therefore also greater economic interests in the use of areas adjacent to the motorway.

Conclusion

The first part of the paper, the historical review, shows firstly that a significant section of the Danish motorways were built without an overall plan for a nationwide motorway network and secondly that the motorways in many cases were constructed to satisfy a particular demand and to cater for traffic between towns and cities in an existing urban hierarchy. On establishing the Danish motorways, a static perception of the road's relation to its surroundings has thus been the general feature, and the majority of Danish motorways are planned and laid out in the landscape on the basis of this assumption.

Today, however, the Danish motorways have developed via a succession of ad hoc decisions into a cohesive network that along with the bridges over the Great Belt (1998) and the Sound between Denmark and Sweden (2000) - make up the backbone of the national infrastructure. At the same time, the development of the relationship between the motorways and the cities has been shown to be anything but static.

The second part of the paper, the static analyses based on the Danish Building and Dwelling Register and the register-based labour force statistics from 1982 – 2002, show that urban development in many areas is related to the Danish motorway network and that the development in long commuting journeys, in particular, is concentrated around the motorway network where the interaction over long distances has become a viable option. The motorway's ability to both focus the existing traffic flows and generate new flows also means that the areas adjacent to the motorway have become attractive locations for businesses that wish to have contact with a large number of people every day. As a consequence, current developments suggest that service-based and office-based enterprises are to a certain degree choosing to establish their premises close to the motorway, and thereby contributing to the formation of an actual facade looking onto the traffic on the highway.

On the basis of the above, it is natural to consider whether the traffic on the motorways will slowly change in character, as a result of which the motorway will go from being a place where traffic flows at a relatively high average speed (+80 km/h) to a place where the traffic flows at much lower average speeds. The very idea and importance of the motorway as a rapid transit connection is in other words reduced as the motorways become a more integrated part of Danish urban development and part of the city of the future.

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