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Transport effects and environmental consequences of central workplace location

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Abstract

This paper presents results from a study of traffic effects and environmental consequences of locating 12 500 new workplaces in the development area Bjørvika, close to Oslo central station, rather than locating them as the current distribution of workplaces in Oslo. It was found that this annually saves Oslo about 1.7 million car-trips and 24 million vehicle kilometres by car, and hence 4 GWh of energy consumption, 2800 tonnes CO_2 emissions, 5 tonnes NO_X, and 1.5 tonnes NO_2.

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Keywords: Central station developments; Workplace location; Traffic effects; Environmental consequences

1. Introduction

This paper presents results from a study of transport effects and environmental consequences of locating workplaces near central urban public transport stations, rather than elsewhere in the urban structure.

The study was conducted as a commissioned work for Rom Eiendom AS (referred to as Rom below), responsible for developing the Norwegian National Rail Administration's properties in several Norwegian cities (the study is reported in Tennøy, Øksenholt and Aarhaug, 2013). These properties are normally located in or close to city centres, and often in direct proximity to the central railway stations and other public transport nodes. Working out their strategy

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for developing and transforming these properties, Rom needed a sound knowledge base for assessing transport effects and environmental consequences of such developments.

On basis of existing literature and previous studies, central nodal point developments are expected to generate less traffic volumes and negative environmental impacts, than if activities are located elsewhere in the urban structure. This has been a main argument for large-scale developments close to central railway stations in European cities like Zürich, Lyon, Amsterdam, London, Paris and Stockholm (Bertollini, 1998; Bertollini et al., 2012; MVA, 2005; Peters and Novy, 2012; Wolf, 2012). This was also a main argument in discussions concerning the large-scale Bjørvika development, located between Oslo Central station and the Oslo fjord, where Rom is a major developer. In this project, a subsea tunnel was constructed, replacing a major road carrying about 100 000 vehicles per day. This freed large areas in the centre of Oslo for urban development. The area is now under construction. The new Opera and several office- and apartment buildings are already built. Fully developed, the area, covering about 70 hectare, will have room for 15 – 20 000 workplaces and about 5 000 apartments, as well as shopping and service, the new Main City Library and the new Munch museum.

Fig. 1. The Bjørvika development area (Barcode), located between Oslo central station and the Oslo fjord (photo: Tomasz Majewski).

The commissioned work included a literature review concerning traffic effects and environmental consequences of locating new urban developments in different parts of the urban structure, as well as an empirical study analysing traffic effects and environmental consequences of locating 12 500 new workplaces in Bjørvika in Oslo city centre (as Rom does), rather than locating them as the current distribution of workplaces in Oslo. Only employees' travels to and from work was considered. Environmental consequences related to car-usage as well as public transport were included.

The initial aim of this study was to produce a sound knowledge base helping Rom to assess transport effects and environmental consequences of various ways of developing their properties. This concerned mainly what type of activities they should locate in their centrally located properties and the density of the development, in order to contribute to national and local objectives concerning to reduce car dependency, traffic volumes and transport-related consequences.

Another aim of the paper is to contribute with relevant knowledge for decision-makers and planning practitioners in other countries and cities, who are aiming at steering land use and transport systems developments in directions contributing to less traffic and transport-related environmental consequences. Stopping or reducing traffic growth is a long-standing objective in a number of cities, countries and international institutions (e.g. European Union, 2011; Municipality of Oslo, 2008; Norwegian Ministry of Environment, 2012; Norwegian Ministry of Transport and Communications, 2013; World Bank, 2002). The arguments for this include reducing local pollution, congestion, land take, energy consumption, and greenhouse gas (GHG) emissions, and making cities more liveable. In this perspective, and since developments of central nodal points are discussed in several cities and countries, we found that the work could have relevance for a wider audience.

A third aim is to contribute with empirical evidence to the scientific knowledge base concerning effects of workplace locations on travel behaviour and traffic volumes. By also including calculations of the environmental consequences, and by including emissions and energy consumption of public transport as well as by private cars, we find that our study contribute with evidence that are often missing in similar studies.

The literature review is reported in section 2. Data and methodology for the empirical study are described in section 3, and the findings are reported in section 4. In the concluding section, the findings are summarised and discussed.

2. Literature review

2.1. The impact of land use and transport systems developments on traffic volumes

There are strong research-based evidences that the spatial structure of urban regions, together with the absolute and relative quality of transport systems for cars, public transport, bicycle and walking, to a high degree affect transport demand, modal splits and traffic volumes (e.g. Banister, 2008; 2012; Cairns et al., 1998; Downs, 1962; Hull, 2011; Litman and Steele, 2013; Newman and Kenworthy, 1989;1999; Næss, 2006; 2012; Owens, 1986; UN Habitat, 2013).

The interrelations between *spatial structure* and travel behaviour concern mainly proximity and accessibility. The denser an urban region is, the shorter are the average distances between origins and destinations. This allows for higher shares of trips made by non-motorised modes, and for averagely shorter car trips. Further, a dense city can be more efficiently served by public transport than a sprawled city, and a dense city will often offer less favourable conditions for car use (parking restrictions, congestions). These mechanisms cause dense cities to produce less car traffic per capita than sprawled cities (see e.g. Beaton, 2006; Manville and Shoup, 2005; Newman and Kenworthy, 1989; Næss et al., 1996; Næss, 2006; 2012; Turcotte, 2008; UN Habitat, 2013). Several studies have demonstrated that this is also the case when accounting for socio-economic and demographic factors (e.g. Beaton, 2006; Bhat and Guo, 2007; Brownstone and Golob, 2009; Næss, 2006). Barnes (2003) found that workplace density affects commute modes more than residential density.

How various activities are *located* within the urban structure also affect car use and traffic volumes. Normally, centrally located activities are more accessible by public transport than more peripheral located activities. Further, the number of people living within walking and bicycling distance are often higher, and the conditions for car usage worse. This contributes to centrally located activities (e.g. housing, workplaces, shopping) generating less traffic than more peripherally located activities. This is documented in a number of studies during the last decades, as we will return to (see Næss (2012) for an overview of Nordic studies).

For such reasons, what is often referred to as the Dutch ABC-principle (Verroen et al., 1990), recommends that activities attracting many people per square metre (employees, visitors) should be located in the more central parts of the city. This allows a high portion of those travelling to these activities to reach them by other modes of transport than private car. Following from this, in order to minimize car dependency and road traffic in the urban region, the most central areas should be developed with high densities in order to give room for many workplaces and other activities in the areas that are most accessible by other modes that car.

Further, the absolute and relative *qualities of the transport systems* for various modes affect travel behaviour. If car accessibility is good, that is, if there is limited congestion as well as cheap and plenty parking, car shares will be higher than if the conditions were different (e.g. Banister, 2005; Cairns et al., 1998; Downs, 1962; Newman and Kenworthy, 1989). Likewise, if accessibility by public transport, walking and bicycling is improved, more travellers are likely to choose these modes.

2.2. Effects of workplace location on traffic volumes

Hence, centrally located activities can be expected to generate less car traffic than more peripherally located activities, because central location improves the competitiveness of other modes of transport compared to the private car. When looking into empirical evidence concerning effects of workplace locations on travel behaviour and traffic volumes, we found clear evidence that this is also the case. Hartoft Nielsen (2001) gathered travel data from over 13,000 employees in 52 companies in Copenhagen Metropolitan Area. He found that the shares of commutes by car to workplaces located within the city centre were between 10 and 25 percent, while the figures for workplaces located close to central areas were between 40 and 45 percent, and 80 percent for workplaces located more than 30 km from the city centre. For workplaces located in central areas, an average car commute reached 3 to 12 vehicle kilometres (vkm) per employee per day, depending on business type and specific location. The daily vkm travelled by car were 30 to 45 km for the more peripheral locations. Similar results has been found by other researchers, such as Strømmen (2001), Meland (2002), Tennøy and Lowry (2008) and Konst (2003), as we return to in the discussions chapter.

Næss (2012) compiled 30 Nordic studies examining the impact of urban form on travel behaviour. Eight of these studies concerned the influence of workplace location on travel behaviour. Næss (2012:18) found that "*Common to these studies is, however, the finding that lower proportions of the employees commute by car and higher shares travel by public transit, bicycle or by foot to workplaces located in the inner-city than to suburban jobsites*". He also found that compared to the amounts of studies on urban form characteristics and travel behaviour, studies concerning effects of workplace location (distance from city centre) on modal split and transport volumes were considerably fewer. Further, that studies concerning effects of location of workplaces were fewer than studies concerning effects of location of residences.

In our literature review, we found few studies from other parts of the world than the Nordic countries investigating effects of distance from centre on travel behaviour and traffic volumes. This seems to be in accordance with findings in other literature studies, see for instance Litman and Steele (2013) or UN Habitat (2013). One may, however, claim that studies investigating effects of for instance land use mix, local density and so on (for instance Ewing and Cervero, 2010) in reality measure effects of distance to city centre, since such characteristics often co-variate with centrality. Together, the theoretical explanations concerning interrelations between location and travel behaviour and evidences such as those mentioned above, indicate that one may expect centrally located workplaces to generate less car traffic (vkm) than more peripherally located workplaces, at least in Nordic cities.

This effect will normally be stronger for workplaces requiring more specialized employees (such as universities, research institutes, financial advisors), because they need to recruit employees from a larger urban region. In contrast, workplaces requiring less specialized employees (such as retail stores), or workplaces there are several of in the city (such as schools), to a higher degree can be expected to recruit employees living nearby.

2.3. There is need for more evidence on transport effects of workplace location

The literature review hence revealed that mechanisms causing centrally located workplaces to generate less traffic than more peripherally located workplaces are well explained, that empirical studies are in accordance with understandings underpinning these explanations, and that the empirical knowledge concerning effects of workplace location on travel behaviour and traffic volumes needs to be further strengthened. The literature review also revealed that few studies analyse the transport-related environmental consequences of location of new workplaces.

3. Data and methodology for the empirical study

In the empirical part of the study, differences in travel behaviour, traffic volumes and transport-related consequences of constructing 12 500 new workplaces in Bjørvika (as Rom does), rather than locating them as the current distribution of workplaces in Oslo municipality (with about 600 000 inhabitants), were analysed.

3.1. Data

Data from the latest (2009) Norwegian National Travel Survey were used for analysing employees' travel behaviour. The National Travel Survey collects data through self-reported travel diaries for all trips the respondents do during one specific day (Vågane et al., 2011). The base for analysis was 1065 respondents commuting to workplaces located in different parts of Oslo. We did not have data specifically for those working in the newly constructed office buildings in Bjørvika (as these were not yet built in 2009), but assumed that travel behaviour for employees working in Bjørvika would be similar to those working in existing workplaces in Oslo city centre. This assumption probably means that car usage among employees working in Bjørvika are over-estimated, since these workplaces are located closer to the main public transport node (the Central station) than the average workplace in the city centre, and since parking access is worse for employees in Bjørvika than it is for the average workplace in the city centre.

We compared employees' travel behaviour for workplaces located in different parts of Oslo municipality. The main reasons for selecting Oslo municipality, rather than Oslo metropolitan area for comparison, were that *i)* this made the data handling and analyses easier (and our budgets were limited), and *ii)* it makes it easier for decision-makers and others to relate to the analyses. Choosing the municipality rather than the metropolitan area for comparison means that the calculated differences with respect to car usage probably is lower than in reality, since average car shares on travels to workplaces in Oslo metropolitan area are higher than to workplaces in Oslo municipality (according to data from the Norwegian Travel Survey, see Tennøy et al., 2013).

3.2. Methodology

Oslo municipality was divided into five zones, three outer zones (west, east, south), the inner city and the city centre (termed Central Business District, CBD, in the figure), see figure 2.

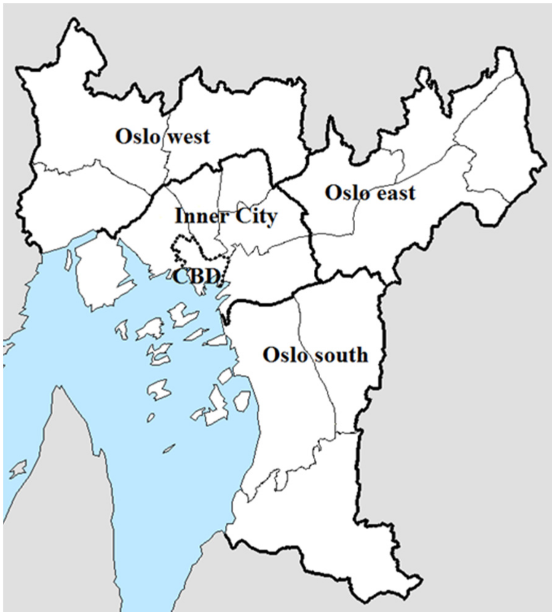

Fig. 2. Zone division used in the study: Oslo west, Oslo east, Oslo south, Inner City and Central Business District (CBD/ city centre).

Modal splits for each zone, as well as the average modal split for commutes in all five zones, were analysed through simple frequency analyses conducted with help of the statistics programme SPSS. By sorting trips with respect to zones of destination, as well as to mode of transport, average trip lengths on all commutes to workplaces in each zone were calculated, as were average trip lengths by public transport and by car for those commuting by these modes. Average trip length *by car* to the city centre was calculated on basis of only 13 respondents, and this result is hence rather uncertain.

Using these data (modal splits and average trip lengths by various modes), car traffic volumes (vkm) and public transport passenger volumes (pkm) generated per employee at workplaces located in each zone and in Oslo municipality (average) were calculated, see equations below.

$$Vkm\ per\ employee_{Zone\ i} = Car\ share_{Zone\ i} \times Average\ travel\ length\ for\ commuters\ by\ car_{Zone\ i}$$

Pkm per employee $_{Zone\ i}$ *= Public transport share* $_{Zone\ i}$ *x Average travel length commuters by public transport* $_{Zone\ i}$

By multiplying figures for traffic volumes (vkm) and for public transport passenger volumes (pkm) per employee in the city centre and in Oslo (average) with 12 500 workplaces, daily traffic volumes and public transport volumes generated by this many workplaces in different locations were calculated and compared.

These figures were used as basis for calculating the environmental effects. Empirical data were collected from the literature on energy consumption (Brunvoll and Monserud, 2011), CO_2-emissions (*ibid*; Statistics Norway, 2013) and local pollution (Hagman et al., 2011) per vehicle kilometre (vkm) for private cars and per passenger kilometre by various forms of public transport (pkm). We calculated figures for energy consumption, CO_2-, NO_X- and NO_2-emissions per vkm and pkm with the traffic and public transport volumes generated by 12 500 workplaces located in the city centre and in Oslo (average). This way, the transport-related environmental consequences for the two were found, and a comparison was made.

We did not conduct analyses to account for differences with respect to demographic, socio-economic, cultural or other characteristics of the respondents. This was mainly because the aim of the study was to analyse the *effects of workplace location* on travel behaviour, traffic volumes and environmental consequences. This was also the main reason why we did not conduct analyses with respect to respondents' place of residence. Such analyses could anyhow have been interesting in order to answer other kinds of questions, and will be considered if this work is taken further.

4. Findings

When analysing data from the 2009 Norwegian National Travel Survey, the share of car drivers commuting to the city centre was found to be 7 percent (figure 3). The public transport share was 64 percent, the share of bicyclists was 7 percent, while the share of pedestrians was 22 percent. On average for all workplaces in Oslo municipality, the car share was 36 percent, the public transport share was 40 percent, the share of bicyclists was 7 percent, while 18 percent commuted by foot. As the figure shows, modal splits on travels to workplaces in the different zones vary significantly. We did not conduct any deeper analysis in order to explain these variations.

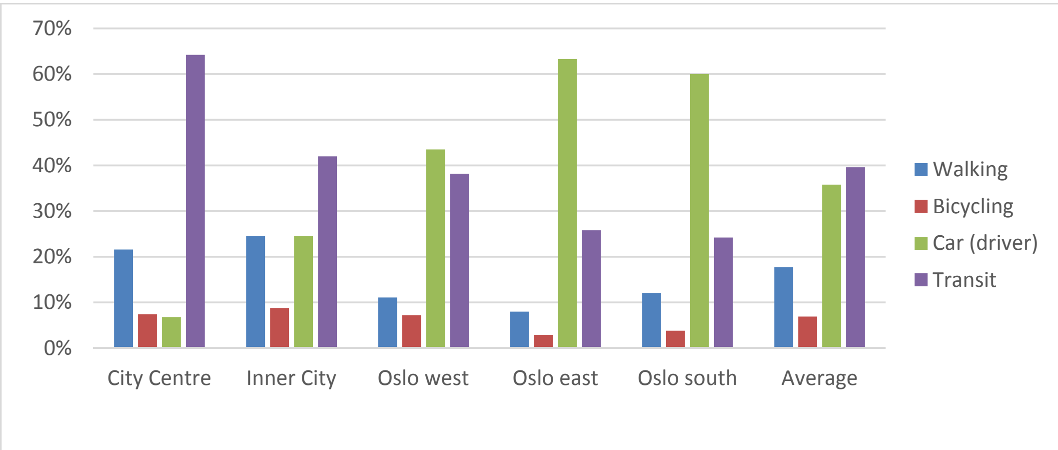

Fig. 3. Modal shares on commutes to different parts of Oslo (percentage is calculated from all travels, but 'car passengers' and 'other modes' are not shown) (N = 1065).

When analysing average lengths of commutes (table 1), we found that those commuting to the city centre travel longer distances (27 km) than the average for all commutes (25 km). Those driving to the city centre have averagely much longer commutes (53 km) than the average for those driving to workplaces in Oslo (33 km). Those commuting to the city centre by public transport travel longer (33 km) than the average for workplaces in Oslo (29 km).

Table 1. Average trip lengths for commuters travelling by all modes, car and public transport (roundtrips)[†], on commutes to the city centre and for all commuters in Oslo municipality (average)[‡].

Average length of trips	N=	Oslo city centre	Oslo, average
All modes (km per day)	1065	27	25
Car drivers (km per day)	386	53§	33
Public transport user (km per day)	446	33	29

When calculating traffic volumes, it was found that each workplace in the city centre generates considerably lower car traffic volumes per employee (3.7 km) than the average for Oslo (12 km), see table 2. Further, each workplace in the city centre generates higher public transport volumes per employee (21.2 km) than the average workplace (11.4 km).

Table 2. Average trip lengths for commuters travelling by all modes, car and public transport (roundtrips)[**], on commutes to the city centre and for all commuters in Oslo municipality (average)[††].

Average length of trips	N=	Oslo City centre	Oslo, average
Per workplace (car vkm)	386	3.7[‡‡]	12
Per workplace (public transport pkm)	446	21.2	11.4

These figures were used when calculating transport-related consequences of locating 12 500 new workplaces in Bjørvika close to Oslo Central Station, rather than locating them according to the current distribution in Oslo, as summarized in table 3.

Table 3. Summary of transport effects and transport-related consequences of locating 12 500 new jobs in Oslo city centre rather than as the current workplace distribution in Oslo. The values are rounded estimates.

Saved	Per day	Per year (230 work days)
Car trips	7 300	1.7 million
Traffic volumes (vkm)	104 000	24 million
CO2	12 tonnes	2 800 tonnes
NOX	0 kg	5 tonnes
NO2	7 kg	1.5 tonnes
Energy use	18 MWh	4 GWh

The main conclusion is that the new workplaces located close to Oslo Central Station in the city centre can be expected to generate significantly less traffic and negative traffic-related environmental consequences than if the same workplaces were located at a pattern similar to the current distribution of workplaces in Oslo. This provides societal benefits in terms of reduced growth in energy consumption, GHG emissions and local air pollution caused by transport. It will also cause less added pressure on the already overloaded main roads in the region, but more pressure

[†] We calculated the distance traveled to work, assuming the return trip were similar.
[‡] Those travelling as car-passenger, or in other ways, are not included in the calculations for 'all modes'.
[§] N=13
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[††] Those travelling as car-passenger, or in other ways, are not included in the calculations for 'all modes'.
[‡‡] N=13

on the strained public transport system. As discussed in the section 3 on data and methodology, the real benefits of locating new workplaces are probably stronger, as we made choices that reduce the calculated differences.

5. Discussion and conclusions

The main finding of the empirical analysis is hence in accordance with theoretical understandings and previous empirical findings as discussed in section 2. Locating new workplaces centrally generates less new road traffic and environmental consequences than locating new workplaces elsewhere in the urban structure. These findings are also in accordance with a recent and similar Swedish study, analysing effects of locating 3500 jobs, 400 apartments and 15 000 m2 of retail in three different parts of Stockholm (Bäckström et al., 2013). The Swedish study found significantly lower traffic volumes and GHG emissions generated by activities located centrally than those located elsewhere. The length of commutes by car per workplace was calculated to 1.9 km to workplaces in the city centre and 15 km to the most peripheral area. Emissions were between 4 300 and 8 000 tonnes CO2 less per day in the most central location compared to the most peripheral locations.

It could be discussed whether centrality is the main explanation for the lower traffic volumes generated by workplaces in the city centre, or if it rather is the density, the low parking access or other characteristics of the built environment (Ewing and Cervero, 2010). In most European cities, there is a clear and strong covariance between centrality and density, parking access, public transport accessibility, and the number of people living within walking- and bicycling distances. This makes it difficult to separate these variables. This covariance is also logical. For instance, workplaces located at the outer parts of cities are hard and expensive to serve well by public transport from all parts of the region. This means that forcing employees to use public transport to such areas by reducing parking access to the level found in city centres, would cause many employees to spend much time on commuting to and from work. Further, there is no reason to believe that high workplace densities in itself will cause low traffic volumes. It is the combination of good access by public transport, many people living in walking and bicycling distance, and worse access by car, that together cause lower car dependency and car-usage.

Another interesting question is whether the results are relevant also for smaller cities than Oslo. Hartoft Nielsen (2001) studied travels to differently located workplaces in several rather small Danish cities. He found that the more centrally the workplaces were located, the lower car shares and the lower traffic volumes they generated, also in the smaller cities. The strength of the effect of centrality was, however, weaker than what he found in Copenhagen. This is logical, since public transport normally has a less important role in smaller than in larger cities, and since accessibility by car to the city centre often is better in smaller cities.

A study of Strømmen (2001) supports this understanding. She did a thorough study of modal splits and traffic volumes among employees in 20 different companies (948 respondents) in central and peripheral locations in the medium-sized Norwegian city Trondheim (about 150 000 inhabitants at the time). She found that the shares of car drivers more than doubled from central to peripheral locations (from 24 to 69 percent). Further, she found that workplaces located in central areas generated less car traffic (3.7 vkm per workplace per day) than more peripherally located workplaces (8.8 vkm per workplace per day), while centrally located workplaces generated more public transport passenger kilometres (pkm) (4.7 public transport pkm per workplace per day) than those more peripherally located (0.6 public transport pkm per workplace per day). Interestingly, car traffic volumes generated by centrally located workplaces in Trondheim are exactly the same as we found in the study of Oslo. More important is that Strømmen's study supports the understanding that the same mechanisms are at work in smaller as in bigger cities, and causing the same effects, but that the strength of these effects are weaker in smaller cities.

Yet another question concerns how to single out effects of workplace location from effects of characteristics of the employees. Studying changes of employees' travel behaviour as their workplace relocate allows for analysing how the travel behaviour of a concrete group of people changes as the conditions for choosing various modes of transport change (Strømmen, 2001). Several Norwegian studies found that relocation of workplaces indeed affects employees' travel behaviour. Studies of companies relocating from central to more peripheral locations found increases in car usage and traffic volumes (Hanssen, 1993; Kollbotn, et al., 1993; Strømmen, 1996). Konst (2003) analysed changes of travel behaviour among employees at the *National hospital* before and after relocating from downtown Oslo to a location about seven kilometres from the city centre. Car shares increased from 19 to 39 percent, while public transport shares decreased from 53 to 42 percent, and walking and bicycling from 28 to 19 percent. The new location is relatively well served by public transport, but less so than the previous location. Further, it provides substantially more parking, direct access to a main road, and there are fewer people living within walking distance.

Meland (2002) analysed changes of employees' travel behaviour as several governmental offices moved from workplaces in different locations in Trondheim, to the centrally located *Statens hus*. Car shares decreased from 63 percent to 20 percent, public transport shares increased from 10 to 33 percent, and commuting by foot and bicycle increased from 6 percent to 12 percent. In the survey, employees explained that this was both due to worse parking conditions and improved accessibility by bus. Average travel time ratio between car and public transport was reduced from 2.7 to 1.7.

Tennøy and Lowry (2008) analysed effects on travel behaviour among employees as six research institutes relocated from different locations in Oslo, to Oslo Science Park about 6.5 km from the city centre. This caused changes in conditions for commuting by various modes. The changes varied between the institutes because their locations before relocation were different. In total, however, the new location was more centrally located, it offered better access by public transport, and worsened parking accessibility (fewer places, rather high prices). Car shares almost halved, from 36 percent to 20 percent. Public transport shares increased from 30 to 39 percent, and bike shares increased from 24 to 29 percent. Commutes by foot remained the same in both situations, 6 percent. The employees were asked before the relocation whether they expected their commutes to improve or worsen as an effect of the relocation (it was known that parking access would be worse after relocation). A higher proportion of the employees expected it to worsen than to improve. After relocating, the employees were asked whether their commute had improved or worsened. The proportion of employees reporting that their commutes had improved was higher that the proportion reporting that it had worsened. The respondents were hence more content with their commutes after the relocation than they anticipated that they would be.

Hence, it seems as even if several factors affect travel behaviour on travels to work, workplace location and distance from city centre seems to have a strong effect. This means that it matters for future car dependency, car-usage, traffic volumes and transport related environmental consequences where new workplaces are developed.

In this study, all kinds of workplaces were included. We expect that the effects would have been stronger if only workplaces requiring specialized employees were included. As mentioned, such workplaces need to recruit employees from a larger area, meaning that a higher portion of the employees needs to travel longer distances to work. If their workplaces are located with very good regional public transport access (as it is in areas close to central railway stations, such as Bjørvika), a higher percentage would use public transport rather than car. If located in areas with poorer public transport access, many would need to travel by car, since walking and bicycling normally is not an option on long journeys.

The results from this study are relevant for developers, planners and politicians. As discussed in the introductory section, debates are going on in several cities concerning how to transform and develop central station areas and other centrally located areas. Density is often a major question in such debates, as is which kinds of activities should be allowed to be developed. Other planning debates concern which areas of the cities new developments should be steered towards. Such debates may be better informed by empirical studies conducted in cities representing different contexts and conditions. The findings in this study support the understanding that central location of new area-intensive workplaces, and to allow high densities in the most central areas of cities, are good strategies if reducing car dependency, traffic volumes and transport-related consequences are important objectives.

Our study contributes to the scientific knowledge by strengthening the empirical knowledge base concerning effects of workplace location on employees' travel behaviour in various contexts. By calculating transport-related environmental consequences, and by including public transport as well as car traffic in the calculations, this study goes beyond the scope of most similar studies. This increases the value of the study.

Still, there is a need for more studies on effects of workplace location on travel behaviour - from different parts of the world, from cities of various sizes, and from different parts of the cities (central, peripheral, close to central and more peripheral public transport nodes, and more). Further, to investigate variations within different kinds of workplaces (highly specialized and less specialized). There is also a need for more studies concerning effects of location of other activities, such as retail and housing.

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