NORDISK ARKITEKTURFORSKNING
NORDIC JOURNAL OF ARCHITECTURAL RESEARCH

1/2.2010

Architecture, Energy and Climate

NORDISK ARKITEKTURFORSKNING

Redaksjon
Eivind Kasa (Sjefsredaktør/Editor-in-Chief)
Ruth Woods (Redaksjonssekretær/Editorial Secr.)
Birgit Cold (Redaktør/Editor)
Rolee Aranya (Redaktør/Editor)

Grafisk form
Ole Tolstad - www.tolstad.com

Redaksjonens adresse
Nordisk Arkitekturforskning
Fakultet for arkitektur og billedkunst, NTNU
Eivind Kasa, Editor-in-Chief
Alfred Getz vei 3
7491 Trondheim
tel (+47) 73 59 50 07
www.arkitekturforskning.net

Tidsskriftets e-post:
nordark@ab.ntnu.no

Design og illustrasjon omslag
Alex Booker, NTNU

ISBN 978-82-92880-07-4

Trykk: Tapir Uttrykk AS, Trondheim 2010

Miljøfyrtårn®

Tidsskriftet er utgitt i samarbeid med
Nordisk Arkitekturakademi

Styrets adresse
Nordisk Forening for Arkitekturforskning
President Peter Thule Kristensen
Kunstakademiets Arkitektskole
Philip de Langes Allé 10
1435 Kbh. K
tel (+45) 3268 6000
arkitektskolen@karch.dk

ABONNEMENT OG MEDLEMSAVGIFTER

PRISER 2008 Tidsskriftet er fritatt for moms Valuta	Sverige SEK	Danmark DKK	Finland Euro	Norge NOK	Utenfor Norden SEK
Abonnement enkeltpersoner*	350	290	38,5	320	425
Abonnement studerende/doktorand*	250	205	27,5	225	305
Abonnement 1 eks institusjon/bedrift*	525	430	57,7	475	625
Abonnement 3 eks institusjon/bedrift*	725	595	79,7	660	825
Kun medlemskap	50	45	5,9	50	50
Løsnummer	100	90	11,8	95	150
Løsnummer, dobbeltnummer	175	150	21,0	170	260
Årgang 87-00	100	90	11,8	95	150
Årgang 01-03	200	175	23,5	190	300
Årgang 04-06	225	200	26,9	215	280

*medlemskap for *én* person i Nordisk Forening for Arkitekturforskning.

Abonnement og løssalg
Nätverkstans ekonomitjänst
Box 311 20, 400 32 Göteborg
Tel. 031 743 99 05
Fax 031 743 99 06
E-post: ekonomitjanst@natverkstan.net
OBS! Subject: NA

Betaling i Sverige til ***Postgirot 419 03 25-3***
i Danmark til ***BG Bank 1-678-0995***
i Finland til ***Leonia Bank 80013-70633795***
i Norge til ***Den norske Bank 7877.08.13769***

Betaling i land **utenfor** Norden i
SEK med SWIFT-adresse
PGSI SESS Account no: 4190325-3,
Postgirot Bank Sweden
SE-105 06 Stockholm

Ikke send sjekker.
Ikke betal til svensk postgiro fra Danmark, Finland og Norge.

NORDISK ARKITEKTURFORSKNING

NORDIC JOURNAL OF ARCHITECTURAL RESEARCH

1/2.2010

THE ARTICLES HAVE BEEN PEER REVIEWED BY AT LEAST TWO OF THE FOLLOWING RESEARCHERS:

ANNEMIE WYCKMANS, NTNU

ARNE FØRLAND, Aarhus School of Engineering

ELI STØA, NTNU

HANNE LEHRSKOV, Aarhus School of Engineering

HANNE TINE RING HANSEN,Rambøll, Denmark

INGER-LISE SAGLIE, University of Life Sciences, Ås

JAAN-HENRIK KAIN, Chalmers University of Technology

LARS-GÖRAN MATTSSON, Royal Institute of Technology, Stockholm

MATHILDE PETRI, Royal Danish Academy of Fine Arts, School of Architecture

PER HEISELBERG, Aalborg University

RASMUS LUND JENSEN, Aalborg University

THOMAS JUEL CLEMMENSEN, Aarhus School of Architecture

TOMAS SVENSSON, Swedish National Road and Transport Research Institute

TORBEN DAHL, Royal Danish Academy of Fine Arts, School of Architecture

MICHAEL JONES, NTNU

MARIE LOUISE ANKER, STFK

SIGMUND ASMERVIK, UMB, Ås

FINN HAKONSEN, NTNU

DAG KITTANG, NTNU

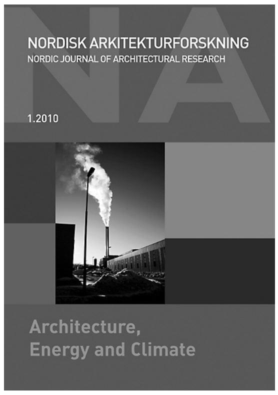
STAALE SINDING-LARSEN, NTNU

MAGNUS RÖNN, KTH

TIM ANSTEY, KTH

BIRGIT COLD, NTNU

ANNE KATHRINE FRANDSEN, SBI



Innhold: Vol. 22, No 1/2.2010

NORDISK ARKITEKTURFORSKNING – NORDIC JOURNAL OF ARCHITECTURAL RESEARCH

TOPIC: ARCHITECTURE, ENERGY AND CLIMATE

4 MICHAEL LAURING — Architecture, Energy and Climate

9 PETTER NÆSS, VICTOR ANDRADE — Housing, mobility and urban sustainability - examples and best practices from contemporary cities

21 MATHIAS HAASE, INGRID ANDRESEN, BERIT TIME, ANNE GRETE HESTNES — Building for climate change – meeting the design challenges of the 21st century

32 ROB MARSH, VIBEKE GRUPE LARSEN, JAKE HACKER — Towards a New Paradigm: Design Strategies for Architecture, Energy and Climate Change using Danish Office Builidings as a Case Study

47 MICHAEL LAURING — From ecological houses to sustainable cities. Architectural minds

61 MARY-ANN KNUDSTRUP — How can we adapt education programmes to the architecture of the future?

74 CLAUS BECH-DANIELSEN — Three types of environmental effort – behavioural changes, technical development, architectural design

83 VICTOR ANDRADE — Integrating Urban Design, Land Use and Transport Policies to Contribute Towards Sustainable Development. The Bus Rapid Transit System (BRT) in Three Developing-Country Metropolises: Curitiba, Beijing and Johannesburg

VITENSKAPELIGE ARTIKLER UTENFOR TEMA

95 INGER-LISE SAGLIE, GRETE SWENSEN — Reusing the past: Popular architecture in Golsfjellet summer mountain farm area

109 CAMILLA RYHL — Accessibility and sensory experiences: designing dwellings for the visual and hearing impaired

123 LEROY OLAF TONNING — The Wooden City of Stavanger. Self image as a basis for development

135 OLE JØRGEN BRYN — Retracing Khufu's Great Pyramid. The "diamond matrix" and the number 7

145 YLVA DAHLMAN — Architects and the creation of images

FORUMARTIKLER

157 KENNETH STOLTZ — Hva skal vi med arkitekturforskningen? Samtale med tre praktiserende arkitekter i Trondheim om arkitekturforskning og praksis

169 INGE METTE KIRKEBY — Om at skabe tankevækkende viden - vidensformer mellem arkitekturens praksis og forskning. Et intevju med Kristian Kreiner

BOKANMELDELSER

177 DAG KITTANG — Tom Nielsen: Gode intensjoner og uregjerlige byer

179 RANDI A. NARVESTAD, DAVID CLAPHAM, EINAR STRUMSE — Åshild Lappegard Hauge: Housing and Identity. The Meaning of housing communication identity and its influence on self-perception

181 EIVIND KASA — Books Recieved/Bokomtaler

Housing, mobility and urban sustainability – examples and best practices from contemporary cities

Petter Næss and Victor Andrade

Nordic Journal of Architectural Research
Volume 22, No 1/2, 2010, 12 pages
Nordic Association for Architectural Research
Petter Næss and Victor Andrade
Department of Development and Planning, Aalborg University
Department of Architecture and Design, Aalborg University

TOPIC: ARCHITECTURE, ENERGY AND CLIMATE

Abstract:

This paper deals with relationships between urban form and travel and shows examples of cities in developed and developing countries that have used spatial planning in order to promote more environmentally friendly mobility. Based upon studies in Copenhagen, Denmark, and Hangzhou, China, the first part of the paper explores how the location of residences relative to concentrations of workplaces, service and leisure facilities influences the physical mobility of the residents and its related environmental consequences. The notion of 'transportation rationales' is important in order to understand the causal mechanisms by which residential location affects travel behavior. The studies show that avoiding low-density urban spatial expansion is indispensable in order to minimize the need for motorized transportation in general and car travel particularly. In particular, densification close to the main center of the urban region contributes to reduce the amount of travel and to increase the proportion of non-motorized travel. In the second part, these findings form the background for a review of a variety of urban development strategies in non-European metropolitan areas that are dealing creatively with urban transportation and its environmental impacts, using land use and urban design to selectively change travel behavior. Finally, the paper offers some public planning and policy proposals in order to reduce the amount of travel, encourage environment- and climate-friendly travel modes and help mitigate climate change.

Keywords:
Residential location, Travel, Energy use, Transport rationales, Sustainable mobility, Environmentally friendly examples

Introduction

Reducing the consumption of fossil fuels (oil, coal and gas) is a key issue in the efforts to promote a sustainable development (WCED, 1987), not the least in order to mitigate climate change. Transportation is probably one of the sectors of society where policies aiming to reduce greenhouse gas emissions will be most controversial. Transportation in urban areas has a number of other negative environmental and social impacts too, including local air pollution, noise, loss of valuable buildings and recreational areas due to road construction, replacement of public urban space by parked cars, the barrier effects of major roads, and traffic accidents. A car-based urban development also entails reduced accessibility for people who are not able to drive a car. Realizing that travel behavior also is influenced by a host of factors other than the spatial urban structures, we still contend that developing the built environment of cities in a way that creates accessibility without being dependent on a high amount of motorized travel is important in a sustainability perspective. Distinct from some of the factors influencing travel behavior (such as gender, household composition, or income level), the spatial urban development is something that urban public planning and policy can actually influence through available legal instruments. Moreover, some other possible policy instruments aiming to reduce urban motoring (such as road pricing) will be less effective and more difficult to implement if the spatial urban at the same time contributes to make car travel more and more indispensible.

Studies in a number of cities in different countries have shown that residents living close to the city center travel less than their outer-area counterparts and carry out a higher proportion of their travel by bike or by foot (e.g., Mogridge, 1985; Næss, Røe & Larsen, 1995; Næss, 2006; Zegras, 2010). In spite of decentralizing trends, most cities still have a higher concentration of workplaces, retail, public agencies, cultural events and leisure facilities in the historical urban center and its immediate surroundings than in the peripheral parts of the urban area. For residents in the inner and central parts of the city, the distances to this concentration of facilities will be short. Average trip distances could therefore be expected to be shorter among these residents than among their outer-area counterparts, and with a higher share of trip destinations within acceptable walking or biking distance.

Among architects, however, the attention to relationships between the built environment and travel behavior has been directed mainly towards the influence of local-scale urban structural conditions. This also applies to the dominating focus of research into land use-travel relationships in the United States. Local-scale urban design principles, such as street pattern, availability of sidewalks and bike paths etc. and aesthetic neighborhood qualities, can influence the attractiveness of different travel modes and can for some travel purposes also affect trip destinations. For example, among 38 research studies reviewed in a recent American article (Cao et al, 2009), only 5 included variables indicating the location of the neighborhood relative to the city center. In European research, there has been much more focus on the level of the city as a whole/the metropolitan area.

Below, material from studies of residential location and travel in Copenhagen and Hangzhou will be used to shed light on how and why urban structures influence travel behavior. In the second part of the paper, a number of examples from non-European countries of urban developmental strategies aiming to reduce car dependency and urban motoring through land use planning will be reviewed.

The Copenhagen as well as the Hangzhou study was carried out by means of a combination of quantitative and qualitative research methods. Besides recording urban structural conditions from maps, aerial photographs and visits in the investigated urban districts and residential areas, the investigation was based on a number of qualitative interviews (17 in the Copenhagen case and 28 in the Hangzhou case) and answers from individuals participating in questionnaire surveys (1932 in the main survey of the Copenhagen study and 3155 in the survey of the Hangzhou study). More detailed information about the methods and results of the two studies is available in Næss (2005; 2006; 2009 and 2010).

Copenhagen Metropolitan Area (population: about 1.8 million) is one of the largest urban areas of Northern Europe and a major node for international air and rail transport. The inner city of Copenhagen has an unchallenged status as the dominating center of the city region. The central municipalities of Copenhagen and Frederiksberg, making up only 3.4 % of the area of Copenhagen Metropolitan Area, have one third of the inhabitants and an even higher proportion of the workplaces (Næss, 2006). The center structure of Copenhagen Metropolitan Area could be characterized as hierarchic, with downtown Copenhagen as the main centre, the central parts of five formerly independent outer-area towns now engulfed by the major conurbation as second-order centers along with certain other concentrations of regionally oriented retail stores, and more local center formations in connection with, among others, urban rail stations and smaller-size municipal centers at a third level.

Hangzhou is the capital of the Zhejiang province and is located in south-eastern China, 180 kilometers south-west of Shanghai and is the economical and political center of this province. Hangzhou Metropolitan Area includes 5 million inhabitants, about half of which live in the continuously built-up urban area of the city of Hangzhou. Similar to European cities, the historical urban cores of Chinese cities are usually the areas with the highest concentration of workplaces, retail stores and other service facilities. Hangzhou Metropolitan area is no exception. The inner city of Hangzhou has an unchallenged status as the dominating center of the metropolitan area. The population density in this part of the region is considerably higher than in the outer parts of the region. In addition to the major center, the metropolitan area includes three second-order centers (one of which still not completely developed) and six third-order centers. These centers, too, include a more or less comprehensive set of center functions, but with a more narrow range and with a lower number of facilities within each category than in the main city center.

Our two case cities differ considerably in terms of affluence level, cultural traditions and political conditions. In Copenhagen metropolitan area, the mobility level has been high for decades, and three quarters of the households have one or more private cars at their disposal. Distinct from this, motor vehicle ownership has until recently been very low in Hangzhou, where sales of automobiles were restricted before 2004. Since then there has been an almost explosive growth in car ownership as well as ownership of other motor vehicles. Car ownership increased from 0.7 private cars per 100 households in 2001 to 15.4 cars per 100 households in 2007. At the time of our investigation (2005), 6 % of the respondents belonged to a household with a car.

In spite of these differences, there are, as we shall see, considerable similarities in the relationships between residential location and travel found in the two studies.

Inner-city residents travel shorter distances and are less dependent on motorized transport

Figure 1 shows average distances[1] traveled by car, non-motorized modes, public transport and (in the case of Hangzhou) electric bike among respondents living in different distance belts from the city centers of Copenhagen (to the left) and Hangzhou (to the right). In both metropolitan areas, each distance belt includes about one fourth of the total number of respondents.

In Copenhagen as well as in Hangzhou, travel by motorized modes is generally lower among inner-city respondents than among suburbanites. This reflects the fact that a high proportion of the respondents living in the outer distance belts

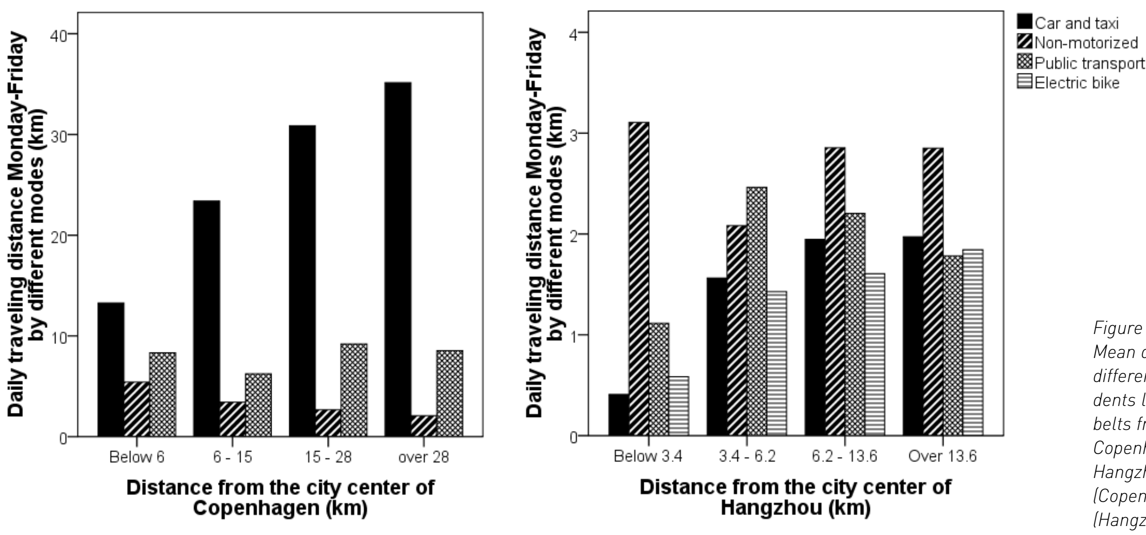


Figure 1: Mean daily traveling distances by different modes among respondents living in different distance belts from the city centers of Copenhagen (to the left) and Hangzhou (to the right). N = 1804 (Copenhagen) and 2829 (Hangzhou).

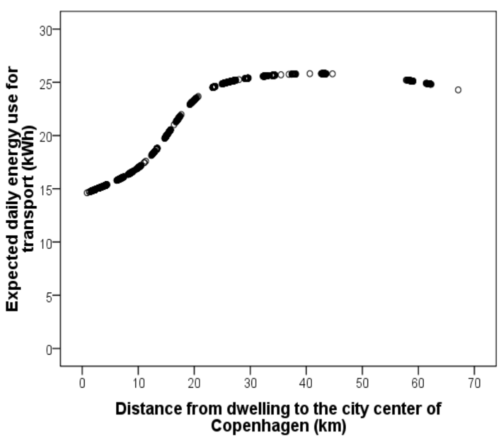
have to travel to destinations beyond acceptable walking or biking distance in order to reach the facilities they use on weekdays, in particular workplaces and places of education. In Hangzhou, suburbanites travel longer distances than inner-city respondents by car and taxi, public transport as well as by electric bike. In Copenhagen too, outer-area respondents travel considerably longer by car than their inner-area counterparts. In Copenhagen, respondents living less than 6 km from the city center travel on average about equally long distances by public transport as those living in the two outer distance belts. This reflects that on the one hand, the availability of public transport opportunities is highest in the central parts of the metropolitan area, but on the other hand, inner-city residents can reach a large number of facilities within walking or biking distance and are thus less dependent on motorized travel. In both metropolitan areas, inner-city residents travel longer distances by non-motorized modes than the suburbanites do. Combined with their lower amount of motorized travel, this implies that the proportion of distance traveled by non-motorized modes is considerably higher among those respondents living close to the city center.

We also see that traveling distances are generally much longer in Copenhagen than in Hangzhou (notice that the scale of the vertical axis is ten times as high in the diagram for Copenhagen as for Hangzhou). This reflects the much higher mobility level in Copenhagen, cf. above.

In Figure 1, travel behavior has been shown as variables depending on the location of the dwelling relative to the main center of the metropolitan area. There are also relationships in both metropolitan areas between travel behavior and the location of the residence relative to lower-order centers and more local neighborhood characteristics. These relationships are, however, considerably weaker than the relationships with the location of the dwelling relative to the main center. This has been demonstrated by means of so-called multivariate statistical analyses, where all investigated factors of influence have been 'kept constant' apart from those, the effects of which we want to examine. In addition to comparing the influences of different urban structural characteristics of the dwelling, the multivariate analyses also included a number of demographic, socioeconomic and attitudinal variables. By including such variables in the analysis, we reduce the risk of drawing false inferences about influences of residential location on travel in situations where (parts of) these relationships might be due to differences in socioeconomic and other individual characteristics between respondents living in different areas.

As could be seen in Figure 1, outer-area respondents in both metropolitan areas travel considerably longer by energy-demanding travel modes than their inner-city counterparts do. Below, results of multivariate analyses of factors influencing the respondents' energy use for transport will be shown. Since space constraints prohibit a thorough account of the relationships between residential location and all aspects of travel behavior, energy use has been chosen as an indicator. Besides its obvious relevance to the discussion on environmentally sustainable urban structures, energy use is a variable summarizing key aspects of travel behavior, as it depends on both traveling distances and travel modes.

Figure 2 shows how daily energy use[2] for transport varies with the distance from the dwelling to the city centers of Copenhagen and Hangzhou, respectively, when controlling for a number of demographic, socioeconomic and attitudinal characteristics of the respondents. The variables



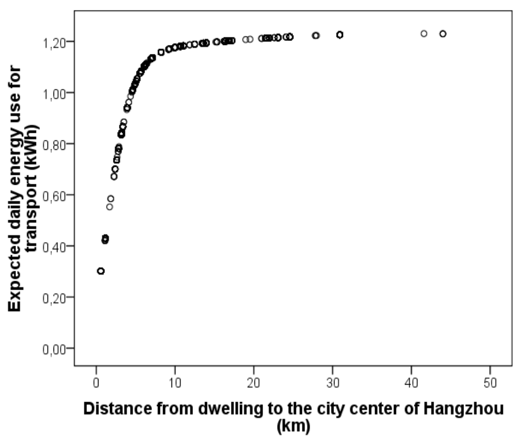


Figure 2:
Expected daily energy use for transport among respondents living at different distances from the city centers of Copenhagen (to the left) and Hangzhou (to the right). N = 1567 and 2156, respectively. P = 0.0000 in both cases.

kept constant when calculating the graphs shown in the figures include sex, age, number of children younger than 7 years of age in the household, number of children aged 7–17 in the household, number of adult persons in the household, education level, personal income, driver's license for car, whether or not the respondent is a workforce participant, whether or not the respondent is a student, transport-related residential preferences, and a few variables indicating particular activities, obligations or circumstances that may influence traveling distances.

In both metropolitan areas, inner-city living is associated with considerably lower energy use for transport, also when taking a number of individual characteristics of the respondents into consideration. But we also notice the very large general difference in transport energy use between the Danish and the Chinese context (the scale of the vertical axis is 40 times larger for Copenhagen than for Hangzhou). In Copenhagen Metropolitan Area, we also find that proximity to second- and third-order urban centers and high local-area density contributes to lower energy use, but these effects are by far not as strong as the effect of the distance from the main city center. In Hangzhou Metropolitan Area, we find, in addition to the effect of proximity to the main city center, a slight tendency of decreasing energy use when living close to a third-order center, but not any effects of other neighborhood characteristics. Among the non-urban-structural variables, we find, as might be expected, tendencies in both metropolitan areas of increasing energy use among respondents with a high income and driver's license for car, and men also tend to use more energy use for travel than women do.

Rationales influencing travel behavior

Why does travel behavior in the two case city regions depend more on metropolitan-scale than on local-scale built environment characteristics? Material from the qualitative interviews has shed light of some important rationales on which people base their travel behavior. The relative importance of metropolitan-scale and neighborhood-scale built environment characteristics to travel behavior depends in particular on people's *rationales for location of the activities* in which they participate.

For most travel purposes, most people do not necessarily choose the closest facility, but rather they travel a bit further if they can then find a better facility. They thus tend to emphasize a rationale of *choosing the best facilities* above a rationale of *minimizing the friction of distance*. This is especially true as regards workplaces, and it holds true both for the Danish and the Chinese context. Travel distances therefore depend more on the location of the dwelling relative to large concentrations of facilities than on the distance to the closest facilities. People who live close to the city center have a large number of facilities within a short distance from the dwelling and therefore do not have to travel long, even if they are very selective as to the quality of the facility. Since travel distances are often short, inner-city residents carry out a higher proportion of trips by bike or on foot.

The following circumstances tend to contribute to a high priority attached to the rationale of choosing the best facility, compared to distance minimizing: Specialized job skills, specialized leisure interests and 'exclusive' cultural taste, much time available, high mobility resources, many facilities available in the local area of the dwelling, and short distance from the local facilities to the closest competing concentration of facilities.

Our material from both case cities suggests that the propensity for using local facilities depends partly on which facilities exist in the proximity of the dwelling, and partly on the *competition* from non-local facilities. In the districts next to the downtown area, a relatively broad supply of local facilities often exists, but at the same time there is a strong competition from facilities in the city center. Conversely, the local supply of facilities is often more modest in the outer parts of the metropolitan area, but the long distance to the concentration of facilities found in the central city at the same time weakens the competition from the latter facilities. Figure 3 illustrates this relationship for one of the investigated types of activities, i.e. visits to cafes and restaurants.

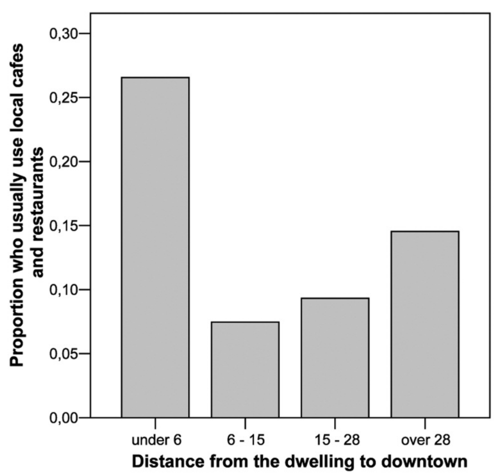


Figure 3:
Proportion of respondents living within different distance belts from downtown Copenhagen who usually use facilities less than 1 km away from the dwelling when visiting cafés or restaurants.
N = 1876.

The interviewees' choices of *travel modes* are influenced by a number of different and interconnected rationales. These rationales could be classified into two main groups:

- Rationales concerning the *efficiency* of the movement from origin to destination
- Rationales concerning the *process* of moving from origin to destination

The first of these two groups includes concerns related to time consumption, economic costs and accessibility benefits of traveling by different modes. The second group includes concerns related to physically, psychologically and socially positive or negative aspects associated with traveling by a particular mode. Several of the rationales are hinted at indirectly through a criterion of *trip distance* as an important condition influencing the interviewees' choices of travel modes. Since long trips will be very time-consuming as well as physically exhausting if they are made by non-motorized modes (in particular by foot), rationales of time-saving and limitation of physical efforts will logically imply a dependence of travel modes on trip distances. Living close to relevant trip destinations thus does not only contribute to shorter traveling distances, but also implies a higher propensity of using non-motorized modes.

Environmentally oriented land use and transport strategies in non-European countries

A review of best practices outside Europe presents empirical evidence of the implementation of innovative policy and design tools for integrating urban form, land use and accessibility in order to mitigate greenhouse gases emission. The winner of the 1996 World Habitat Award, Curitiba is an example of how a fast growing metropolis in a developing country can successfully integrate land use and transport planning for fostering environmental sustainability. Other successful examples include Bogotá (Colombia), Singapore, Hong Kong (China) and Portland (USA), (Dodman, 2009, Rabinovitch, 1996; Haughton & Hunter, 1994; Newman, 1996).

Since the 1970`s, Curitiba`s development has been defined by three main characteristics: (i) an integrative approach to land use and transport policies — concentrating urban expansion along bus-ways (Bus Rapid Transit) and densification along them through regulations and incentives; (ii) integration of the transport modes, enhancing their complementarity; and (iii) pedestrianisation of streets and discouragement of private vehicular traffic and parking in Downtown Curitiba (WBCSD, 2004).

Curitiba's bus system is composed of a hierarchical feeding system including minibuses, conventional buses and the Bus Rapid Transit – which is the spine of the system and operates on the main arteries radiating out from Downtown Curitiba. In order to generate more transit ridership per square foot, Curitiba's Master Plan motivates highly dense mixed use growth along these arteries and high-density residential use in developments within two blocks of the arteries.
Moreover, beyond two blocks from the arteries, residential densities are defined in proportion to distance from transport corridors.

Despite the fact that Curitiba has more cars per inhabitant than any other Brazilian metropolises, over 70 percent of commuters use public transportation in their daily journeys. According to Goodman (2006), the integration of an efficient transport infrastructure and land use policy has resulted in a reduction of 27 million private motorized trips per year – saving about 27 million liters of fuel annually. In comparison to eight other Brazilian metropolises, Curitiba uses 30 percent less fuel per capita. Moreover, the inhabitants spend only around 10 percent of their income on travel – much below the Brazilian average (Goodman, 2006).

Curitiba`s integration of Bus Rapid Transit system technology with land use policies has been an alternative followed by several metropolises, providing public transportation with impressive ridership figures and reducing greenhouse gas emissions at a much lower cost than rail investments (Rodríguez & Targa, 2004). Currently, more than 40 Bus Rapid Transit systems are operating around the world – including Bogotá, Porto Alegre, São Paulo, Mexico City, Cape Town, Lagos, Johannesburg, Brisbane, Honolulu, Nagoya, Hanoi and Jakarta – and more than 80 cities are planning similar system (WBCSD, 2004).

In Latin America, Bogotá stands next to Curitiba as a successful example of integrated transport policy, land use and public space revitalization. Bogotá has experienced fast population growth in the last 60 years, which has often challenged local governance. Over the last fifteen years, however, Bogotá has undergone a renaissance helped by a comprehensive development strategy –Vision Bogotá 2038 – aiming to create a more sustainable city through the promotion of compact development, efficient public transport system and cycling amenities.

Following Curitiba`s example, Bogotá has also implemented a Bus Rapid Transit system - called TransMilenio – opening the first bus rapid lane in 2001. In 2006, the TransMilenio infrastructure included 69 km of exclusive road lanes, 94 stations and 747 buses averaging a speed of 26 km per hour. Moreover, TransMilenio is used for an average of 1.6 million trips each day. Since 2001 Bogotá has removed 7,000 small private buses from its roads, reducing the use of bus fuel by more than 60 percent (Estupinán & Rodríguez, 2008).

According to the United Nations, TransMilenio and its related urban infrastructure reduces greenhouse gas emissions because of its greater energy efficiency compared to other bus transport and due to the partial replacement of private autos by public transport. The United Nations Framework Convention on Climate Change estimates that the TransMilenio will prevent the emission of two million tons of CO_2 in the atmosphere during a period of 10 years (UNFCCC, 2009).

In 2008, TransMilenio became the first mass transit system in the world approved by the United Nations Framework Convention on Climate Change to generate and sell carbon credits – being recognized as a clean development mechanism in accordance with the Kyoto Protocol. The carbon credit system may help to finance TransMilenio`s maintenance and expansion. In other to gather funds, other governments could also try to recognize their similar transport systems as clean development mechanisms.

In Asia, Singapore also demonstrated a successful strategy where public transport is developed integrated with land use policies – taking into account the metropolitan as well as the neighborhood scale. At the metropolitan level, the Mass Rapid Transit lines are developed taking into account the accessibility of districts and centralities. While at the neighborhood level, the areas adjacent to transport stations are densified and mixed use is incentivized (APEIS & RISPO, 2006).

To date, Singapore`s public transport infrastructure has a hierarchical structure composed by the Mass Rapid Transit (covering 109 km with 66 stations) – as the spine of the system – the Light Rapid Transit (covering 29 km with 33 stations) and buses as feeders to the rapid transit stations. By 2020, Singapore`s Land Transport Authority expects to double the rapid transit system network from 138 km today to 278 km by adding new lines and extensions (LTA, 2008).

Together with massive investments in public transport infrastructure, complementary policies were also established in order to discourage car usage: Area License Scheme (1975), the Vehicle Quota System (1990), and the Electronic Road Pricing Scheme (1998).

Similar to Singapore, Hong Kong`s experience highlights valuable lessons of how to fully integrate transport infrastructure and land use development. While most wealthy cities present a figure of car-per-thousand inhabitants ranging from 350-550, Hong Kong`s figure is only 55. Prior to expansions of the public transport system, properties adjacent to stations are acquired for densification in order to generate high ridership (World Bank, 1996).

Hong Kong has attracted private investors through incentives when redeveloping properties adjacent to stations. Instead of being reactive and wait for the market to generate demand over time, the authorities of Hong Kong generate demand by intervening in the property market and redeveloping properties adjacent to stations. Revenues generated are divided between the private partners and the Hong Kong`s Mass Transit Railway which uses it to finance the system maintenance and future expansions (Nieweler, 2007).

However, it is important to note that Hong Kong and Singapore have benefited from their unique geographic and political situation: (i) strong centralized authority, facilitating land acquisition and development control; and (ii) the conjunction of land constraint and fast demographic raise. While most metropolises deal with an opposite scenario: (i) complex institutional and jurisdictional structure leading to political and managerial challenges; and (ii) edge-land availability and fast demographic growth leading to urban sprawl (Fisher, 2001). Inspired by Hong Kong and Singapore as examples, many metropolises have during the recent years successfully implemented the strategy of attracting transit oriented redevelopments around stations that were once characterized by low density zoning.

Hangzhou, our example city from the first part of the paper, has been facing the difficult task of accommodating a high population growth as well as a rapid increase in floor area per capita without consuming too much of scarce land resources. The Main City Plan of Hangzhou emphasizes intensive and economical use of land and improvement of land use efficiency in the central area of the city as key principles. The planned development of Hangzhou implies that Hangzhou

Metropolitan Area – the main city as well as the lower-order urban settlements – will continue to be characterized by dense urban structures. Although there has been considerable road development, Hangzhou has in recent years taken important steps to improve public transport, notably in the form of a (still not completed) metro (Næss et al., 2010).

In North America, Portland, Vancouver and Toronto are other examples following strategies of coordinated land use and transport planning in order to reduce the amount of urban motoring. During the last fifteen years Portland has been implementing an innovative and comprehensive regional plan – the 2040 Growth Concept – to reduce greenhouse gas emissions. Portland`s plan promotes high density and mixed-use developments that have a physical and functional connection to a public transport station, through a partnership with the private sector. New urban developments have been mainly implemented on already existing urban centers – annual land converted to urban use was 40 percent lower in 2002 than it was in 1999 (WBCSD, 2004).

The local authority has been acquiring station-adjacent properties that are locked up by fragmented ownership. After the acquisition, the area is re-parceled and then sold with public transport oriented conditions to private developers. Incentives are used to compensate the higher costs of orienting the development to public transport and pedestrian uses. As a result, Portland residents decreased their per capita vehicle miles traveled by 11 percent between 1996 and 2002, while the remaining Americans increased vehicle miles traveled by 6 percent on average during the same period (California Energy Commission, 2007).

Public planning and policy proposals

Integrated land use and transport policy must be acknowledged as an alternative to enhance public transport ridership, as well as reducing land consumption and greenhouse gas emissions. It is of course not reasonable to expect any single instrument (such as urban land use planning) to be able in itself to induce the necessary changes toward environmentally sustainable mobility. If the reductions of transportation's environmental loads necessary to make a difference in relation to the global climatic challenges are ever to be possible, there will probably be a need to combine more energy-efficient vehicles, fuel taxes, road pricing, improved public transport in cities, as well as spatial planning limiting the needs for transport. Economic measures (e.g., radical increases in gasoline fees and/or road pricing with restrictively high rates per kilometer) could potentially change transportation patterns significantly in the course of a short time. However, if any economical measures against the growth in car traffic are to work according to their purpose, the share of inhabitants who accept more time-consuming trips or reduced options for workplaces and service facilities must increase, while the proportion choosing to surmount the friction of distance by buying themselves a high mobility must be reduced. For outer-suburban households who do not consider themselves able to reduce their transport, road pricing or other economic instruments to reduce urban motoring will be an additional economic burden.[3] On the other hand, the more transport-requiring the urban structure, the higher taxes will be necessary in order to change travel behavior among the households causing the heaviest environmental load through their daily traveling. This highlights the necessity to ensure that economic traffic demand management measures and urban spatial strategies pull in the same direction.

In this regard, it is essential to establish a metropolitan sphere of decision with enough power to implement comprehensive policies. Urban management on the metropolitan scale constitutes one of the main contemporary challenges, especially in the developing world where urban development is often characterized by a dichotomy between formal and informal developments, undermining efforts to implement a comprehensive urban policy. A prevalent condition is that of a complex network of administrative bodies and an absence of a metropolitan sphere to guide comprehensive approaches to environmental management. Such a set-up does not provide a platform for dealing with urban problems on a metropolitan scale and in the context of local ecosystems (Andrade & Ribeiro, 2005).

Besides addressing the above mentioned challenge, for example by establishing new metropolitan-level planning and decision-making bodies, policy makers should emphasize the role of density and mixed land use together with car-restrictive transport policies as important determinants of energy use and emission. Low-density suburban development should be actively discouraged through land regulation, and the (usually hidden) subsidizing of housing types requiring high infrastructure costs per dwelling should be avoided. Bearing in mind both regional and local scales, it is important to identify sites suitable for densification – usually central areas and properties adjacent to stations – and then to elaborate a local plan and design guidelines addressing energy efficiency and transport efficiency.

The recommendation of locating the construction of new housing close to city centers in order to reduce car dependency and energy use for transport rests with the assumption that there are actually some centers toward which residential development can be centralized. According to some authors, historical urban cores have lost much of their dominant position during the recent 30 or 40 years. For example, the German architect Sieverts (1999) holds that contemporary cities can no longer be fitted into a hierarchic system according to central place theory. Instead, they should be understood as a network of nodes, where there is a spatially more or less equal, scattered distribution of labor with spatial-functional specializations. Such net-shaped cities or city regions have polycentric instead of a monocentric or hierarchic center structures, and constitute larger, fragmented and very complex territories. However, this clearly does not apply to our two case cities, Copenhagen and Hangzhou. Most cities still have a higher concentration of workplaces, retail, public agencies, cultural events and leisure facilities in the historical urban center and its immediate surroundings than in the peripheral parts of the urban area (cf., among others, Newman & Kenworthy, 1999:94-95; Nielsen & Hovgesen, 2006). Even urban regions where decentralization of workplaces and residences is a dominant tendency are usually characterized by a hierarchical intra-metropolitan structure with a main center and several lower-order centers, rather than being genuinely polycentric. In Sieverts' archetypical example, the Ruhrgebiet in Germany, residents living close to the centers of cities like Dortmund, Bochum and Essen have a higher likelihood of finding employment, shopping opportunities and leisure facilities within a moderate distance from the dwelling than their counterparts living in the suburban field between these cities, and they have also generally better opportunities for using public transport when traveling to other cities and towns within the polycentric Ruhr region.

Residential segregation is also a key issue for the good governance of cities and sustainable mobility and must be addressed by public policies. The isolation of people of different socio-economic groups and ethnicities has potential environmental, economic, political and social consequences – including increasing daily commuting and unequal access to and quality of education, health and other services (Quigley, 1994). In North America, dispersal of jobs from inner cities to the suburbs has taken place to a higher extent and inner city districts have been gentrified to a lesser extent than in many European cities. Several studies in North American cities thus indicate that job opportunities have continuously increased in the suburbs and this has created an increasing spatial mismatch between inner city minorities and suburban jobs. Housing choices of minorities are constrained by segregation and discrimination, which leads them to live far from affluent neighbors and employers. Consequently, housing segregation increases the distance between minorities and job opportunities. The trend in several American metropolises is toward high concentrations of poverty in the inner city and a concentration of low-wage and low-skill job opportunities in the suburbs, resulting in increasing commuting distances (Simpson & Veen, 2006).

Concluding remarks

The studies in the metropolitan areas of both Copenhagen and Hangzhou show that avoiding low-density urban spatial expansion is indispensable in order to minimize the need for motorized transportation in general and car travel particularly. In particular, densification close to the main center of the urban region contributes to reduce the amount of travel and to increase the proportion of non motorized travel.

City planners, urban designers, technicians and politicians must work in cooperation, searching for creative and, at the same time, realistic alternatives to tackle urban sprawl and poor accessibility. The lessons previously introduced share one essential characteristic: long term policies that integrate land use and transport policy. All lessons highlight useful policies and tools that could be adapted to diverse urban conditions. Nevertheless, it seems that emission reduction strategies related to urban form and transport will differ from case to case and that no single universal strategy will work in all urban scenarios. Each metropolis has its specific challenges and potentials and policy makers must to explore innovative policies and implement them having in mind these challenges and potentials.

AUTHORS

Petter Næss
Professor, Dr. Ing.
Department of Development and Planning, Aalborg University, Denmark
petter@plan.aau.dk

Victor Andrade
Assistant Professor, PhD
Department of Architecture and Design, Aalborg University, Denmark
vsil@create.aau.dk

NOTES

[1] As a main motivation for the research studies presented in this paper has been to investigate how residential location in urban regions influences on energy use and greenhouse gas emissions, we have used traveling distance as a measure of the volume of transport, rather than travel time. The latter is a poor indicator of the environmental impacts of urban transportation, since the travel modes requiring the least energy use and causing the least pollution (walking, biking and public transport with high capacity utilization) are generally more time-consuming than the private car, except under highly congested conditions. The Copenhagen area study did, however, also include analyses of urban structural and other factors influencing travel time. These results have been published elsewhere (Næss, 2006, pp. 158-159).

[2] In the calculations of energy use for car travel, considerations have been made about the influence of travel speeds on fuel consumption per vehicle kilometer. Since inner-city dwellers that have got a car mainly use their cars for trips to suburban and exurban locations, while suburban commuters often drive a considerable part of their daily journeys under congested conditions, we do not consider it likely that energy use per vehicle km by car will be significantly higher among inner-city residents than among their suburban counterparts. In the Copenhagen study, energy use per vehicle km by car for all respondents was thus calculated as a weighted average of fuel consumption figures for driving under 'urban' and 'highway' conditions, based on information from the Danish Road Directorate (For more details, see Næss & Jensen, 2005, pp. 429-430.) In the Hangzhou study, energy use per vehicle km for cars was based on the average of figures from two different Chinese sources (Committee on the Future of Personal Transport Vehicles in China et al., 2003 and Wu, 2008). Energy use for different types of public transport in the two studies was calculated from figures based on Danish/Scandinavian and Chinese sources, respectively.

[3] Low-income suburbanites are also highly vulnerable to rising oil prices, which must be expected due to growing global demand relative to production, geopolitical insecurity and longer-term supply uncertainty (Dodson & Sipe, 2008).

LITERATURE

ANDRADE, V. & RIBEIRO, G. (2005a) Intra-metropolitan Inequalities in Rio de Janeiro and the Guanabara Bay Cleanning Programme. In A. Kungolos, C. A. Brebbia and E. Beriatos (editors) Sustainable Development and Planning II. Southampton, Boston: WIT Press. (pp. 1319-1328). 2005

ASIA-PACIFIC ENVIRONMENTAL INNOVATION STRATEGIES (APEIS) & Research on Innovative and Strategic Policy Options (RISPO). 2006. Strategic Policy Options

CALIFORNIA ENERGY COMMISSION (2007) The Role Of Land Use In Meeting California's Energy And Climate Change Goals.

CAO, X; MOKHTARIAN , P. L. & HANDY, S. (2009): "Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Empirical Findings." Transport Reviews, Vol. 29, 2009, pp. 359–395.

COMMITTEE ON THE FUTURE OF PERSONAL TRANSPORT VEHICLES IN CHINA, National Research Council, National Academy of Engineering and Chinese Academy of Engineering : Personal Cars in China. Washington, D. C., The National Academies Press, 2003.

DODMAN, DAVID (2009) Urban Density And Climate Change. In: Analytical Review of the Interaction between Urban Growth Trends and Environmental Changes. United Nations Population Fund (UNFPA). Revised Draft – April 2, 2009

DODSON, J. & SIPE, N. (2008): Shocking the Suburbs: Urban Location, Homeownership and Oil Vulnerability in the Australian City, Housing Studies, Vol. 23, pp. 377-401.

ESTUPINÁN, N.; RODRÍGUEZ, D. (2008) "The relationship between urban form and station boardings for Bogota´'s BRT." Transportation Research Part A 42 (2008) 296–306

FISCHER, T. (2001) Towards a better consideration of climate change and greenhouse gas emission targets in transport and spatial/ land use policies. In: Meeting of the Global Environmental Change Research Community, Rio de Janeiro, 6-8 October.

GOODMAN, J; LAUBE, M. & SCHWENK, J. (2006). "Curitiba's Bus System is Model for Rapid Transit." Race, poverty & the environment, winter 2005/2006. pp. 75-76.

HAUGHTON, G. AND HUNTER, C. (1994) Sustainable Cities. Jessica Kingsley, London.

LTA (Land Transport Authority), 2008. Land Transport Masterplan. Singapore: LTA.

HEAD, P. & LAWRENCE, G. (2008) Urban Development To Combat Climate Change: Dongtan Eco-city and Risk Management Strategies. In: CTBUH 8th World Congress 2008

MOGRIDGE, M. J. H. (1985): "Transport, Land Use and Energy Interaction." Urban Studies, Vol. 22, s. 481-492.

NEWMAN, P. W. G. & KENWORTHY, J. R. (1999): Sustainability and Cities. Overcoming Automobile Dependence. Washington DC/Covelo, California: Island Press.

NEWMAN, P. W. G. (1996) "Reducing automobile dependence." Environment & Urbanisation 8(1), 67-92.

NIEWELER, S. H. (2007) Public Transport Orientated Development: An International Policy Perspective. In: ETC Conference, October 2007

NIELSEN, T. S. & HOVGESEN, H. H. (2006): Developments in the relationship between large cities - the suburban zone and the rural/urban hinterland. Analysis of commute patterns around large European and American cities. Paper for the EURA Conference, Cities in City Regions, 11-14 May 2006, Warsaw, Poland.

NÆSS, P. (2005): "Residential Location Affects Travel Behavior - But How and Why? The case of Copenhagen Metropolitan Area." Progress in Planning, Vol 63/2, pp. 167-257.

NÆSS, P. (2006): Urban Structure Matters: Residential Location, Car Dependence and Travel Behaviour. New York/London: Routledge.

NÆSS, P. (2009a): "Residential Self-Selection and Appropriate Control Variables in Land Use–Travel Studies." *Transport Reviews*, Vol. 29, pp. 293-324.

NÆSS, P. (2010): "Residential location, travel and energy use: the case of Hangzhou Metropolitan Area." Forthcoming in Journal of Transport and Land Use, Vol. 3, 2010.

NÆSS, P. ET AL. (2010): On their road to sustainability? The challenge of sustainable mobility in urban planning and development in Copenhagen, Oslo and Hangzhou. Draft paper in progress.

NÆSS, P.; RØE, P. G. & LARSEN, S. L. (1995): "Travelling Distances, Modal Split and Transportation Energy in Thirty Residential Areas in Oslo." Journal of Environmental Planning and Management, Vol. 38, no. 3, pp. 349-370.

QUIGLEY, J. (1994) "New directions for urban policy." Housing Policy Debate. Vol. 5, pp 9-106

RABINOVITCH, J. (1996) "Innovative land use and public transport policy: The case of Curitiba, Brazil." Land Use Policy, Vol. 13, 51-67.

RODRÍGUEZ, D. & TARGA, F. (2004) "The value of accessibility to Bogotá's bus rapid transit system." Transport Reviews, Vol. 24, pp. 587–610.

SIEVERTS, T. (1999): "Zwischenstadt - zwischen Ort und Welt, Raum und Zeit, Stadt und Land." (The between city – between place and world, space and time, city and countryside.) Bauwelt Fundamente 118, 3. oplag. Wiesbaden: Vieweg.

SIMPSON, W; VEEN, A. (2006) "The Economics Of Commuting And The Urban Labour Market." Journal of Economic Surveys. Vol. 6, pp. 45–62.

UNFCCC (2009) Clean Development Mechanism (CDM) United Nations - UNFCCC http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php

WBCSD (World Business Council for Sustainable Development) (2004) Mobility 2030: Meeting the Challenges to Sustainability (Geneva: WBCSD).

WORLD BANK (1996) Sustainable Transport: Priorities for policy Reform. World Bank, Washington DC.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (1987): Our Common Future. Oxford/New York: Oxford University Press.

WU Z: Introduction of Transportation Energy Situation & Challenges in China. Power Point presentation May 22, 2008, accessed on the internet September 8, 2008. Beijing, Tsinghua University and The Atlantic Council of the United States, 2008.

ZEGRAS, P. C. (2010): "The Built Environment and Motor Vehicle Ownership & Use: Evidence from Santiago de Chile." Forthcoming in Urban Studies, Vol. 47, 2010.