Commuting, Health, and Wellbeing

Mode and duration matters

Mattisson, Kristoffer

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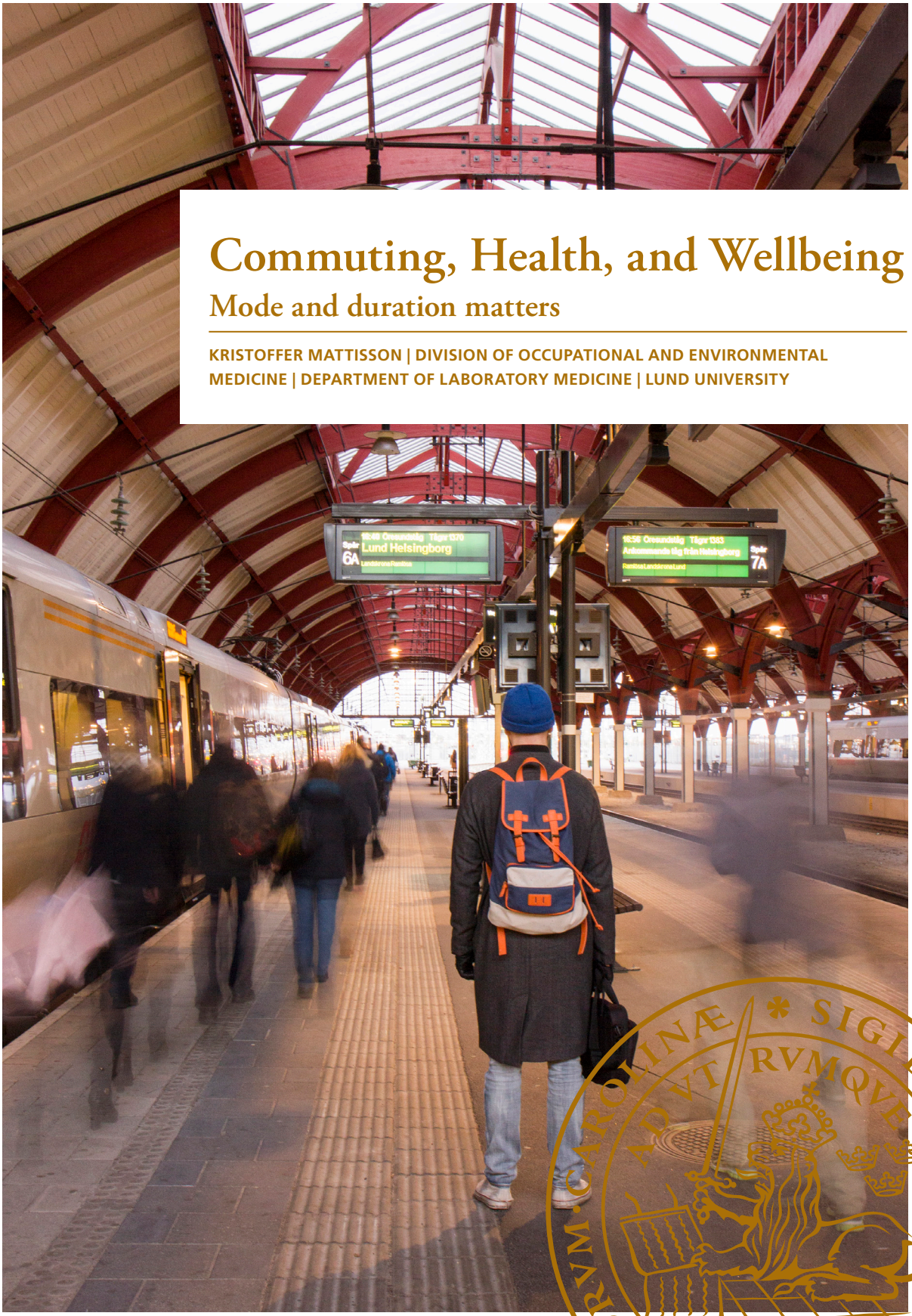

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KRISTOFFER MATTISSON | DIVISION OF OCCUPATIONAL AND ENVIRONMENTAL MEDICINE | DEPARTMENT OF LABORATORY MEDICINE | LUND UNIVERSITY

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Kristoffer Mattisson

LUND
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Commuting, Health and Wellbeing

Abstract

In many western countries commuters are expected to daily travel long distances and durations in order to reach work. Commuting, daily travel between home and work, can be added to the total workday, and consumes a considerable part of the commuters' day.

The general aim of this thesis was to study how commuting is related to health and wellbeing in order to better understand the impact on public health. We used cross-sectional data from the Public Health Surveys in Scania which are large datasets containing self-reported information on socioeconomic status, gender, family situation, education, health related behaviour, health and wellbeing. Information about income, residential and workplace location was obtained from national registers for each individual commuter. Self-reported mode and duration were used to address commuting combined with individually calculated commuting distance and duration based on registry data and GIS.

Car and public transportation commuters reported lower levels of health and wellbeing in comparison to active commuters. The association between car commuting and stress showed spatial and temporal heterogeneity with areas with higher prevalence of stress among car commuters identified in different area for different years. Further, we found lower social participation and general trust among car and long duration public transportation commuters. Including health status in study designs commonly used in transportation planning to study mode choices of travel, showed associations between commuters health status and mode choice of commuting.

Few studies with similar sample size have studied the associations between commuting and wellbeing and social capital. Spatial heterogeneity in the association between car commuting and stress highlighted the importance of considering geographical context and changes in commuting mode and duration over time.

The results are in concordance with prior research and we found supporting evidence for the existence of a so-called commuting paradox, that is, commuters are not fully compensated for longer commuting time. Reduced health and wellbeing among commuters can potentially lead to substential economic cost through more sick leaves and increased demand for health care.

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Commuting, Epidemiology, GIS, Health, Medical Geography, Stress

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To my family and friends

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Finalizing this thesis has truly been a challenge, but along this road of tests there have been plenty of rewards as well. Studying Physical Geography I did not expect to end up in Epidemiology, but so I did. Multidisciplinary research means learning many new things, but in the end I am convinced that this has enriched the thesis.

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List of papers

This thesis is based on the four papers referred to by the following roman numbers:

I. Hansson E, Mattisson K, Björk J, Östergren P-O, Jakobsson K. Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden. BMC Public Health. 2011;11:834.

II. Mattisson K, Håkansson C, Jakobsson K. Relationship between commuting and social capital among men and women in southern Sweden. Environment and Behavior. 2015;47(7):734-753.

III. Mattisson K, Cromley E, Håkansson C, Jakobsson K. Spatial heterogeneity in repeated measures of perceived stress among car commuters in Scania, Sweden. International Journal of Health Geographics. 2016

IV. Mattisson K, Idris A, Cromley E, Östergren P-O, Håkansson C, Jakobsson K. Modelling the effect of health indicators on commute mode choice a cross-sectional study in southern Sweden. (Manuscript)

Thesis at a glance

	Aim	Type of study/Study population	Primary outcome /method	Main findings and conclusion
Paper I	Study associations between commuting (duration and mode) and health and well-being.	Cross-sectional/Public Health Surveys in Scania 2004 and 2008	Perceived sleep, everyday stress, exhaustion, mental health, self-rated health and sickness absence/Logistic regression	Car and public transportation commuters experience more negative health than active commuters.
Paper II	Study associations between commuting (duration and mode) and social capital.	Cross-sectional/Public Health Surveys in Scania 2004 and 2008	Social participation and general trust in other people/Poisson regression	Car commuter have lower social participation and general trust than active and public transportation commuters
Paper III	Investigate spatial heterogeneity in stress levels among 30-60 min car commuters and changes over time.	Cross-sectional repeated measures/ Public Health Scania Cohort 2000, 2005 and 2010	Everyday stress/Geographically weighted proportions, Wards algorithm, test of single proportions.	There is spatial and temporal heterogeneity in the association between stress and 30-60 min car commuting
Paper IV	Study associations between commuter's health status and commuting mode choice.	Cross-sectional/Public Health Survey in Scania 2012	Choice of commuting mode/Discrete multinomial regression	Health is associated with choice of commuting mode.

Populärvetenskaplig sammanfattning

Allt fler personer reser allt längre sträckor för att ta sig till och från jobbet. En starkt bidragande orsak till detta är en strävan att öka den ekonomiska tillväxten genom att göra arbetskraften tillgänglig över allt större geografiska områden. I Sverige har både pendlingstid och avstånd stadigt ökat under de senaste decennierna och idag tillbringar den genomsnittliga pendlaren mer än en timme sammanlagt om dagen på resor till och från jobbet.

Att pendla innebär för många en upplevelse av stress. Resan i sig kan vara stressande av flera anledningar. Osäkerhet kring om man kommer fram i tid, en känsla av att sakna kontroll, trängsel, buller och bilköer är exempel på saker som kan bidra till att resan är stressande. Orsaken till att pendlare blir stressade och mår dåligt är inte bara att resan i sig, utan kan också bero på man förlorar tid som kunnat användas till annat.

Enligt ekonomisk teori ska den individuella pendlaren kompenseras för den längre pendlingen genom högre lön, billigare eller bättre boende eller ett mer stimulerande jobb, som skulle kunna bidra till ökat välmående. Tidigare studier på långtidspendlare har dock visat att pendling också kan föra med sig negativa konsekvenser för hälsa och välmående.

Syftet med detta avhandlingsarbete var att studera sambanden mellan olika typer av pendlingsätt och pendlingstider och hälsa och välmående. Vi ville också se om det fanns geografiska särdrag, och om dessa geografiska särdrag i så fall förändras över tid.

Studierna utgick ifrån de skånska folkhälsoenkäterna som skickats ut vart fjärde år (2000, 2004, 2008, 2012) till knappt 50,000 skåningar, varav dryga häften svarat vid varje tillfälle. Vi använde också data från deltagare år 2000 som fyllt i uppföljningsenkäter 2005 och 2010. I enkäterna frågades om ålder, kön, arbete, familjesituation, levnadsvanor, hälsa och välmående samt pendlingssätt och pendlingstid. Personer som var mellan 18-65 år, jobbade mer än 15 timmar i veckan och hade svarat på frågorna om hälsa och pendling valdes ut. Enkätdata kompletterades med registeruppgifter om inkomst, hem- och arbetsplatsadress. Utifrån adressuppgifter beräknades pendlingsavstånd och pendlingstid med hjälp av Geografiska Informations System (GIS).

Vi fann att bil- och kollektiv pendlare rapporterade lägre självskattad hälsa i jämförelse med aktiva pendlare (gående och cyklister). Förekomsten av låg självskattad hälsa och lågt välmående ökade med ökande pendlingstid. Bland kollektivpendlarna så mådde de som hade längre än en timmes pendling enkelväg

sämst. Bland bilpendlarna mådde de som pendlade 30-60 minuter sämst. En möjlig förklaring till detta skulle kunna vara att bilpendlare som har mer än 60 minuter enkelväg färdas i en lugnare trafikmiljö. Det är också en grupp som skiljer sig avseende socioekonomiska förhållanden.

En av våra studier fokuserade på bilpendlare som pendlade mellan 30-60 minuter enkel väg. Vi fann en högre förekomst av stress hos bilpendlare i sydvästra Skåne för åren 2000 och 2005. Mönstret var ändrat 2010. Då fanns högstressområdet i nordöstra Skåne. Sociodemografiska skillnader kunde inte förklara varför vi såg dessa skillnader och pendlingsmiljön (bilköer, hastighetsgränser, landskapet) är en trolig förklaring.

Socialt deltagande är en viktig aspekt av välmående och betraktas tillsammans med förtroende som en viktig del av det som kallas socialt kapital. Vi såg att det sociala deltagandet och generella förtroende för andra människor var lägre hos bilpendlare än hos kollektiv- och aktiva pendlare och minskade med ökande pendlingstid för bilpendlare. Men även kollektivpendlare som pendlade mer än en timme enkel väg hade lägre socialt deltagande.

Studierna i detta avhandlingsarbete är så kallade tvärsnittsstudier och det går därför inte att säkert veta om pendlingen lett till sämre hälsa och välmående eller om det är tvärtom. Resultaten kan därför inte användas för att bestämma orsakssamband.

När pendlingstiden ökar förlängs den totala arbetsdagen. Liksom man funnit i tidigare studier av pendling och hälsa såg vi att pendlingstid och färdsätt verkade påverka hälsan och välmående för pendlare i Skåne. Mindre ledig tid och sämre hälsa och välmående för pendlaren kan även få konsekvenser för pendlarens familj. Ökad pendling med bil och kollektivtrafik kan även få konsekvenser för samhället om det ger högre kostnader på grund av sämre hälsa och välmående och mindre möjligheter till samhällsengagemang och deltagande.

Abstract

In many western countries commuters are expected to daily travel long distances and durations in order to reach work. Commuting, daily travel between home and work, can be added to the total workday, and consumes a considerable part of the commuters' day.

The general aim of this thesis was to study how commuting is related to health and wellbeing in order to better understand the impact on public health. We used cross-sectional data from the Public Health Surveys in Scania which are large datasets containing self-reported information on socioeconomic status, gender, family situation, education, health related behaviour, health and wellbeing. Information about income, residential and workplace location was obtained from national registers for each individual commuter. Self-reported mode and duration were used to address commuting combined with individually calculated commuting distance and duration based on registry data and GIS.

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Few studies with similar sample size have studied the associations between commuting and wellbeing and social capital. Spatial heterogeneity in the association between car commuting and stress highlighted the importance of considering geographical context and changes in commuting mode and duration over time.

The results are in concordance with prior research and we found supporting evidence for the existence of a so-called commuting paradox, that is, commuters are not fully compensated for longer commuting time. Reduced health and wellbeing among commuters can potentially lead to large economic cost through more sick leaves and increased demand for health care.

Abbreviations

BMI – Body Mass Index

GIS – Geographical Information Systems

GWP – Geographically Weighted Proportions

PHS – Public Health Surveys in Scania

PHSC – Public Health Scania Cohort

POR – Prevalence Odds Ratio

PR – Prevalence Ratio

Introduction

The commuting paradox

Streets, sidewalks, bicycle lanes and railways run like veins through populated parts of the world. People travel along these paths every day in order to reach the locations at which they conduct their daily activities. Commuting, travel between home and work, is one of the most common reasons for travelling along these networks [1]. In line with political and economic initiatives to increase the size of local labour markets to generate wealth through a more flexible workforce, the duration of commuting times is increasing in most western countries [2]. According to economic theories, commuters are expected to be compensated for the time loss during the commute with higher salaries or better housing [3, 4]. If this were the case, and also lead to increased wellbeing, commuters working far from home would have the same health status and experience the same level of wellbeing as commuters living closer to their work. However, studies have shown that this does not seem to be the case [3, 5-9]. Long commutes not only consume time but also generate additional costs, for transportation may be stressful and interfere with work-family balance [3, 10]. Stutzer and Frey refer to this phenomenon as the commuting paradox [3]. Commuters who travel long durations and are not compensated with a better life have to carry this burden. It is not only the commuter that may be affected but also the commuter's social networks [11, 12]. Partners, family and friends of the commuter are obligated to take a larger responsibility for home care and children, and in cases where this is not possible the quality of life for the commuter and their social network will suffer [10, 13]. This will not only have an effect on the individual commuter with family and friends, but society will also have to carry the burden of unhealthy commuting as well. Studies have shown increased sick leaves and absence from work is associated with commuting mode and time [14, 15]. Decreased health and wellbeing will use health care system resources, and can potentially have a significant economic impact. In order to understand these implications and the costs for society we need to understand the connection between commuting and health and wellbeing.

How do people commute?

People all over the world need to go to work. Commuting refers to the trip between home and work, but in statistics and studies about commuting different definitions of commuting exist. According to, for example, Statistics Sweden workers who live in one municipality and work in another are considered to be commuters [16]. In this thesis, we define commuting as everyday travel between home and work independent of the distance, duration or mode.

Commuters use different modes of travel such as walking, cycling, driving or public transportation (bus or train). Modes that require physical activity are often referred to as "active commuting" and include e.g. walking or cycling. Motorized modes that do not require high levels of physical activity are referred to as "passive commuting" and include driving or riding in a car and taking the bus or train. The commute consists of one or more of these modes and can have different levels of complexity depending on the number of transfers. Transfers can include shifts between different modes, e.g. walking to the bus, driving to a parking lot and continuing as a passenger in a different car, but also transitions within the same mode such as transferring buses. Public transportation commuting is generally more complex than active and car commuting since walking or cycling to a bus stop or a train station is usually part of the trip, as well as transfers between buses and trains.

Commuting mode share differs between countries, but in all western countries, to various levels, car commuting is the dominant mode. In Sweden, national statistics about mode share for daily commuting between home and work are hard to find. The national travel survey uses a definition of commuters that is similar to our definition, but also includes school and business trips. In Sweden in 2011, the car was the dominant mode, followed by active and public transportation, which is shown in Figure 1 [17].

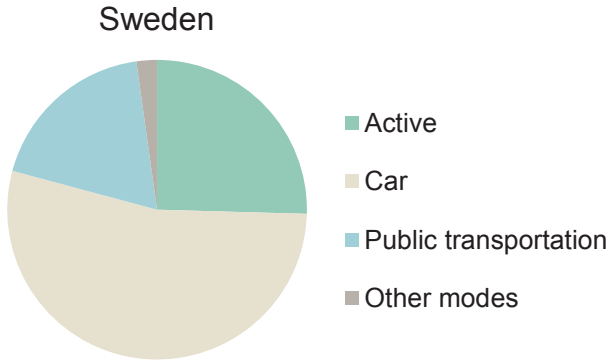

Figure 1:
Commuting mode share in Sweden according to the Swedish National Travel Survey in 2011.

In the US, population density is lower than in Europe, and people living there are more car dependent [18]. According to the United States Census Bureau a majority of all Americans commuted by car in 2013 [19]. Mode share for other modes is shown in Figure 2. Australia and Canada are other examples of car dependent societies with similar statistics [20, 21].

The United Kingdom is a European country that just like the North American countries can be considered to be car dependent [22]. The mode shares of commuters in England and Wales in 2011 are shown in Figure 2 [23]. The mode share pattern varied regionally and the London region deviated strongest from the average with less than one third of the commuters using cars (31 %).

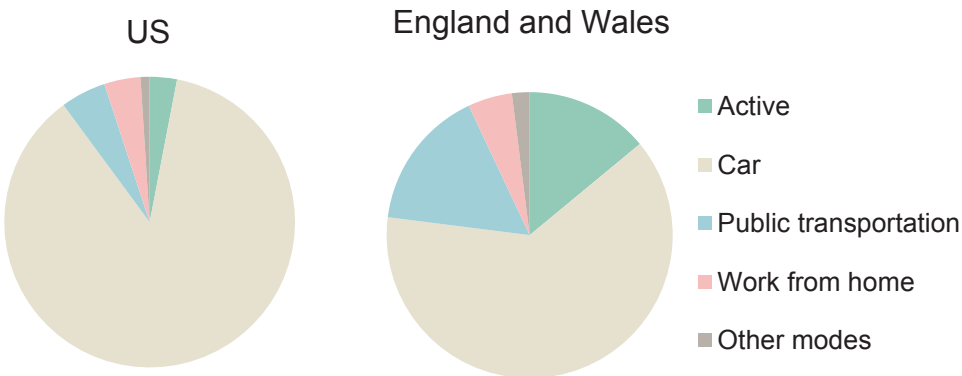

Figure 2:
Commuting mode share in US in 2013 and England and Wales 2011.

The Netherlands is considered to be the leading country in the world in using the bicycle as a mean of transportation [24]. A third (29 %) of all commuter trips in the Netherlands are made using active modes of transportation (Figure 3) [25]

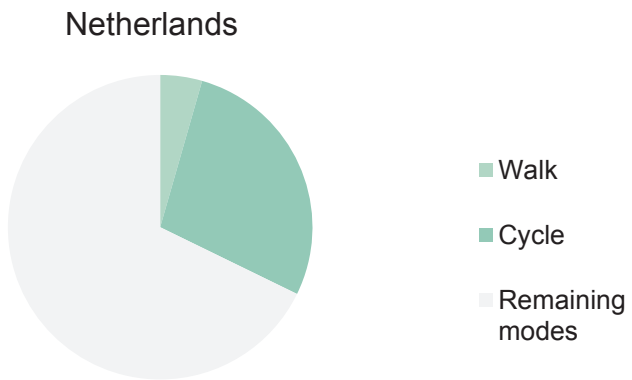

Figure 3:
Commuting mode share of active commuters in the Netherlands.

Duration and distance are other aspects of the commute that are important. In Sweden, both commuting distance and duration are increasing according to the national travel survey [17, 26] (Figure 4).

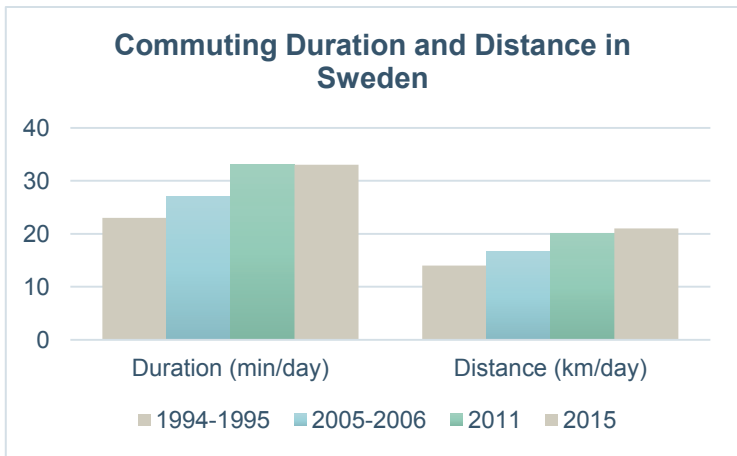

Figure 4:
Daily average of commuting duration and distance in Sweden from 1994-1995 to 2015 according to the National travel survey.

Stutzer and Frey compared commuting duration between European countries in 2000 and the US in 2002 [3]. Commuting duration ranged from 51 min in Hungary to 29 min in Portugal. Both average commuting distance and duration have increased in many countries such as the US, Spain, Netherlands and Italy [27, 28]. In the Netherlands, commuting distances has increased by 23 % and commuting durations by 17 % over the time period 1993 to 2005 [18].

Commuting patterns vary on a national as well as, on regional and local levels. The average commuting duration in Canada in 2010 was 52 min per day overall [21]. In smaller metropolitan areas the average was 38 min but 60 min per day in larger metropolitan areas (more than 1 million inhabitants). Commuters in larger metropolitan areas commuting by car on average spent 54 min while public transportation commuters spent 92 min, although the average distance was longer for car commuters.

As well as differences in mode share, distance and duration between different geographic areas' traffic intensity varies over the day and along with this the commuting duration. During peak hours, more congestion occurs which increases the commuting duration. Taking Sweden as an example, there is a clear peak between 7 and 8 am in the morning and 4 to 5 pm during workdays. More than five times as many trips are conducted in the morning and three times as many in the afternoon when compared to lunch hours (12 am to 1 pm) [29]. Dewulf et al. studied differences in commuting duration in Flanders, Belgium and found that the difference between peak and off-peak hours were high between cities and low within, showing the importance of geographical context [30]. The average for commuting trips in all of Flanders with a car was 21 min off-peak and 25 min during peak hours. Commuting duration for public transportation was lower than for cars during peak hours but higher during off-peak hours.

Most commuters change some aspect of their commute over the course of a life time, that is, commuting patterns are not static over time both on the individual and societal level [22]. Changes in commutes can occur due to shifts in residential or workplace location, but also due to a shift of mode.

Sociodemographic differences

Commuting patterns do not look the same for different sociodemographic groups. Men and women do not commute in the same way. In Sweden in 2005/2006, men on average commuted a distance of 16.6 km and women 13.7 km [26]. The duration independent of gender was 27 min, showing that men commuted at a faster pace. In Sweden, the car is the dominant mode for both men and women, but women use active and public transportation to a greater degree [17]. Car commuting was more common among older workers in US [19]. Commuters

living inside cities used the car to a lesser extent (78 %) than those living outside cities (89 % outside metro area; 91 % outside principal city in metro area). Native-born people drove alone to a higher degree (79 %) than those who were foreign born (65 %).

The commuting experience

The experience of travel can be both positive and negative [31]. But commuting has been rated as one of the least enjoyable daily activities [32]. Relatively few studies have been conducted on the affective appraisal of the commute but the experience of stress is the one that has been most studied [33]. Some of the negative feelings that could be experienced are stress, boredom, not feeling relaxed, not having control and not feeling free. Anable and Gaterleben compared how commuters using different modes rated instrumental aspects (flexibility, convenience, cost, predictability, environment, health) and affective aspects (relaxation, freedom, stress, control, excitement) [33]. They found that overall instrumental aspects and especially convenience were more important than affective aspects.

However, not all workers experience their commute as negative. Olsson et al. found that positive feelings were more common than negative ones during the commute in a Swedish study population including active, car and public transportation commuters [34]. Similar results were found in a report by Statistics Canada where more Canadian workers liked their commute (38 %) than disliked it (30 %) [35].

An important aspect of how commuters feel about their commute is how they make use of the time. Time spent on different activities during commuting was studied among British railway commuters in a cross-sectional follow-up between 2004 and 2010 [36]. Reading was the most common activity, followed by window gazing and working. Working along with text messaging and answering emails were the activities for which fewest felt that they had wasted their time. Window gazing and sleeping, on the other hand, were the two activities considered to be the greatest waste of time. There was an improvement over time in how the commuters made use of their commute. Some commuters seem to be able to use their time for something useful but many might not. Overall 24 % of the commuters in 2004 thought they wasted their time and 16 % in 2010. Increased use of mobile devices could be a possible explanation for this [36].

The experience of the commute could also be related to external constraints given by employment. Commuters being able to use flex-time had lower driver-stress

levels and less feelings of time-urgency [37]. Similar constraints can emerge from social engagements or family responsibilities.

In transportation planning and in studies investigating the experience of commuting, travel time in itself is seen as a cost [33]. The ideal commuting duration has been studied among commuters in San Francisco, US. and was found to be between 10 to 24 minutes among three fourths of the study sample [1]. Mode was not stated in the study, but it is likely that there was a large majority of car commuters. Many commuters experienced their commute as too long (52 %), although there were also commuters that considered their commute to be too short (7 %). Some of the activities that could explain this positive utility (satisfaction with the trip) could be related to opportunities for social interaction, time for reading, working, or planning the workday, benefitting from a transition period between home and work, enjoying the scenic view, driving a high-status car [1, 36, 38].

Commuting and stress

The concept of stress is very complex and there are many different ways of conceptualizing stress [7]. Concern about how stress is associated with commuting has existed for decades [39-42].

In this thesis, we have used a model created by Koslowsky et al. as a framework in our understanding of stress related to commuting [43].

The commuter is exposed to a number of objective stressors during the commute. These stressors are related to and stem from the environment and include, e.g. noise, air pollution, congestion [44], temperature [43], crowding [45], unpredictability [46], lack of control [47] and delays. The commuter's experience of stress depends upon how sensitive the commuter is and how well the commuter can cope with the stressors he or she experiences. The sensitivity of the commuter depends on personality, health, life situation and expectations of the commuter. Different personality types are prone to feeling stressed and a sense of experiencing a lack of time to different extents [48]. Expectations that can lead to stress arise, for instance, if the commuter has an important meeting to attend or needs to get home in time to pick up children at school. Coping ability of the commuter is related to the way the commuter prepares for the commute and is able to use the time during the commute. If the commuter has a well-balanced life situation with physical activity, recovery and good sleep he or she will be better prepared to handle stress [43]. Chronic stress is a risk factor in regard to future bad health and diseases, and can lead to more severe impacts on wellbeing [49].

Many of the prior studies have focused on car commuters' experience of stress, but other modes has been studied as well. Wener and Evans studied the association between car and train commuting and stress and negative mood among commuters in New York. They found that car commuters experience more stress and negative mood than train commuters [50]. Gaterleben and Uzzell found similar results in the UK [51]. They found that car commuting was experienced as more stressful due to delays and other road users, while public transportation commuters were more prone to feel bored.

Time lost due to the commute

As well as being exposed to a number of stressors during the commute, the commuter loses time that could be spent on more health beneficial activities such as training, relaxing, social participation or sleeping. The time loss during commuting has been found to be negative for health and wellbeing [9]. In a study from urban counties in the US, the loss in time spent on health-related activities due to commuting was investigated [52]. Commuters, mainly car commuters (93 %), were divided into categories based on durations of 30, 60, 90, 120, 150 and 180 minutes total commuting time in a day. Sleeping was the activity where most time was lost; by about 30 % for all commute categories. Physical activity was the second most affected health-related activity, ranging from 12 % among those having a commute of 30 min to 20 % among those having a commute longer than 120 min.

Commuter health and wellbeing

The association between commuting and health and wellbeing has lately received more and more attention [53]. Associations with both negative and positive measures of health and wellbeing have been found, in relation to commuting mode and duration [9, 43, 54].

Unhealthy commuting

In a study from London, two dimensions, positive and negative aspects of wellbeing were assessed and compared to different modes of commuting, adjusting for commuting distance [53]. Self-rated life satisfaction was used for positive aspects, and mental distress for negative aspects. Walking was found to be positively associated with higher life satisfaction compared to driving. The study

also found that connectivity for public transportation, that is, public transportation network density, was negatively associated with high mental stress among commuters using public transportation. Other studies have also found associations between commuting and health [9, 27, 55]. Mauss et al. studied both physical and mental health among 3805 industrial workers in southern Germany [56]. They did not find any association between duration and health except for waist circumference. The study did not consider mode of commuting. There are also studies that did not find any associations between commuting and mental wellbeing indicating that more research is needed in order to understand the association [57, 58].

Long duration commuters have a longer total workday, and are likely to have less time for sleep. It is well known that sleep is important for health; short sleep duration has been found to be associated with higher mortality, hypertension, cardiovascular disease, diabetes and obesity [59]. Walsleben et al. studied sleeping disorders among railway commuters in New York [60]. They found that long duration commuters slept less during weekdays compared to short duration commuters, and that the long duration commuters tried to compensate for this on the weekends by sleeping longer. Long duration commuters also had a stronger association with self-reported hypertension.

Physiological reactions have also been measured as an effect of commuting. Schaeffer et al. found that car commuters travelling at a lower speed (<32 km/h) had higher blood pressure than commuters travelling at higher speeds [61]. Further they found that single drivers were more hostile and anxious directly after the commute compared to car-poolers. The analysis included 26 solo drivers and 17 carpooling commuters.

Primarily car commuters, but also commuters using public transportation spend a large part of their commute sitting, which can be negative for their health. The evidence that sedentary time is negative for health is strong. Review papers have shown sedentary behaviour to be associated with all-cause mortality, cancer, diabetes, cardiovascular disease and weight gain [62-64]. An Australian study of car commuters showed that those who used the car on a daily basis over a four year period gained about two kilograms in weight, while commuters not using or occasionally using the car did not have any statistically significant weight gains [65].

Active commuting inside cities often takes place close to roads with high levels of air pollution. These levels often peak during morning rush hours when commuters are travelling to work. The physical activity carried out under this type of commuting further increase the inhalation of air pollution. Exposure to air pollution during commuting has been studied in a review paper by Bigazzi and Figliozzi [66].

Commuting even seems to have an effect on mortality. Sandow et al. conducted a longitudinal register-based survival analysis on 2,700 Swedish long-distance commuters [67]. They calculated survival rate for long-distance commuters (defined as having at least 50 km Euclidean distance between home and work) and matched controls. Female long-distance commuters had a lower survival rate, especially women with a lower education and income. In contrast, male long-distance commuters did not have a lower survival rate compared to the reference group. Thus, there seems to be a gender related difference in the burden of commuting.

Healthy commuting

The positive effects of active commuting have been studied rather well [27, 53]. Active commuting is considered to be the healthiest type of commute. Through active commuting, the level of physical activity increases which in its turn can have a positive effect on health. In a review paper Oja et al. studied health benefits from cycling [54]. Based on four intervention studies, they found strong evidence for improved cardiorespiratory fitness. A meta-analysis including only prospective studies investigated the connection between active commuting and the protective effect against cardiovascular disease [68]. Based on 173,146 participants in eight prior studies (mainly from Finland) they found an overall reduction of 11 % in cardiovascular risk (mortality, incident coronary heart disease, stroke, hypertension and diabetes). Further they also found that the protective effect was greater among women than among men. Mytton et al. found a positive association with better mental health, but not with physical health, among commuters that maintained commuting by bike [69].

Social participation and work-family balance

Stress and loss of time occurring during and due to the commute can have a negative impact on social participation and the number of socially oriented trips declined due to longer commuting duration [11]. Delmelle et al. found lower satisfaction with social contacts among commuters in Vienna [70]. Other studies have found similar results [71, 72]. This decline in social participation can have implications both for the individual and for society. For instance, Newman et al. found that time spent commuting was negatively associated with political participation [73]. Long duration commuting has also been found to be associated with lower trust in general [74]. Both social participation and general trust are indicators of social capital, which is a resource for society, just as economic or

cultural capital. The foundation of social capital is the network through which trust and reciprocity are formed and a decrease in social capital can have severe implications for the society [75, 76]. According to the American political scientist Robert Putnam, the deterioration of social capital in the US since the 1960s can partly be explained by the increased use of the car [77]. Social capital has been described by the World Bank as "the glue that holds societies together and without which there can be no economic growth or human well-being" [78]. A low level of social capital has been associated with tax evasion, low levels of political engagement, poor educational performance and bad health [76, 77]. Public transportation per se includes interaction with other people as does to some extent, active commuting.

As commuters spending time away from home seem to have lower wellbeing, the commuter's family may also be affected. Sandow studied the possible implications on partner relationship among commuters in Sweden and found higher separation rates among long-distance commuters [10]. The pattern differed between men and women. Among long-distance commuting men, separation rates increased for long-distance commuting if this type of commute had been ongoing for less than five years. While for long-distance commuting women the separation rates increased if the long-distance commute had been ongoing longer than five years.

The children of commuters could also be affected by the parents being stressed and not having time for them. Only a few studies have investigated this. In a German study, Jianghong and Pollmann-Schult studied how fathers' commuting duration affected their children [13]. They found that a longer duration time of commuting was associated with lower quality relations between fathers and their children along with more emotional symptoms and hyperactivity among the children.

Commuting and ability to work

Commuting seems, as presented above, to have a negative effect on health due to stress and loss of time for health beneficial activities. It is therefore reasonable to believe that absenteeism and sick leave would be more prevalent among commuters that experience a negative impact on their health. Absenteeism has been found to be higher among German long duration commuters [14]. The authors stated that excluding the effect of commuting would lower absenteeism from work due to illness by 15-20 %. Mytton et al. studied cycling and sick leave longitudinally and found that commuters who bicycled had lower levels of absenteeism due to illness corresponding to about one day less per year [69]. Karlström and Isacsson studied long-term sick-leaves (more than 14 days per year)

in a large register-based study (1.7 million observations) [15]. They did not find an association between long-distance commuting and sick leave in adjusted models, but observed a positive association in subgroup analyses of women and men with low income. The retirement age of commuters in relation to distance and duration have been studied in two prior studies [79, 80]. Chapela found 1.6 years later retirement age among male commuters in US with more than 5 min to work compared with those with less (working from home or having very close to work) [80]. In the second study the timing of age of retirement in a Swedish register-based was analysed [79]. Long-distance commuting men with high education were found to retire earlier while no such association was found for women.

Gender differences

Commuting patterns differ between men and women (Section Sociodemographic differences). Women and men also have different expectations and responsibilities that influence their mobility [81]. Women are often the primary caregivers and take greater responsibilities for children and housework. This means that if employed women take on more responsibility at home and at the same time need to commute for long periods of time they will have little spare time left for themselves. This would likely also have a negative effect on health and wellbeing as less time is left for recovery [81].

Feng and Boyle used a panel survey with 5,216 respondents between 1991-2006 to study self-rated general health among commuters [2]. They found that women commuting more than 30 min by car and more than 60 min by public transportation experienced lower self-rated health, but not men. Further, female car commuters living with children had a 2.6 higher risk of experiencing bad health, compared with women living without children. Roberts et al. 2011 found that commuting was associated with lower psychological health in women, but not men, and also argues that responsibilities at home and taking care of children could be a plausible explanation [27]. Long duration commuting also seems to have impact on women's mortality [67].

The importance of geographical context

The stressors that commuters are exposed to are dependent on the geographical context and important for how the commuter experiences the commute. Commuting in urban areas is often associated with congestion. Driving in

congested areas exposes the commuter to time delays and feelings of lack of control, adding to the experience of stress [43]. High levels of congestion can also increase the exposure to air pollutants, especially in high density urban areas. Karanasiou et al. conducted a review on exposure to air pollution for particulate matter and black carbon when travelling and concluded that geographical context is important for all modes in relation to how much pollutants are inhaled [82]. For cyclists, the placement of the bicycle lane in relation to other traffic is a very important component. For car commuters the ambient air quality, linked to traffic intensity, is important to how much air pollutants the commuters inhale. They also found that for public transportation users, exposure varied among different metro systems. Noise exposure in environments where people commute also varies from a background stimulus to a noxious stimuli between different areas [43].

The level of service, and thus flexibility and control, for public transportation is often better in urban areas, but differs between and within cities. Numbers of passengers, risk for delays and quality of buses and trains are important variables in the experience of the transit commute, which varies from place to place. The experience of the outdoor environment when looking through the window of the bus or car could also have an effect on how the commuters experience the commute [1].

Prior studies have found differences in the association between commuting and health and social participation due to the geographical context [10, 53, 70]. Chng et al. studied if connectivity affected the association between self-rated health and commuting in London. They found that commuters living in neighbourhoods with better connectivity for public transportation were less likely to have lower level of mental health. The association between social satisfaction and commuting has also been found to differ between neighbourhoods in Vienna [70]. Neighbourhoods with higher levels of service for public transportation and higher car ownership were found to be associated with higher levels of social satisfaction among commuters.

Determinants of commuting mode choice

In order to get commuters to switch to healthier modes of commuting, it is important to understand what factors influence mode choice. A review investigating intervention studies trying to reduce car use showed that many interventions did not succeed [83]. This suggests that our understanding of people's mode choice is incomplete.

Commuters' mode choice is complex, and there are a number of factors that influence the decision connected both to the commuting environment and individual factors but also their relationship to each other [84]. The environment in which the commute takes place is important and can be divided into three categories of determinants: sociodemographic attributes, travel characteristics and geographical context [85]. Sociodemographic variables such as family situation and economy are important mode choice determinants. Having to pick up children at school after work could increase the chance of the commuter choosing to use a car, while having insufficient income to afford a car would limit the choice to active or public transportation [86]. Little is known about how health status influences the mode choice of commuters and it is possible that health status is one of the missing pieces in understanding commuter's choices of mode.

Travel characteristics are related to the commuting trip itself, for instance, distance, duration and the quality of the trip. Geographical context refers to environmental factors such as population density, accessibility to public transportation and availability of parking. Population density is an important measure associated with commuting mode. High population density is important for both public and active transportation. For buses and trains a minimum number of passengers are needed. Access to transit stations is also important for getting commuters to choose public transportation. Bicycle lanes and sidewalks are often extensive within cities, which invites more active transportation. The spatial location of residences, workplaces and shops are also determinants of commuter mode choice [87].

How the commuter evaluates the environmental factors and acts upon them is also determined by perception, experience and habits [88]. Some of these socio-psychological factors could increase or decrease the likelihood of the commuter choosing one mode or the other. Other factors could set limits for the choices that are available, i.e. not being able to afford buying a car. Also, health could be a limiting factor. Thus, the relationship between health and wellbeing and commuting is bi-directional and has to be understood as a dynamic system.

Implications of commuting on society

In order to have sustainable development it is necessary to provide a good liveable environment where people can live and work [89, 90]. Providing people with an attractive environment promoting growth, life quality and accessibility to activities is crucial. In order to do so, it is important to coordinate the planning and building of infrastructure and green structure [89]. The mode choice of travellers has been highlighted as important in regional strategies in order to be able to achieve

sustainability [89, 91]. According to the Bicycle strategy for Scania, the county would be able to save 1.8 billion SEK each year due to improved public health if the total share of trips by bike increased from 16 % to 19 % [91]. Increased physical activity and healthier living environments through reductions in noise and air pollution are pointed out as reasons for the cost reduction. Exposure to noise and air pollutions from traffic in urban environments constitute a considerable threat to public health [92-97].

In order to create a more sustainable and healthy society, it is not only important to encourage commuters to switch to active modes of commuting but also to improve the commuting environment for those using passive commuting modes [90]. The potential for saving resources and improving the life quality of commuters is even greater if the reduction in stress, sleep disturbance and wellbeing that passive commuters such as car and public transportation users experience is considered [89]. Commuting is one of the most common reasons for traveling [1] and changing commuter mode choices to more healthy modes is therefore a key challenge in improving public health in relation to transportation. Equally important is to understand how the commuting trip in itself is affecting health and wellbeing and possibilities for social participation.

Aims

The general aim of this thesis was to study how commuting is related to health and wellbeing in order to better understand the impact on public health. The specific aims of the papers were to:

1. study associations between commuting (duration and mode) and health and wellbeing (Paper 1)
2. study associations between commuting (duration and mode) and social capital (Paper 2)
3. investigate spatial heterogeneity in stress levels among 30-60 min car commuters and changes over time (Paper 3)
4. study associations between commuter's health status and commuting mode choice (Paper 4)

Material and Methods

This chapter describes material and methods in the four papers included in the thesis. In brief, self-reported information on outcome, exposure and covariates originated from the Public Health questionnaire Scania (PHS). In addition to this, register data from Statistics Sweden on income, occupational status, work and home location were used. Logistic regression and Poisson regression, considered to be more traditional methods in biostatistics, were used in papers I and II. In paper III spatial statistics were introduced, and in paper IV statistical methods often used in transportation research were added.

Study area

The study area was Scania, the southernmost county in Sweden. In 2000, when the first data were collected, Scania had a population of 1.13 million which increased to 1.30 million by 2015 [98]. The population is centred towards the west coast. The largest city in the county is Malmö which had a population of 259,579 in 2000, increasing to 322,574 in 2015. Other main cities in the county are Lund, Helsingborg, and Kristianstad (Figure 5). The number of gainfully employed in Scania between 16-64 years old increased from 482,831 (48% women) in 2000 to 540,096 (49% women) in 2012. Scania is the gateway to Sweden from Europe via land. Public transportation is well developed but there is a lack of capacity for trains and future investments are needed [99]. Active commuting is popular in Scania as a large part of the population live in the flat south western parts of the county. In 2000 the Öresund bridge was completed, connecting Malmö and the Danish capital Copenhagen. At its opening in 2000, 4,600 persons commuted between Sweden and Denmark, increasing to15,000-20,000 daily commuters at present [100]. A large majority of the commuters live in Sweden and work in Denmark.

Figure 5:
The figure shows the study area Scania. Major cities and roads and the two local labour market areas in 2010. The population and road infrasturcture is centred towards the west coast.

Source population

The primary datasets originate from the Public Health surveys in Scania (PHS) performed by the division of Social Medicine and Global Health, Lund University and the Unit of Public Health and Social Sustainability, Region Skåne in collaboration with The Swedish Association of Local Authorities (2000, 2004, 2008, 2012) and the Region Skåne Regional Social Insurance Office (2000, 2004). PHS is a questionnaire that has been sent to residents in Scania every fourth year since 2000 in order to map public health status (Figure 6). The questionnaire consisted of more than 130 questions including information on socioeconomic status, gender, family situation, education, health related behaviour, health and commuting. The survey was performed in 1999/2000, 2004, 2008 and 2012 (in order to simplify the designation of the 1999/2000 questionnaire it will be referred to as 2000). People registered in Scania aged 18-80 were eligible. The selection procedure for participants was stratified spatially with a stratum containing 200 men and 200 women in each municipality and with additional strata in the larger cities of Malmö, Lund, Helsingborg and Kristianstad. The number of people eligible, participants and response rate each year are given in Table 1.

Table 1.
Number of questionnaires sent out each year and number of participants answering (PHS data set).

	2000	2004	2008	2012
Source population	24,922	47,621	52,142	56,600
Participants answering	13,604	27,963	28,198	28,029
Response rate	55 %	59 %	54 %	50 %

In 2005 and 2010 follow-up questionnaires were sent to all participants in the PHS from 2000 (Figure 6). The Public Health Scania Cohort (PHSC) was collected by the Division of Social Medicine and Global Health. This dataset is thus longitudinal. In total, 8,206 individuals answered the questionnaires at all three time points.

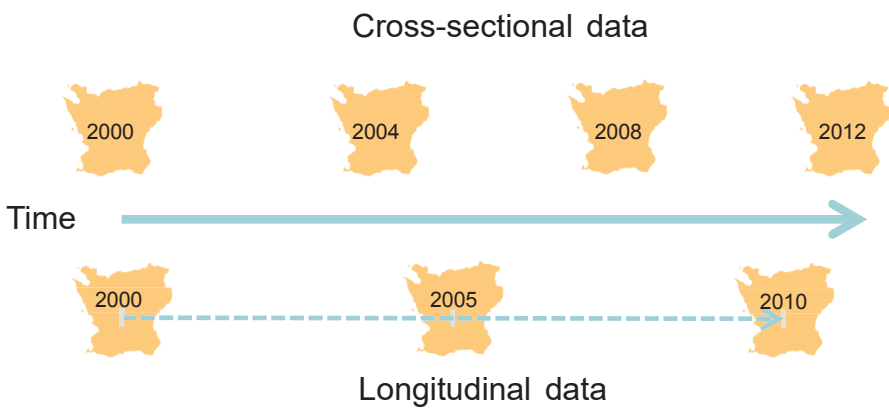

Figure 6:
Survey years for PHS and PHSC.

In papers I and II, respondents from 2004 and 2008 were combined into one source population. Respondents aged 18-65 years, working more than 30 hours per week, and answering questions about commuting, were selected as the study population. For paper III, respondents that had answered the questionnaire at all three time points were used as the source population. Respondents aged 18-65, years, working 15-60 hours/week, commuting 30-60 min by car, and with residential and workplace locations inside Scania were selected as the study population at each cross-section. For paper IV the PHS in 2012 was used as the source population. Respondents 18-65 years, working 15-60 hours per week, answering the question about commuting mode with residential and workplace locations inside Scania were selected as the study population. An overview of the data used in the papers is given in Figure 6.

Commuting mode, distance and duration

Self-reported commuting mode and duration were used to address commuting. Commuting mode was obtained with the question, "How do you usually get to work?" with the alternatives walking, biking, car, bus, train, and other. Multiple alternatives could be chosen. These alternatives were classified into three categories active, car and public transportation. Priority was given to the least flexible mode in the classification. Active commuting included only walking or cycling. Car commuting included those only using car or car and any of the active modes. Public commuting included all those answering train or bus, independent of whether they also used the car or active modes. Commuting duration was obtained with the question, "How much time does it take to get to work (single journey)?" Six response alternatives were available 1) less than 15 min 2) 15-30 min 3) 30-60 min 4) 1 to 1.5 hours 5) 1.5-2 hours 6) more than 2 hours. These alternatives were recoded into three categories 1) less than 30 min 2) 30-60 min 3) more than 1 hour.

These two questions were combined into a common measure of exposure in papers I and II consisting of seven categories; 1) Active (walk and bicycled) less than 30 min 2) Car less than 30 min 3) Car 30-60 min 4) Car more than 60 min 5) Public transportation (bus or train) less than 30 min 6) Public transportation 30-60 min 7) Public transportation more than 60 min.

In paper III, distance was used in addition to self-reported duration in PHS in order to give a detailed measure of distance within the category 30-60 min car commuters. Euclidean distance was calculated based on residential and workplace locations. Calculating commuting distance between home and work enabled a finer differentiation of the extent of the commute for these commuters. Depending on the level of congestion, the same commute duration could be associated with varying distances between home and work.

In paper IV, Google directions API [101] was used to calculate mode specific distance and duration between home and workplace. A real-time update of the traffic situation at 8:00 am on November 28, 2012 was used to estimate a representative value for travel time during the period when PHS 2012 was collected. Distance was used as the measure of travel cost for active commuters and duration for car and public transportation commuters.

Measures of health

In order to study health as a broad concept, a number of indicators were selected based on questions in PHS and PHSC. This means that our way of addressing health was restrained by the way public health authorities and researchers in Scania from 1999 and onwards conceptually perceived and measured health. A large number of health measures were available through the questionnaires. Health measures in the present studies were selected based on having a presumed short latency time, which is to occur in close relation to the exposure, prerequisite for studying associations in cross-sectional study designs.

Everyday stress: Everyday stress was measured with the question, "Do you often feel stressed in your everyday life?" The question had three response alternatives: 1) Yes, often 2) Yes, sometimes 3) No, never. This question was dichotomized into Stressed (1) and Not stressed (2, 3). The strict cut-off was selected to capture only those that perceived higher levels of stress as moderate stress is less likely to cause a negative impact on wellbeing.

Perceived sleep: Sleep quality was measured with the question, "Do you think you get enough sleep to feel rested?" with the following alternatives 1) Yes, in general 2) Yes, but not often enough 3) No, never or almost never. A strict cut-off was used for the same reason as for stress and dichotomized into Good perceived sleep quality (1, 2) and Poor perceived sleep quality (3).

Exhaustion: The Swedish SF-36 vitality scale was used to measure vitality [102]. The cut-off value was selected based on an earlier Swedish study measuring diurnal salivary cortisol secretion and exhaustion with the Swedish SF-36 vitality scale [103]. For a detailed description of the classification of exhaustion see paper I.

Mental health: The GHQ12 instrument was used to measure mental health. GHQ12 is a well-known screening instrument for early signs of mental health [104]. The measure consists of 12 questions and if three or more of the items were rated on the negative scale the respondent were classified as having a low mental level of health. For a detailed description see paper I.

Self-rated health: Was measured with the question, "How do you feel right now, physically and psychologically considering your health and wellbeing?" The respondent answered on a seven-point scale from "Could not have been worse" to "Could not have been better". This variable was dichotomised with answers lower than five rated as low self-rated health. This cut-off was chosen on the theoretical assumption that commuting would be associated with the absence of feeling well, rather than feeling really bad. Self-rating is one of the most frequently used

measures for health [105]. Many studies have shown that self-rated health is a good predictor of morbidity and mortality [106, 107].

Sickness absence: The respondent was asked about the number of days of absence due to illness during the past year, with cut-offs for 0, 5 and 15 days. These cut-off values correspond to the ones used by the public sector in Sweden as indictors of low sickness absence [108].

BMI: Body mass index was calculated based on self-reported weight and height of the commuter and dichotomized into Not being obese (BMI < 30) and Obese (BMI ≥ 30).

Having difficulty walking: This was addressed with the question, "Can you take a shorter walk (about five min) at a moderate pace?" Respondents answering no were classified as having difficulty walking.

Long-standing illness: This was addressed with the questions, "Do you have a long-standing health condition, discomfort an after accident, disability or other long term health condition?" followed by "Does this condition lower your work performance or obstruct you in your daily activities?" with the following alternatives 1) No, not at all 2) Yes, to some extent 3) Yes. Respondents answering yes to the first question and Yes, to some extent or Yes on the second question were classified as having a long-standing illness.

Measures of social capital

Social capital is a resource that emerges from interaction in social networks and can be used for solving problems of an individual and collective nature. Many prior studies have investigated the association between social capital and health and found associations with higher mortality, self-rated health and low mental health [109-111]. The foundation of social capital is the network through which trust and reciprocity are formed [75, 76]. Social capital can be characterised in terms of structural and cognitive components [112]. The cognitive part is formed through participation in social activities [113]. In this thesis, the structural part of social capital was measured as social participation in a number of activities and the cognitive part was measured as general trust in others.

Social participation: The structural part of social capital was measured with a question about how many of different types of formal and informal groups the commuter had participated in during the last 12 months (study circle or course at work, study circle private, union meeting, association meeting, theatre/cinema, art exhibition, religious gathering, sport event, submitted letter to a newspaper, rally, nightclub or similar, family gathering, private party, none of the above). This

question has previously been considered relevant in the Swedish context [114]. Respondents that participated in more than three activities were classified has having a high level of social participation and three or less as low [115].

General trust in other people: The cognitive part of social capital was measured with the question, “Can you trust most people?” The answers were dichotomized into Low general trust in others (disagree completely, and disagree) and High general trust (completely agree, and agree). Prior studies have used similar ways of measuring social capital [116].

Covariates

Most covariates were obtained from PHS and PHSC. These included sex, age, place, of birth, education, cohabiting, having children living at home, job strain, problems in paying bills, history of unemployment, overtime work, working inconvenient working hours, part-time employment, job satisfaction and neighbourhood connection. Many of these are standard questions and the individual papers provide detailed descriptions of the categorization. Other questions are presented below.

Job strain: This was assessed using JCQ (Job Content Questionnaire). The cut-offs for physiological demand and degree of control were set to the median for each of the two survey years [8]. Those having high physiological demands and a low degree of control were classified as experiencing job strain.

Financial stress: This was measured with the question, “How often during the past 12 months have you had difficulties paying your bills?” The four response alternatives were 1) Every month 2) About half of the months 3) A few times 4) Never, were entered as a categorical variable.

Job satisfaction: This was measured with the question, “Is the company/workplace that you work at today the one that you wish to work for in the future?” The alternatives were yes and no.

Neighbourhood connection: this was measured with the question, “Do you feel rooted and have a strong sense of belonging with your residential area?” Four alternatives were available 1) To a high degree 2) To some extent 3) Not especially 4) Not at all. The answers were dichotomized as high degree versus all other alternatives.

In addition to self-reported data register information was added to the individual commuter record. The register information included occupational status, income,

residential location and work place location. All register data originate from Statistics Sweden.

In papers I and II the same set of covariates were included to adjust for confounding. The covariates were added in two steps in order to first adjust for fundamental sociodemographic characteristics (i.e. sex, age and education) and were more likely to be set long before the commuting started. In the second step, covariates more likely related to the present situation (i.e. over time work, having children living at home and job strain) were added.

In paper III proportions of covariates were used in comparisons between high and low stress areas to the rest of the county.

In paper IV health indicators were used as determinants and not as outcomes. We first added indicators of the geographical context and commuting characteristics for each individual commuter. In the second step we added sociodemographic indicators related to the individual situation and in the last step we added health indicators.

Material and methods for individual papers

Paper I

Title: Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden

Aim: Study associations between commuting (duration and mode) and health and wellbeing.

Study population: Participants (N=21,088) from the PHS 2004 and 2008 18-65 years old, working more than 30 hours per week and have responded to the questions about commuting mode and duration.

Commute data: Self-reported answers about commuting duration and mode.

Health outcomes: Self-reported answers about everyday stress, mental health, vitality, self-reported health, sick leave and perceived quality of sleep from PHS.

Study design: Cross-sectional study with logistic regression used to calculate OR with active commuters less than 30 min as the reference category. A variable for survey years was included in the models, but did not alter the results and therefore was not included in the final models. Due to gender differences in mode choice, found in the descriptive data, possible gender differences were tested by

stratification on gender for perceived poor sleep quality. Only minor differences were found and no further stratification was therefore conducted.

Paper II

Title: Relationships between commuting and social capital among men and women in southern Sweden.

Aim: Study associations between commuting (duration and mode) and social capital.

Study population: Participants (N=21,088) from the PHS 2004 and 2008 aged 18-65 years old, working more than 30 hours per week and have responded to the question about commuting mode and duration.

Commute data: Self-reported answers about commuting duration and mode from PHS (see section Commuting mode, distance and duration).

Outcomes: Self-reported answers about social participation and general trust in other people from PHS.

Study design: Cross-sectional study with Poisson regression used to calculate PR with active commuters less than 30 min as the reference category. A model was constructed for all study participants as well as separate models for men and women.

Paper III

Title: Spatial heterogeneity in repeated measures of perceived stress among car commuters in Scania, Sweden.

Aim: Investigate spatial heterogeneity in stress levels among 30-60 min car commuters and changes over time.

Study population: Participants (N=997) from the PHS 2000, 2005 and 2010 aged 18-65 years old, working 15-60 h/week and commuting 30-60 min by car at least at one of the three years.

Commute data: Self-reported answers about commuting duration and mode from PHS (see section Commuting mode, distance and duration). Only 30-60 min car commuters were included. Calculated Euclidean distance between home and workplace based on data from Statistics Sweden.

Health outcome: Spatial heterogeneity in self-reported answers about everyday stress.

Study design: Spatial heterogeneity in stress was studied by calculating geographically weighted proportions for each 30-60 min car commuter in a particular year. Geographically Weighted Proportions (GWP) were calculated in ArcMap 10.2.2 which is a Geographic Information System (GIS) software. Ward's algorithm was used to classify geographically weighted proportions observed at individual residential locations into geographically contiguous groups. Proportions of self-reported sociodemographic indicators and income and occupational status from register data along with commuting distance and working or living in Malmö/Lund in the highest stress group were compared to the study population as a whole group for each year separately. Register data about residential and workplace location was used to calculate the distance and included as a covariate.

Paper IV

Title: Modelling the effect of health indicators on commute mode choice: a cross-sectional study in southern Sweden

Aim: Study associations between commuter's health status and commuting mode choice.

Study population: Participants (N=7,574) from the PHS 2012 18-65 years old, working 15-60 h/week, answering question about commuting mode and living and working inside Scania.

Outcomes: Self-reported question about commuting mode choice. Travel distance and duration were also calculated using Google directions API.

Indicators of mode choice: The models included indicators of health (obesity, difficulty walking, long term illness, vitality and stress) along with socioeconomic and demographic (age, gender, educational level, income, occupational status, part-time work, working inconvenient working hours, cohabiting, children living at home) and spatial indicators and commuting characteristics (walking distance, transit duration, car duration, residential location, workplace location, access to transit from home and work, living in a villa).

Study design: Discrete multinomial regression was used to study the association between health indicators along with traditional indicators (sociodemographic indicators, commuting characteristics and spatial indicators) and mode choice. Three models were developed in order study how indicators from the different areas could add to the explanatory degree. In the first step spatial indicators and commuting characteristics was added as a basic setting for where the commute took place. In the second step sociodemographic indicators was added to include individual prerequisites. In the third step health indicators was added to see if they added something to the model after adjusting for more traditional indicators.

Results and comments

Paper I

Car commuting was the dominant mode followed by active and public transportation. Commuting patterns differed between men and women and for different socioeconomic groups. Women used more active and public transportation. Immigrants used more public transportation. Long duration commuters had higher levels of education, especially those using public transportation. In the fully adjusted regression model, we found that commuters using public transportation had higher POR for negative health (perceived poor sleep quality, everyday stress, low self-rated health, exhaustion) with increasing duration of commute. For the category more than 60 min, POR ranged from 1.2-1.6, for the different health outcomes, except for sick absence which had a POR close to 1 (Figure 7). Different associations were found for car commuters. POR increased with increasing commuting duration up to 30-60 min (OR ranging from 1.2-1.4, except for low mental health which showed no effect) and then lower for the category more than 60 min (Figure 8).

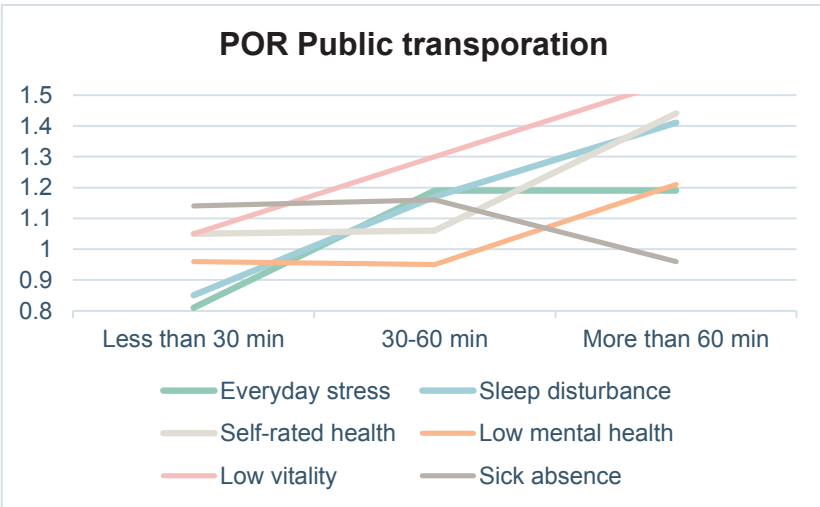

Figure 7:
Prevalence ratios for six different health outcomes among commuters using public transportation with active commuters less than 30 min as the reference category.

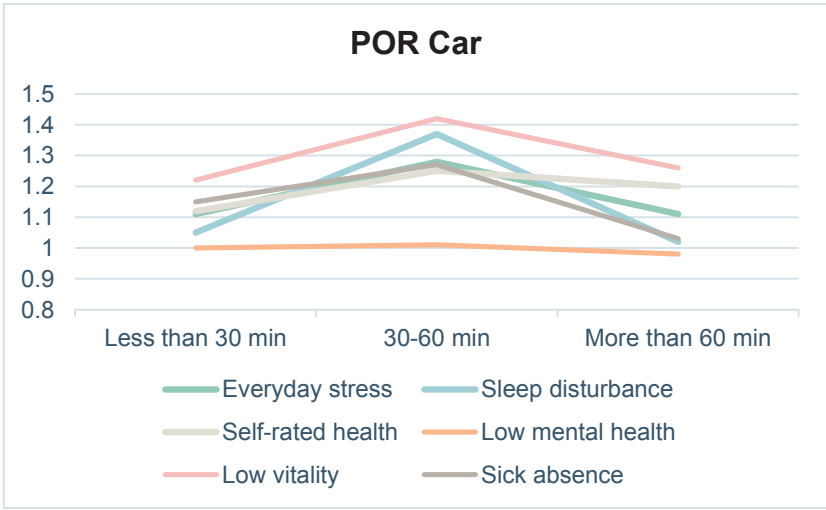

Figure 8:
Prevalence ratios for six different health outcomes among commuters using car with active commuters less than 30 min as the reference category.

Comments: We used active commuters with durations shorter than 30 min as the reference group. This group was selected as we, based on prior research, could expect active commuting to be the healthiest mode. Active commuting longer than 30 min was rare and therefore not suitable as a comparison group. When interpreting the results, it is important to consider that the results do not only reflect the negative effect that commuting could have on health, but also the positive effects from active commuting.

We tested for gender differences through building separate models for women and men for sleep disturbances, but did not see any differences. Exploring the other health outcomes would have been a good addition to the analysis.

An interesting finding in the study was the concave downwards association for car commuters. The "healthy commuter effect", where commuters experiencing negative health from their commute changed their commute, could be a possible explanation. More than 60 min car commuters had a higher income and might therefore be a group that more easily could change their situation. Higher salaries among these commuters also indicate that they are compensated to a larger degree for their commute. Commuting more than 60 min by car in Scania also meant that the commuter most probably spent a considerable part of the commute outside congested cities. Commuters using public transportation generally had higher POR, for the health outcomes, with increasing commuting duration. This could possibly be explained by more complex journeys and higher probability of delays for public transportation users in comparison to drivers.

The finding of a downward concave association with car commuting inspired the work conducted in paper III studying spatial heterogeneity in the association with stress.

Paper II

Social participation was higher among men than women, while general trust was slightly higher among women. Men and women had markedly different commuting patterns with a higher use of public transportation and active transportation among women. When adjusting fully for covariates in the combined model for men and women, car commuters had lower levels of social participation and general trust in others (Figure 9). In contrast, public commuting was not associated with lower levels of social participation and general trust, except among long-duration commuters, which reported lower levels of social participation (Figure 10). Separate models were developed for men and women with similar patterns, although not always statistically significant.

In the gender specific models, similar PR estimates were found although not all of them statistically significant. One of the exceptions was women commuting more than 60 min with a car where the PR was very close to one.

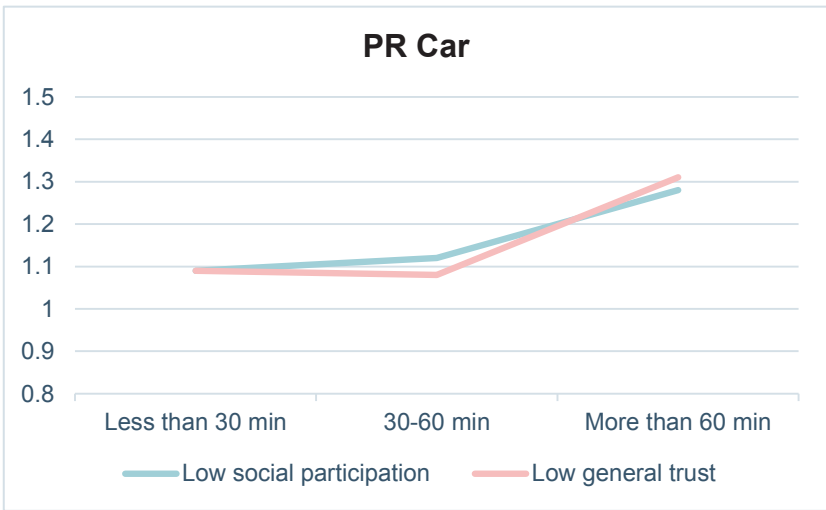

Figure 9:
Prevalence ratios for low social participation and low general trust among commuters using car with active commuters less than 30 min as the reference category.

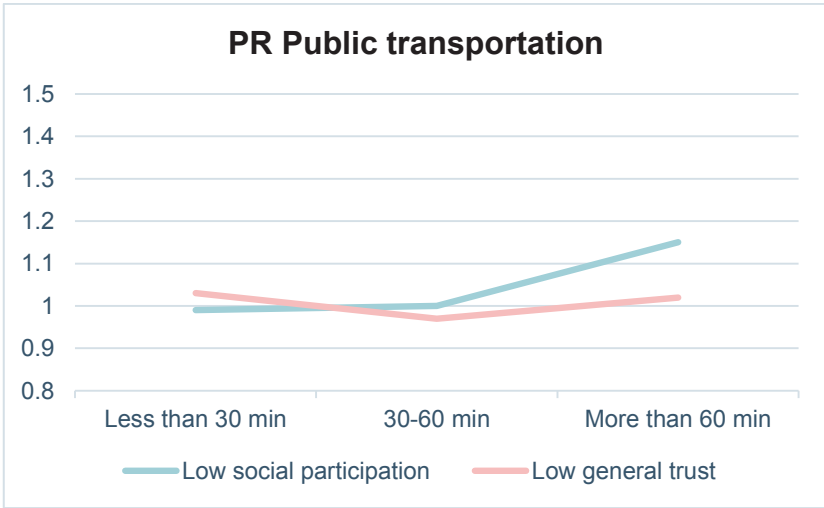

Figure 10:
Prevalence ratios for low social participation and low general trust among commuters using public transportation with active commuters less than 30 min as the reference category.

Comments: In paper II, we used the same reference group (active less than 30 min) and categorisation of the exposure variable as in paper I, enabling an easier comparison of the results. Longer duration would mean less time for social participation during spare time, therefore we used a reference category with commuting less than 30 min. We believed car commuting to be the mode that isolated the commuter from other commuters most strongly, while both active and public transportation was considered to be more interactive with other commuters.

In comparison to paper I, we focused more on studying possible differences between men and women by first including gender as a multiplicative interaction variable with gender and commuting but also constructing separate models for men and women. Gender effect was also tested by adding a multiplicative interaction variable but no difference was found.

Women commuting more than 60 min by car was a small group (N=93) making it harder to find any statistically significant results for this group. In comparison to men commuting more than 60 min by car, this group also differed by cohabiting with a partner and having children living at home to a lower degree, thereby possibly leaving out unmeasured confounding.

Car commuters had lower social participation and general trust than active and public transportation commuters. A plausible explanation would be that car commuters are more isolated in their vehicles, while active and public commuting offers more possibilities to interact socially. Another explanation could be that less social commuters choose to use the car instead of active and public modes.

Adjusting for personality trait, which is considered to be stable over time, could have allowed us to better address this, but no such question was available.

Besser et al. found an association with increasing commuting duration and lower participation in socially oriented trips in the US [11]. As opposed to what we found in paper II, they saw a stronger association with non-socially oriented trips and active and public transportation. The US has become a strongly car dependent society and respondents were recruited from the whole country. The contradictory results in comparison to paper II could be explained by the context. Nowadays, people in the US are more dependent on the car to reach their social activities than in southern Sweden. This further highlights the need for considering geographical context when studying the association between commuting and social participation and health.

Paper III

We found evidence for spatial heterogeneity in the association between 30-60 min car commuting and stress. The proportions of commuters who reported high stress were different in different areas of Scania for each of the three years (Figure 11). When comparing proportions between sociodemographic variables for commuters within the identified high and low areas, with the county as a whole, we found few significant differences. The existence of high stress areas could therefore, not be fully explained by differences in sociodemographic characteristics. Further we found that the areas with the highest stress did not occur in the same place over time. Commuters included in the study population also shifted commuting duration and mode over time. More than half of the commuters that shifted mode from 30-60 min car commuting shifted to a shorter duration by car. In the final step of the analysis, we saw that the study population changed both home and workplace location to a large degree.

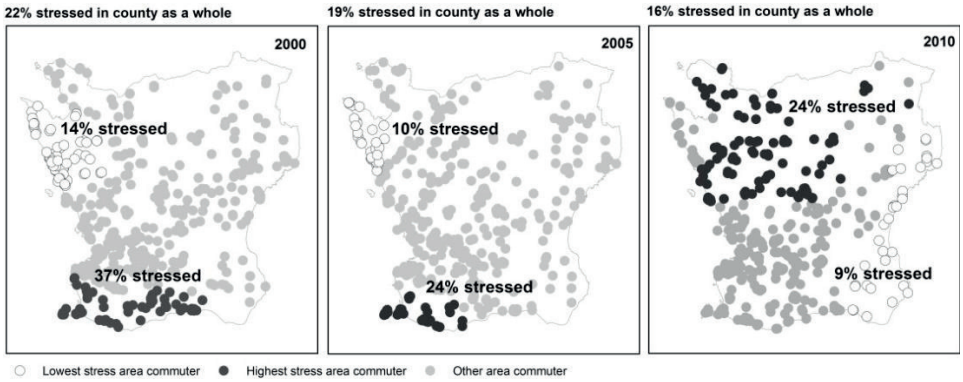

Figure 11:
Areas with the highest and lowest proportions of stressed 30-60 min car commuters by year with proportion stressed among 30-60 min car commuters in the county as a whole.

Comments: In addition to using the self-reported commuting time in order to select the study population, we also calculated Euclidean distance between home and the workplace. Calculating distance enabled us to compare if commuting longer or shorter distances than the median in the county could help explain the existence of high and low stress areas.

We chose to use a statistical method that identified areas with high and low stress. In further analysis it would have been interesting to use methods that could adjust for the geographical context such as geographically weighted logistic regression. It would also have been interesting to have included more variables describing the geographical context such as congestion levels, speed limits and road network quality.

The ambition was to study spatial heterogeneity in a longitudinal setting. This was partly done through studying spatial heterogeneity in repeated cross-sections. The data available was not suited for true longitudinal follow-up as we only had health outcome data for every fifth year.

The results highlight the importance of considering the geographical context. In transportation planning the method used in this study could be used to identify areas where the connections between commuting and health and wellbeing are stronger and thereby in greater need of interventions. Results from studies investigating association between commuting and health and wellbeing should be interpreted with this in mind. Stronger associations in one part and weaker associations in another part of the study area, could even out these associations.

Paper IV

We found that having difficulty walking was negatively associated with using active or public transportation. Obesity and stress were negatively associated with active commuting. We did not find any association for long-standing illness and exhaustion. Spatial indicators, commuting characteristics and sociodemographic indicators were also associated with commuting mode choice.

Covariates were added in two steps with increasing explanatory degree with increasing complexity; however the highest rho-square value was 0.34, which indicates that there are still important unmeasured factors.

Comments: Self-reported mode was used as in earlier studies, but new measures for distance and duration were calculated. Google directions API was used to calculate distance and duration for a specific day in close relation to when the respondents answered the questionnaire. This enabled us to consider the possible route the commuter took and congestion along this route. The route calculated was the quickest route and we cannot be certain that the individual commuter actually took this route, but as many commuters want to minimize the time they use it can be considered to be a likely route.

While health status being intuitively a reason for mode choice, this has been little studied. When selecting health indicators, we tried to select those that we believed were less likely to be an effect of using that mode. Difficulties walking and long-standing illness reflect physical disability and are not likely to be an effect of using a certain commuting mode. BMI is related to the effort needed to be put into moving actively, and is also a result of a sedentary lifestyle; thereby the association between BMI and mode is likely to be bidirectional. We were also interested in how mental aspects affect commuting mode choice. We included stress and exhaustion, although these associations are likely bi-directional.

Considering the health status of the commuter improved our mode choice model. In order to get the best result from interventions, for the purpose of getting the commuter to switch mode from car, including health status could help improve the explanatory degree of the model. More studies would preferably be needed to strengthen these results and understand in what way commuting mode affects health and vice versa, before implementing policies.

This study was conceived through collaboration with a transportation researcher during a six month exchange to University of British Columbia. The design and analytical methods belong in transportation research, which might also make the findings more available for transportation planners.

Discussion

General discussion

Commuting makes up an important part of many people's daily lives and consumes a considerable part of the day's 24 hours. In order to create a more flexible workforce to generate economic growth, commuters are expected to travel longer distances in order to get to work. Long duration commuters are believed to be compensated for their longer commutes. The commuter can find a job with a better salary, a more satisfying job, or employment if unemployed. The commuter could also be compensated through cheaper housing or finding a place to live with a higher standard of living, and thereby have increased wellbeing. But are commuters really compensated? The results presented in this thesis strengthen the existence of a so-called "commuting paradox", that is, the commuters seem not to be fully compensated for longer commuting duration.

In Scania, car commuters seem to be compensated economically for increasing duration to some extent. Income increased with increasing duration in male and female car commuters. In contrast income increased with increasing duration among male public transportation commuters, but not in females. Thus, gender seems to influence how the commuter is compensated.

Although the commuters were economically compensated to some extent we found that both car and public transportation commuters had lower levels of health and wellbeing compared to short duration active commuters, thereby not fully compensated. For public transportation, the lowest levels of health and wellbeing were found for those commuting more than 60 min. For car commuters the lowest levels of health and wellbeing were found in the category 30-60 min, thus indicating some difference in compensation or experience depending on the commuting mode. Lower levels of social participation were found for car commuters with increasing duration, and also for long duration (>60 min) public transportation commuters. Time lost during the commute means less time for social participation. A cross-sectional study cannot address causality; travelling alone in a car isolates the commuter from others, but it is also plausible that less social people would prefer to use a car.

The primary aim of this thesis was to study how commuting as an exposure could have a negative impact on health and wellbeing. But the association between commuting and health is more likely bi-directional. From the literature and through collaboration with transportation planners during the doctoral study period, the question of how the health status of the commuter could influence the commuter's mode choice was also raised. Thus, paper IV used a reverse approach with analytical methods common in transportation planning. There have been few large scale studies investigating the health status of the commuter as a determinant of mode choice, especially regarding mental health and wellbeing.

In general our results correspond well with prior research on commuting and health and wellbeing (See Introduction). Commuting is grounded in time and space which implies that associations between commuting (duration and mode) and health and wellbeing cannot be expected to be spatially and temporally consistent. Even on regional level, in a rather homogenous population, there were patterns of spatial heterogeneity. The conditions for commuters in relation to congestion, level of service, tranquillity in the commuting environment and serenity in the environment differs spatially and are plausible explanations for some of these differences. Thus, the importance of the geographical context when studying commuting and its association to wellbeing and health should be highlighted.

Overall the results in this thesis make an important contribution by adding evidence in a field of research which is relevant to the majority of the working population.

Generalizability

We used data that had already been collected and was available. The purpose of these questionnaires was to map the public health status in Scania over time and the first questionnaire was developed in 1998-1999. Our way of measuring health was thereby framed by the way Scanian health authorities' and experts conceptualized public health at that time. Many of the prior studies investigating commuting and health typically have smaller study samples and the large study sample is a strength [6, 7, 53]. Drop-out has been studied and there was an underrepresentation of men, foreign born and younger, but overall the generalizability of the study population can be considered to be good [117]. The study sample also included commuters using different modes, which is another strength in relation to understanding the commuters' situation in a study area [33].

Commuting patterns in Sweden are similar to those in other western countries and is in that sense representative for other similar settings. But as seen in paper III the context of where the commuting takes place seems to be important and results not

considering such aspects should therefore be interpreted with caution when generalizing to other areas.

Novelty

Few studies with similar sample size have studied the association between commuting and wellbeing. Even fewer population-based studies have investigated the associations with social capital.

In paper III geographically weighted proportions were used to study spatial patterns in the association between commuting and health. This method has not been used to study commuting and wellbeing. The results highlight the need for considering the geographical context. The method could be used to identify areas of special need for interventions. It could also be used to study other health outcomes in relation to commuting, but also other exposures. Further we highlighted the importance of considering changes over time. Commuting patterns are not stable over time and it is challenging to develop longitudinal studies of commuting when individuals change their residential locations, workplaces and commuting modes over time.

The concern about how health is related to mode choice of commuting has previously received little focus in transportation planning. The inclusion of health status in a study design commonly used in transportation planning could highlight the importance of commuters' health and also make it easier for transportation planners to interpret the results.

Methodological discussion

Exposure assessments

Distance and duration are commonly used measures of commuting impedance [2, 9, 67]. To a large extent they measure the same aspects of the commute, and distance is often used as an estimate of the duration [85]. Duration include congestion and would in that sense be a preferable measure if only one is available. The loss of time during the commute is an important aspect of the connection between commuting and health and this time loss is better measured with duration.

In this thesis the way we were able to address duration/distance progressed. In papers I and II we relied solely on the self-reported duration. Self-reported

commuting duration was reported in categories. The questions about commuting mode and duration were not included in PHS and PHSC for research on commuting, but were for assessment of air pollutions during commuting. When studying long duration commuting 45 min is sometimes used as the cut-off [10]. In our data one of the categories was 30-60 min. It would have been preferable if we had been able to divide this group in two categories of 30-45 min and 46-60. This would have enabled us to have a 15 min increase per group instead of 30 min, if the groups had included enough commuters. Similar categorization has been used regarding duration. Feng and Boyle also tried a cut-off at 20 and 45 min instead of 30 and 60, but found similar results and decided for the 30 and 60 min cut-off [2].

In paper III we calculated Euclidean distance, which does not consider the route of the commuter, but has been found to be a good proxy for the actual distance [118]. In paper IV we used Google directions API to calculate the distance and duration. This enabled us to consider route, although it was not possible for us to know whether this was the actual route the commuter used. We assumed that the commuter tried to minimize commuting time and use the quickest route. These more objective measures made it possible to arrive at a continuous measure of the distance/duration. We did not have the actual commuting duration, which would have been the most accurate measure. This would have been possible to obtain if we had been able to follow commuters with a GPS.

When calculating the distance/duration in Google directions API we used the traffic flow at 8 am for a typical day during the period the questionnaires were collected. This is the time point when a random commuter is most likely to commute to work, but the time during the day that commuter travel to work would differ. Using this high peak situation means that we used a worst case scenario, but also the most likely.

There is some uncertainty in the calculations of both Euclidean distance and routes with Google directions API due to the precision of the residential and workplace locations. This precision is not likely to result in any systematic over or underestimation as it should be randomly distributed.

The number of days each week the commuter travelled between home and work was not addressed. This could lead to an over estimation of the exposure if the commuter did not commute all days of the week. The inclusion criterion about a minimum number of work hours per week minimizes this bias, especially in paper I and II.

In epidemiological studies simplifications need to be made in order to be able to get large enough populations to study. We categorised commuters into active, car and public transportation. We did this on order to have groups of commuters that were large enough to study. There are studies that argue that this kind of

categorisation is too broad and that active forms for instance walking and cycling need to be treated separately [53].

The stressors that commuters are exposed to also differ within a certain mode. Crowding, air quality, delays and noise differ between buses and trains. For car drivers' congestion levels and other driver's behaviour and for active commuters weather, environment and access to sidewalks, just to mention a few. The complexity of commuting as an exposure is very comprehensive. To get an understanding of cause and effect on this level a more qualitative approach would be needed. Interviews with commuters could help to entangle these associations and generate hypotheses. Well-designed longitudinal studies would then be needed to address causality.

Outcome assessments

The health outcomes used in this study were selected to occur close in time in relation to the exposure. The focus in this thesis was to study commuting in association with wellbeing and not manifested diseases. However, self-rated health is also considered to be a good indicator of future negative health and manifested disease [106, 119, 120].

Connecting register-based outcomes such as morbidity could have been an alternative to the self-reported outcomes, and registry data from primary health and hospital care is indeed available in the Scania region. This way of addressing outcomes has been used in prior longitudinal studies [67]. Using register data would have enabled focusing on more specific health outcomes, but the experienced wellbeing of the commuter would not have been possible to capture through registers.

When we measured self-rated health we used a cut-off to dichotomize the answers and identify commuters with low self-rated health. The prevalence of low-self rated health, as we defined it, was above 20 %. (Notably, the use of the term low-self rated health in other studies often focus on the most extreme category when studying associations to i.e. mortality [106]). We used this cut-off based on theoretical assumptions that commuters would not have severely reduced overall health due to the commute. In order not to confuse the reader we could preferably have used another name for the group with what we call low self-rated health.

The question used to measure social capital has been used in Sweden since the 1960s and has for long been considered to be a relevant measure [114, 121]. The same and similar questions to measure social participation have been used in prior studies [11, 114, 115]. One could argue if the question with its alternatives still reflects social participation during the study period. The use of social media and

the possibility of staying connected and take part of what happens in society during the commute has opened up new possibilities [122]. Although the use of social media has exploded during recent years use in 2004 and 2008 was not as extensive as it is today, and the question has likely not lost its validity.

There are different forms of social capital such as bonding or bridging [112, 122]. Bridging social capital refers to the weak ties, for instance formed between colleagues. Bonding social capital refers to strong ties, for instance formed in families. These different forms of social capital give rise to different opportunities and benefits for the members of these networks. The self-reported measures available for us did not make it possible to differentiate between these different forms.

In paper IV we considered commuting to be a necessity in order to travel from home to work and not done for enjoyment. Further, we took into consideration that commuters make rational decisions and try to minimize their time spent commuting. This is a common approach in mode choice modelling, but this way of thinking can be challenged. As presented earlier, Redmond and Moktharian found that the ideal commuting duration was longer than zero minutes [1]. Further they also found that a small proportion (7 %) of the commuters experienced their commute as too short, although a majority (53 %) considered their commute as too long. For some, commuting in itself could therefore be considered to be a positive experience, although a majority still experiences their commuting time as negative. Separating these two types of commuters in the analysis of how commuting is associated with health and wellbeing would plausibility strengthen the associations with negative health outcomes for those commuters that do not consider the time they commute as something positive.

To what extent the commuter actually has a choice in regard to deciding on which mode to use differs due to geography and individual factors. If the commuter has a long distance between home and work, motorized mode might be the only solution. Difference in duration between car and public transportation might also pose a constraint. If taking the bus takes much longer time than driving, the only feasible choice might be to get a car or change job. The degree of constraint differs and can be divided in three categories, personal capacity and resources, coupling and power [123]. Personal capacity and resources can restrain the commuter for instance via a physical disability or lack of income. Coupling means the need to interact with other people and could limit commuters' choice of using public transportation. Power represents collective demands on the commuter from society, i.e. being unemployed and forced to take a job far from home. In paper IV, we include a number of indicators to see what is associated with mode choice but we did not include constraints per se. Some of the constraints are plausibly captured by including gender, income access to public transportation and physical

disabilities while others might be missed and thereby leave out potentially important determinants.

Statistical considerations

The statistical methods used in the paper included traditional epidemiological methods as well as spatial statistics and statistical models used in transportation planning. Over the course of the papers there has been an increased complexity in the statistical models used.

The information that can be obtained about each respondent was comprehensive, enabling a good opportunity to adjust for covariates and measure different aspects of wellbeing. Additional register information on income as well as residential and workplace location further improved the use of the questionnaire.

Logistic regression is a traditional method often used in epidemiological research to study associations between exposure and health outcomes. The odds ratio is a commonly used measure and therefore interpretations of the results are more available for other researchers. Odds ratios are commonly thought of as a risk ratio and in relation to that the estimate provided by OR can overestimate if the outcome is more common [124]. As the prevalence was more than 30 % in paper II, we used Poisson regression to calculate PR in order to avoid overestimation.

In paper III the methodology was expanded from the more traditionally used methods in paper I and II to spatial statistics. Geographically weighted proportions are a method used in spatial analysis to study spatial heterogeneity. The contribution for paper III is therefore not only the results that can be seen, but the application of a new method. Using spatial statistics enabled us to see patterns in the association between commuting and health which more traditional epidemiological methods would not have been able to do.

In paper IV discrete multinomial regression were developed based on the theory of Random Utility Maximization [125, 126]. The work was performed in collaboration with transportation researchers at the University of British Columbia. Random Utility Maximization assumed that commuters make rational decision and try to maximize their utility. Kahneman questions this way of thinking and says that it do not reflect people's actual choices [127].

The focus of the questionnaire was not to study commuting, which helped to avoid report bias. Respondents were not guided by having commuting in mind while answering the questions. At the same time not having a focus on commuting in the questionnaire was a downside as limited information about the perception of the commute was available.

Prior studies have shown differences in the association between commuting and health among men and women. We saw differences in the commuting patterns between genders but we found no clear differences in relation to the outcomes. In paper I and II we stratified the analysis on gender, although only for one health outcome in paper I. In paper III and IV we included gender as a covariate, but did not stratify the models. It is possible that there might not be any major differences between genders in our data, but it would have been interesting to study this more thoroughly.

Limitations and bias

A limitation in this study was that the study designs of all four papers were cross-sectional by nature and we were therefore not able to study causality. In paper III we used repeated-measures, but this method was not able to study causality.

In this section we will discuss possible sources for systematic errors and limitations of the study. Systematic errors can be divided in three broader categories: selection bias, information bias and confounding.

We selected a reference group that consisted of active commuters travelling less than 30 min. This reference group also experienced the positive effect of active commuting, for instance through increased physical activity, which possibly could have a positive effect on the mental wellbeing of the commuter as well. An alternative to using the active commuter as the reference category would have been to use people that worked from home. A problem with using such a reference group would have been that we possibly would have introduced selection bias. This type of selection bias is referred to as the "healthy worker effect" [128]. The reason for some of the workers working from home might be that they were not fit enough to commute. The prevalence of negative health in this group might therefore have been higher. Other alternatives for reference groups could have been homemakers and unemployed, but we believe similar biases could be introduced by using these groups as well.

Using cross-sectional study designs could have introduced a self-selection bias that we refer to as "the healthy commuter effect" [8]. That is, commuters that experience negative health from their commute might choose to shift to another type of commuting. We would thereby see a weaker association between the type of commuting that potentially has a negative impact on health and the different outcomes.

A possible information bias could be that those being stressed or experiencing negative health could affect response rate negatively for these groups as well as having long duration commute, thus, making it harder to see associations. Using

self-reported duration may also lead to overestimation of the duration as stressed commuter potentially could overestimate their commuting duration.

Most of the covariates, exposure and outcome were self-reported. For some of these questions recall bias could have been introduced. The most likely variable for this occurred in commuting duration and mode in paper III. In the questionnaire from 2010 mode and duration were asked for retrospectively. The possible problem to recall would most probably not differ in relation to the outcomes and it would therefore be a non-differential misclassification. Because commuting is such an important regular activity associated with the working day, we believe that most of the commuters would be able to remember how and for how long they commuted back in time.

Although we were able to adjust for a large number of covariates, it is plausible that residual confounding on an individual level still exists. We were for instance not able to consider the perception of the commute. We also did not know for how long the commuter had been using that specific mode, i.e. the commuters' habits.

Moreover, commuting is context-dependent, and the use of such data was limited in our studies. There are probably confounding factors in the geographical context such as congestion, noise, air pollution, crowding and accessibility that we could not include [129].

Conclusions

- There is an association between longer commuting duration and low self-rated health.
- The association differs between car and public transportation, possibly due to differences in travel complexity, geographical context and socioeconomic situation between long duration car and public transportation commuters.
- There is an association between commuting and low social capital. Car commuters had lower levels of social participation and general trust in others with increasing duration. Long duration public transportation commuters' had lower levels of social participation.
- We found spatial heterogeneity in the association between stress and car commuting. This shows the importance of including geographical context in the analysis of these associations.
- Commuters change mode and duration. This needs to be considered in the design of longitudinal studies of commuting and when interpreting the results from cross-sectional studies.
- Health status was associated with commuting mode choice. Traditional factors such as sociodemographic and commuting characteristics still seem to be more important.
- Overall our results strengthen the evidence for the existence of the commuting paradox

Policy implications

The studies conducted within the frame of this thesis found supporting evidence for the commuter paradox, that is commuters do not seem to be fully compensated for longer commutes. Polycentric regional expansion with increased commuting duration and a more flexible workforce increase economic growth, but potentially may lead to reduced health and wellbeing and increased costs for sick leaves and health care. This needs to be considered to understand the overall implications that commuting has on society, and needs to be incorporated in economic calculations.

Most of the commuting time is unproductive. Commuters lose time and the time spent commuting can is added to the total workday. This means less time for the commuter to engage in family and other social activities. Aside from implications on health, wellbeing and social activities for individual commuters and their families, this can also have an impact on the commuters' engagement and trust in society. A decrease in social capital can potentially have large negative impacts on the civil society.

Also with increasing sizes of local labour markets, it is desirable to get commuters to shift to more healthy modes. Getting more commuters to choose active commuting will improve health not only for the individual commuter but also the environment. There is potentially a large group of commuters that would have the possibility to change to more active modes. Within Scanian cities 35 % of all trips are less than 35 km [91]. The evidence is strong concerning the benefits of active commuting. Health and economic analyses have been made showing the very large potential for saving monetary costs. A potential improvement in reduced stress and improved wellbeing in shifting from passive mode to active could also be expected.

We found that health and wellbeing were associated with both mode and duration of commuting. The association between commuting and stress showed spatial heterogeneity, which highlights the importance for planners and policy makers to consider local differences.

Mode choice of commuters is also important in relation to air pollution, noise and availability of space inside cities [130]. Cars consume a lot more space than both bicycles and buses. If commuters used fewer cars, a lot of space inside our already dense cities could be made available for other uses such as parks, sidewalks and

recreational facilities. Many cars on the roads often also mean more congestion. Congestion consumes time for the individual commuter, but also increases fuel consumption. Sustainable transportation policies thus include environmental, economic and public health aspects.

Future research

Results from this thesis highlight the need to consider the geographical context when studying commuting and health. Studies that consider both the individual commuters preconditions and the commuting environment could provide important pieces of information. In spatial statistics, there are methods like spatially weighted regression that provide tools which could be recommended for further use.

Most of the present knowledge on the associations between commuting and health are based on cross-sectional studies. In order to understand the causal relationship between commuting and health longitudinal studies are needed. Qualitative research studying how commuters experience exposure to different type of stressors such as delays, congestion and flexibility could generate hypotheses, which then can be tested in longitudinal study designs. Disentangling how commuting modes affects health and how health status of the commuter affects mode choice are important in order to understand the complex relationships. Further, we found that commuters change their commute over time. Longitudinal studies as well as qualitative research are needed in order to understand why this occurs and if it is related to reduced health and wellbeing among long duration commuters.

New technology like cell phones has opened up opportunities of great potential to follow commuters' travel patterns in more detail in real time and longitudinally. A combination with apps where commuters could report experiences due to commuting delays in real time, and consequences of these delays, could provide a powerful tool of improving exposure assessments and outcome measures. These types of study design could be used to collect very large study samples by collecting GPS signals from millions of commuters thereby giving exact routes, distances and durations, combined with register data for different health outcomes. However, there are important ethical considerations to address in order to protect the commuters.

In paper II we found that car commuters had lower social participation than both active and public transportation commuters. The use of mobile devices and social media has exploded, providing non-driving commuters with new alternatives in regard to how to spend their time during their commute. Understanding how social

media can replace or be an alternative for other forms of social interaction and how commuters make use of this is important.

Commuting patterns differ between men and women. Some studies also show that the associations between commuting and health and wellbeing differ between the genders, while others do not observe these differences. A better understanding of the relationship between gender and commuting is important in order to provide good and healthy transportation options for both men and women.

Little research has been conducted on how commuting affects social relationships and health within families. A few researchers have investigated how separation rates among long duration commuters and how social relationships between fathers and their children are affected. In addition, how the wellbeing of children of commuting parents is affected would be a very interesting perspective to study.

In our models we have adjusted for covariates that mirror the constraints from work such as overtime and job strain. Studies focusing on the interaction between work and commuting, considering commuting as a part of the total workday, and the combined effects on health and wellbeing are needed. Factors that would be interesting to study include opportunities to work from home, flex-time and the opportunity to work while commuting. Understanding if and how these could improve the situation for commuters that experience stress and negative effects on wellbeing could help to provide solutions.

In this field of research it is important to collaborate trans-disciplinary in order to understand different aspects to be able to find solutions to improve health and wellbeing of commuters.

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Every day, I wake up, get dressed, eat breakfast and hurry away to reach the train that will take me to work. Riding my bike towards the station I always wonder; -why did I not leave home two minutes earlier so I wouldn't have to worry about catching the train? Many people can relate to being stressed during their commute. Commuting also prolongs the workday. During the four years that I have worked on this thesis I have spent roughly 1500 hours travelling between home and work (that is without delays included).

This thesis studies the relationships between commuting, health and wellbeing in a context were commuting duration continues to increase due to political and economic initiatives.

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