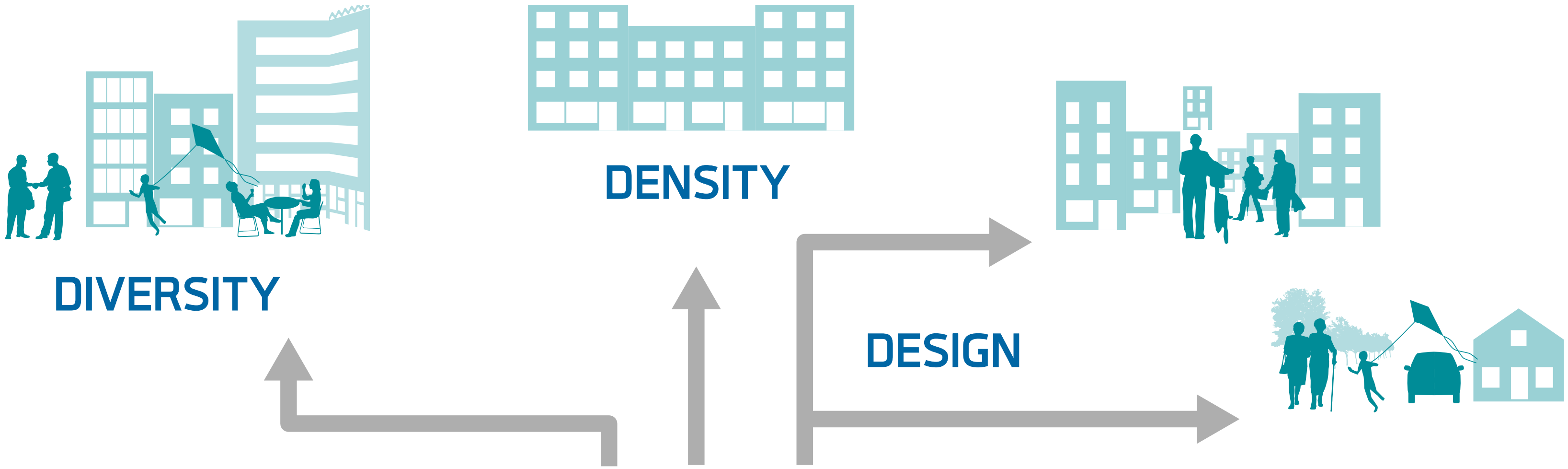
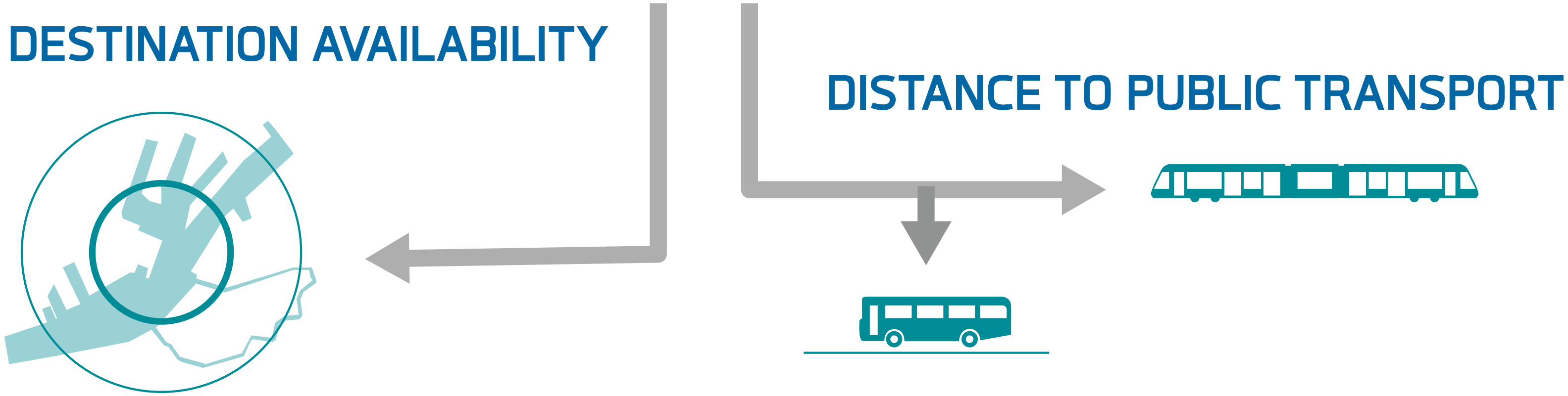


LOCATION INDICATORS FOR SUSTAINABLE TRAVEL HABITS



GÖTEBORGS REGIONEN | SPACESCAPE

October 2019

SUMMARY

To attain Sweden's environmental goals, 2010 levels of emissions from national transport modes must be decreased by 70 percent before 2030. 93 percent of emissions in 2017 came from road traffic. New fuels and vehicles must be developed in order to reduce emissions together with a comprehensive switch from energy-intensive modes of transport to more energy-efficient ones.

There is a broad consensus in the research world on the central role urban development plays in travel habits and motor vehicle ownership. These relationships have been studied in several major meta analyses, both globally and in a Nordic context. A categorisation that is commonly used of what affects travel habits is called the "5 Ds" (distance to fast public transport, density, diversity, destination availability and design).

Despite its known correlation, there are today no simple, research-based, tools to estimate the importance of urban construction for traffic generation.

In turn, this means difficulties in demanding both responsibility for the form of traffic generation and the possibility of steering planning in order to attain reduced road traffic targets at an early stage.

In order to activate urban planning as a means of raising the proportion of sustainable transports, the Gothenburg Region has wanted to develop research and locally-based models that can assist planners and decision-makers in better understanding the consequences of various expansion policies. This project has been funded by the "Regional Analysis" research project. The links between the around 200 hypothetical location indicators connected to the 5 Ds and travel data from the West Swedish Agreement have been studied. In summary, this result confirms previous research on the significance of the 5 Ds. In total, seven location indicators and one socio-economic control variable (median income) have been identified as being of particular significance.

DENSITY

Street length per person within 1 km
Proportion single-family houses

DIVERSITY

Mix of residents and employed within 1 km

DESIGN

Crossing density within 1 km

DESTINATION AVAILABILITY

Distance to regional centre
Distance to major urban areas (more than 25,000 inhabitants)

DISTANCE TO FAST PUBLIC TRANSPORT

Access to regional public transport

Location indicators categorised by the 5 Ds.

Developed location indicators and models can be used in the next step to model travel habits given different expansion policies and to calculate CO_2 emissions from transport.

In order to reduce emissions from passenger transport by means of urban planning, the following seven recommendations have been compiled.

1. Prioritise expansion near the regional centre

2. Prioritise expansion within 1 km from rail station or express bus stop with high frequency service.

3. Construct residences where there are premises and construct premises where there are residences

4. Transform roads into streets

5. Limit the proportion of single-family houses

6. Increase the service frequency of express buses in suitable station communities

In summary, the study shows a great potential for using the developed models when it comes to more comprehensive expansion analyses or greater investments in public transport in the region. As geographically more detailed travel data becomes available, more precise location indicators could also be developed and used in individual major plan projects. Such an analysis, financed by the Swedish Energy Agency and carried out by Spacescape and Trivector, is currently being carried out in parallel within the city of Gothenburg and is expected to be completed in 2020.

CONTENTS

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1. INTRODUCTION

BACKGROUND AND OBJECTIVES

BACKGROUND

To attain national environmental goals, 2010 levels of emissions from national transport modes must be decreased by 70 percent before 2030. Of these, domestic transport from road traffic stands for 93 percent (Energy Agency 2016). Both new fuels and vehicles must be developed in order to attain this goal, together with a switch from energy-intensive modes of transport to more energy-efficient ones through community planning. This applies not least after 2030 when emission targets will become even stricter. A switch from motor vehicles to other means of transport is therefore of central importance in achieving these goals.

The potential for energy savings through urban planning that benefits walking, cycling and public transport is good in a long-term perspective. According to previous studies, urban construction can be said to explain 1/3 of the variation in travel length and choice of transport, while the socio-economy can be said to explain half (Holmberg & Brundel-Freij 2012). Other assessments show that CO_2 emissions from traffic can be reduced by 15-20 percent through efforts in urban planning (Collected planning details for energy efficiency and limited climate impact, Swedish Transport Agency 2012). In other words, where and how municipalities choose to build can have a big significance for our total emissions. Unfortunately, there are no analytical tools today that can be used on an empirical basis to estimate how travel habits change with different urban planning activities.

In the broader sense, a switch from motor vehicle to pedestrian, bicycle or public transport can also lead to increased urban quality and more competitive cities. Recent studies in Gothenburg, Stockholm and Copenhagen have shown that urban environments with a low proportion of motor vehicle journeys are more attractive to live in (Gothenburg City et al 2017).

The Gothenburg Region has initiated the following study on urban expansion and travel habits in order to investigate the importance of urban planning on the choice of transport mode. The study is included in and funded by the regional analysis research project and has been conducted by the research-based consultancy firm Spacescape in collaboration with Trivector.

OBJECTIVE

The objective of the following study has been to investigate and identify location indicators that may explain differences in motor vehicle ownership, transport mode choices and motor vehicle journey distance.

The location indicators should be easy to use in the early stages of the planning process in order to support the growth of a community that is more transport-efficient, for example through planning analysis, follow-up and policy support.

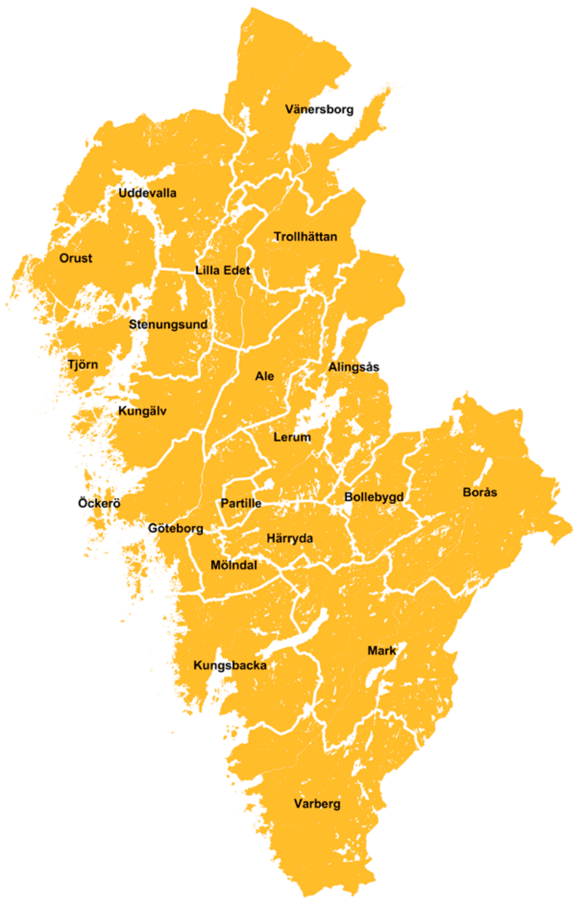
Location indicators can also form the basis for more realistic calculations of CO_2 emissions from transport.

GEOGRAPHIC BOUNDARY

The geographic boundary follows the travel survey within the West Swedish Agreement from 2017.

Due to the fact that travel data is available only for whole municipalities, or as in the case of Gothenburg, Mölndal and Kungsbacka in large parts of the municipality with uniform populations, the analysis has a limited geographic precision.

The limited ability to break down the travel data into smaller geographic areas has meant some uncertainty about whether compiled location data is representative of the environment surrounding those who responded to the travel survey. It has also resulted in fewer areas than would have been desirable to include in the statistical analysis. A total of 21 municipalities have been included. With the municipal districts included, 44 areas have been used in the statistical analysis.



TRAVEL SURVEY AREA IN THE WEST SWEDISH AGREEMENT

Geographically, the study is limited to the area included in the most recent travel survey from 2017 and includes 21 municipalities in western Sweden.

RESEARCH ON URBAN PLANNING AND TRAVEL HABITS

URBAN PLANNING SIGNIFICANCE FOR TRAVEL HABITS

There is consensus today in international research on the importance of urban planning for both choice of transport mode and journey length. Relationships have been studied in several major meta analyses, both globally (Ewing & Cervero 2012) and also in a Nordic context (Naess 2012). In large part, the conclusions can be summed up in the theory of the 5 Ds, that travel habits are influenced by proximity to fast public transport, density, function mix, proximity to service and labour market and how the environment in the local surroundings is designed. The 5 Ds are also used by UN Habitat to describe how cities can actively work to increase the proportion of sustainable transport (UN Habitat 2013)

THE 5 DS

- Distance to public transport
- Density
- Diversity
- Destination Availability
- Design

Ewing & Cervero 2012

However, the indicators mentioned are grossly categorised and the measurements used to measure them are, of course, different in the various research studies.

To test how these, like other hypothetical indicators of significance for traffic, could be used to support the evaluation of travel habits, Stockholm City conducted a study on "simple plan indicators for traffic" in Greater Stockholm together with Spacescape (Spacescape 2018). With the support of travel data gained from 123 base areas and actual motor vehicle ownership in 687 base areas, a large number of location indicators were studied. The study showed that the number of motor vehicle journeys and motor vehicle ownerships could largely be explained by density, centralisation of services, street length per person, proximity to the rail station, proportion of single-family houses and the control variable, income. The study therefore supported both Naess and Ewing & Cervero's studies and showed good opportunities to transform the research result into locally based models, possible to use as support in municipal and local planning. However, what the study lacked was analyses of the plan indicators for travel length. Neither could the study fully explain the number of bicycle trips.

A Swedish study conducted in Skåne by Freij and Holmberg 2012 showed that urban densities, local access to workplaces, services, range of public transport and proximity to the regional centres explained the journey distance and number of trips by motor vehicle and public transport, provided socio-economic control variables were also included in the models. There is therefore a solid foundation. Otherwise, there have been very few Swedish studies carried out. One exception is the research study Building Structure, Travel and Energy for Personal Transport that was carried out in Region Skåne (Bebyggelsestruktur, resande och energi för persontransporter, Holmberg & Brundell-Freij 2012).

In the broader sense, a switch from motor vehicle traffic to pedestrian, bicycle or public transport can also lead to increased urban quality and more competitive cities. Recent studies in Gothenburg, Stockholm and Copenhagen have shown that urban environments with low proportion of motor vehicles are also more attractive to live in, e.g. Value-creating Urban Development (Värdeskapande Stadsutveckling, Göteborg stad et al 2017).

SIMPLE ANALYSIS TOOLS TO MODEL TRAVEL HABITS ARE LACKING

Despite the consensus currently prevailing within research fields, simple evidence-based analysis tools are lacking that can be used in the early stages of urban planning. This means that the fundamental importance of urban planning for traffic generation and, by extension, the city's energy saving potential has not been fully addressed and transformed into a basis for decision.

Today's traffic forecasting and transport network models (e.g. Sampers and Visum) have an unclear link to the individual importance of urban development to traffic. Where people will live or work in the future are given conditions in Sampers and are based on forecasts from

Statistics Sweden (SCB). Today's traffic models are also very complex and require extensive background data and training, making them both expensive, inflexible and less readily available as analysis tools in a dynamic planning process. A simpler and more accessible alternative is the Swedish Transport Administration's traffic generation tool. This does not, however, have a local connection to a district's specific conditions and to what links there are between urban expansion and traffic in the city in question.

NEED FOR NEW TOOLS TO INCREASE CREDIBILITY OF TRAVEL DATA

Besides the lack of simple and at the same time credible analysis tools, there is in many cases also a lack of travel data in municipalities that can be geographically broken down to understand how urban expansion impacts on traffic. In recent years, the response rate for traditional travel surveys has fallen drastically, which in particular reduces representativeness and statistical certainty in the findings for different groups (age groups, gender, socio-economic status, family relationships). This applies not least to the travel survey for the West Swedish Agreement.

With more journeys and people, it is as stated possible to also break down the travel survey into smaller geographic areas, which in the next step makes it possible to also study how more specific location data affects travel habits. Not only a low response rate has made such a study impossible in the following study. New guidelines on personal security (GDPR) also make more detailed studies concerning links between travel and location problematic.

In response to this, new travel apps, among other things, are being developed that are voluntarily downloaded (e.g. TravelVu from Trivector that is used in Umeå) but also new methods for analysing “Big data“ collected via mobile phones and then anonymised but without the participants' knowledge that their journeys form part of the background information (for example, Replica, developed by Sidewalk Labs and used in Portland).

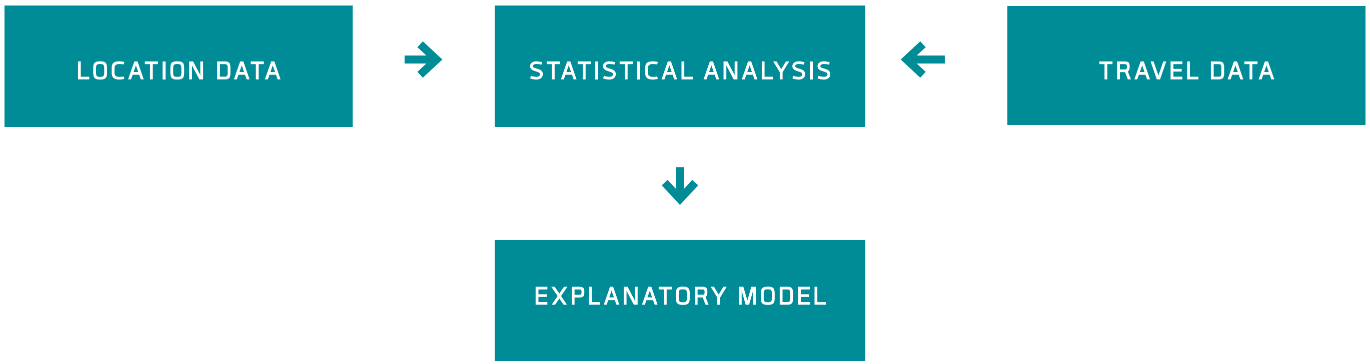
THE IMPACT OF MOTOR VEHICLE OWNERSHIP ON GREENHOUSE GAS EMISSIONS

As a complement to the travel data, statistics on motor vehicle ownership per household from Statistics Sweden have been compiled per area. Motor vehicle ownership is interesting from many aspects. Partly, a model for motor vehicle ownership can be used when planning a reasonable number of parking spaces at newbuilds. But motor vehicle ownership is also interesting from an energy perspective as life cycle analyses show that the manufacture of motor vehicles accounts for a high proportion of total emissions.

Within the Norwegian research centre ZEN – Zero Emission Neighbourhoods (www. fmezen.no), life cycle analyses are used to model emissions in new neighbourhoods. The life cycle analyses are based on key ratios according to Norwegian standards and also include the manufacturing phase of both used buildings and vehicles. The key figures used show that manufacture itself accounts for about 30 percent of the total emissions of a normal size new diesel vehicle during its lifetime. For a medium-sized electric vehicle (with Norwegian electricity),the corresponding proportion is 90 percent.

In terms of total emissions, a normal sized electric vehicle has half as much emissions as a normal sized diesel vehicle during its lifetime. Meanwhile, a large electric vehicle driven in Europe has only 27 percent lower total emissions compared to an average vehicle in Norway.

The life cycle analysis thereby shows that vehicle ownership itself is of great importance in reducing greenhouse gas emissions. In particular, this is very low in electric vehicles so the manufacture will in itself be associated with major emissions, unless new technologies are developed to produce electric vehicles.


LOCATION DATA
STATISTICAL ANALYSIS
TRAVEL DATA
EXPLANATORY MODEL

2. METHOD

2.1. COMPILATION OF TRAVEL DATA

TRAVEL SURVEY DATA RVU 2017

Travel data has been collected from the latest travel survey (Göteborgs stad et al 2018) within the West Swedish Agreement. The questionnaire consisted partly of a background section with questions concerning the household and the individual, partly by a travel journal with questions about all trips made by the individual during a particular day of measurement. The measurement period lasted for over three months from mid-August to mid-November. RVU 2017 includes both weekday trips (Monday – Friday) and weekend trips (Saturday – Sunday).

Linking travel data to geographic areas has been a prerequisite for the study. Residential areas as well as starting points and destinations for each trip are given in the RVU, not where the workplace is located, for example. We have therefore chosen to sort the travel habits based on the place of residence. Partly because there is reason to believe that the location data of the residential area has a major impact on how we travel as at least one daily trip takes place from the residence and one return trip to the residence (normal case). Partly, to reflect the purpose of the report to produce indicators that are useful in community planning where residential planning is an important part.

In total, 19,000 trips performed by 6,000 different respondents within 42 different areas were used to summarise the travel data. It is partly about entire municipalities and, in Gothenburg, Mölndal and Kungsbacka, also municipal districts. Styrsö and Öckerö have been removed from the results as they risk functioning as outliers on the basis of their distinctive travel habits as a result of their geographical prerequisites. The number of journeys taken within the used geographical areas varies between 196 and 1,540. On average, 453 trips have been made by 144 people per area.

Of course, RVU data from a greater number and smaller geographical areas had been preferable but such travel data has not been possible to produce.

In order not to exclude areas with too few journeys, we have chosen not to distinguish journeys based on length.

In summation, the travel data used in the static analysis has the following delimitations

- Trips made by residents 16-84 years old
- Trips with starting point and destination within the region.
- Journeys registered by main mode of transport (if multiple modes of transport have been used, the mode of transport used on the longest part of the route is registered)
- Only everyday trips.
- Weighted to reflect journeys throughout the year.
- Journeys sorted by the respondent's residential area, which corresponds to finely differentiated areas for Gothenburg, Mölndal and Kungsbacka, and entire municipalities for the remaining areas.
- Styrsö and Öckerö have been excluded because their travel habits differ greatly from other municipalities.

Based on these limitations, the following data has been compiled:

- Journey length vehicle/day/respondent
- Number of vehicle journeys/day/respondent
- Number of public transport journeys/day/respondent
- Number of pedestrian and cycling journeys/day/respondent

MOTOR VEHICLE OWNERSHIP

In order to also study the location indicators that can explain vehicle ownership, data from Statistics Sweden on 500-metre squares has been collected. Data from Statistics Sweden includes details from the register of vehicles per resident over 18 years old. However, Statics Sweden's data does not include company vehicles. With reference to a previous study carried out in Stockholm (Spacescape 2018), actual vehicle ownership, including company vehicles, may be 20 percent higher.

SOCIO-ECONOMIC CONTROL VARIABLES

In previous studies (Spacescape 2018), socio-economic control variables have proven to be important for a high degree of explanation in developed models. We have therefore also collected data from RVU on median income and proportion of households with children per area.

2.2 COMPILED LOCATION DATA

With the help of GIS analyses, a greater number of hypothetical location indicators have been compiled and tested as independent variables in the statistical liaison analysis. The selection has been made based on previous research and is categorised on the five most common explanatory factors in research (the 5 Ds). As a complement to the location data, the following socio-economic control variables have also been compiled: median income, level of education, proportion of households with children.

SUMMATION OF LOCATION DATA

When the RVU data is summated in significantly larger areas than the location data, different forms of summated location data has been tested. Based on different tests, the summation of average value per residence has proved to have a greater degree of explanation than just the average of the developed 500-metre squares within the areas. The average value per residence was calculated using the "weighted average" function in Mapinfo. (GIS software). This means that the significance of the 500-metre squares for the average value per area is determined by how many people live on each 500-metre square.

MAPPED LOCATION DATA

The details for mapped location data have been delivered from GR on 500-metre squares. In the next step, hypothetical location indicators have been compiled and summarised per RVU area. Access has been mapped both within each respective square within 1 km, 3 km and 5 km. The location data concerning the number of workplaces accessible with different means of transport within 15, 30 and 45 minutes has also been compiled. A total of around 200 hypothetical location indicators have been compiled.

DESTINATION AVAILABILITY

- Distance to regional centre, primary locality and secondary locality (according to GR's typologies) and distance to major locality over 25,000 inhabitants
- Accessible for day population by motor vehicle and public transport in different time ranges and quota
- Accessible for night population by motor vehicle and public transport with different time ranges and quota
- Number of people employed in the wholesale trade, food retail, outgoing culture, café/restaurant, other commercial services, urban activities, primary and preschool
- Number of service categories

DISTANCE TO PUBLIC TRANSPORT

- Rail station
- Bus stop
- Express bus stops
- Frequency for express bus stops
- Commuter parking

DENSITY

- Nighttime population
- Daytime population
- Total population
- Proportion single-family houses

DIVERSITY

- Proportion nighttime population,
- Functional mix, nighttime and daytime populations.

DESIGN

- Proximity to motorway
- Number of street crossings per hectare
- Street length per hectare
- Street length per resident and employed.

2.3 STATISTICAL ANALYSIS OF RELATIONSHIPS

In order to identify the location data affecting travel habits from RVU for the West Swedish Agreement (Göteborgs stad 2017) and motor vehicle ownership (SCB 2019), a large amount of location data and socio-economic data has been summated per area where RVU data is available.

MULTIPLE REGRESSION ANALYSIS

In the next step, a so-called multiple regression analysis has been used. A similar method was used in the study "Enkla planindikatorer för trafik" (*Simple plan indicators for traffic*) that Spacescape together with Evidens conducted for the traffic office in Stockholm City (Spacescape 2018). In statistics, multiple regression is a technique by which one can investigate whether there is a statistical correlation between a dependent variable and two or more explanatory (independent) variables. In this case, motor vehicle ownership and number of journeys with various means of transport as well as journey length by motor vehicle, on average per RVU area, have been dependent variables. The hypothetical location indicators have since been tested as independent variables along with the socio-economic data as control variables. Socio-economic variation is likely to be of great significance for the overall degree of explanation and is therefore important to include in order to identify with greater certainty the unique significance of the other location indicators for travel habits.

In a first step, individual correlations between various independent variables and the dependent variables have been studied. This correlation indicates the strength and direction of a link between them. A significant link means that random factors can be excluded. The variables that show a high correlation and are significant have then been further tested in a multiple regression analysis.

Several independent variables have been added to the multiple regression analysis to increase the degree of explanation. If more independent variables, together with the first, increase the degree of explanation (the model's adjusted r2 value from 0 to 1) and all variables show a significant link and are not concurrent, the regression model will evolve further.

STATISTICAL REQUIREMENTS

To ensure that the proposed location indicators and the models created to explain travel habits and motor vehicle ownership are statistically credible, a number of requirements have been set.

- The degree of explanation for this model should be higher than 50 percent (i.e. an adjusted r2 value of more than 0.5)
- The significance value of the constituent independent variables should not exceed 0.05
- The constituent variables should not have a higher multicollinearity (covariation) than 4 in VIF value
- The number of variables in the explanatory models should not be more than six. Too many variables make the models difficult to use when planning
- External quality review (Anna Clark, Trivector)

3. LOCATION INDICATORS FOR TRAVEL HABITS

LOCATION INDICATORS FOR CAR OWNERSHIP (SCB) PER PERSON

Motor vehicle ownership has been compiled from data from Statistics Sweden on the number of vehicles per person over 18 years and therefore constitutes the actual motor vehicle ownership and not the estimated motor vehicle ownership from an RVU.

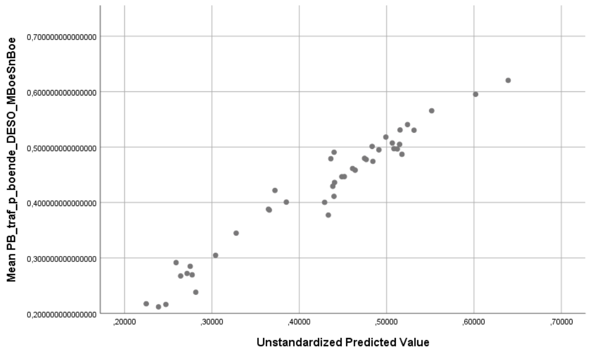
On average, motor vehicle ownership is 43 percent per person over 18 years in the analysis area. Motor vehicle ownership is lowest in central Gothenburg and highest in southern Kungsbacka.

In a previous study on simple plan indicators for traffic in greater Stockholm, motor vehicle ownership from Statistics Sweden was explained to 88 percent with the proportion of single-family houses (or house size), proximity to the regional centre, street length per person, proximity to rail station, density and income (Spacescape 2018).

The present study explains the distance to the regional centre, proportion of single-family houses and street length per person being 95 percent of the variation in motor vehicle ownership per person. The strong statistical relationships and the reference to the Stockholm study suggest that the location indicators found are of great significance for motor vehicle ownership.

The model's effect relationships show that a 100 percent increase in the proportion of single family houses leads to a 23 percent increase in motor vehicle ownership. This result can be interpreted as reducing motor vehicle journeys in municipal districts and municipalities where people live more compactly and where the proximity to the regional centre is good.

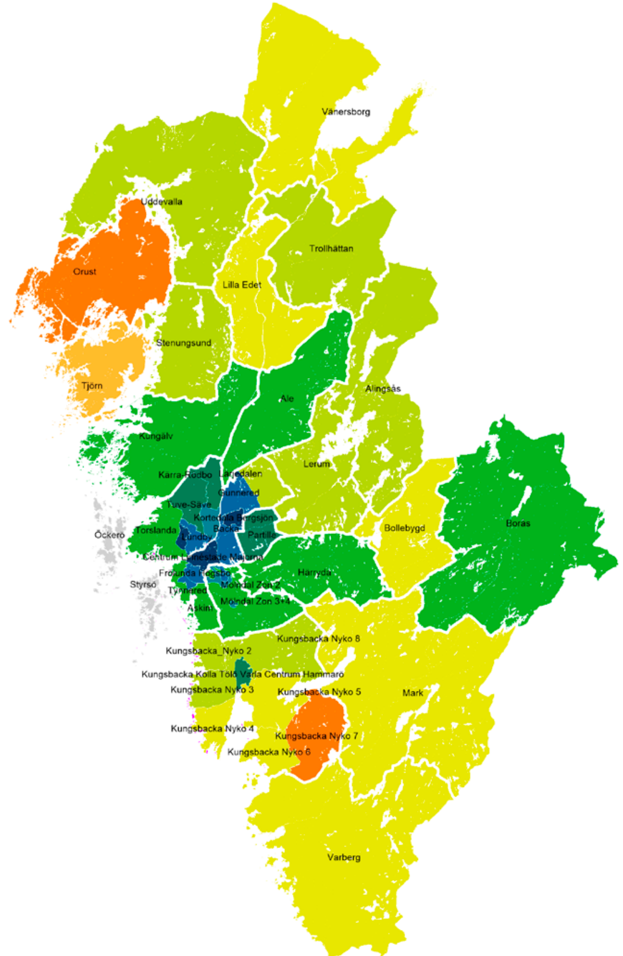
Proportion single-family houses (+)
Distance to regional centre (+)
Street length per person (+)



REGRESSION MODEL EXPLAINS 95% OF THE VARIATION IN NUMBER OF MOTOR VEHICLES PER PERSON

The regression model with the three location indicators has an adjusted r2 value of 0.95. The model contains 42 areas. All explanatory variables have a significance level of below 1%. All VIF values are below 2, which indicates that the independent variables in the model do not covariate. Overall, this model meets the statistical requirements.

Regression formula: y = 0.215 + (distance to regional centre in metres * 0.00000147) + (Proportion of single-family houses * 0.229) + (street length per person within 1 km * 0.001)



MAP: MOTOR VEHICLES PER PERSON

>0.65 ■ 0.65 ■ 0.6 ■ 0.55 ■ 0.5 ■ 0.45 ■ 0.4 ■ 0.35 ■ 0.3 ■ 0.25 ■ < 0.25

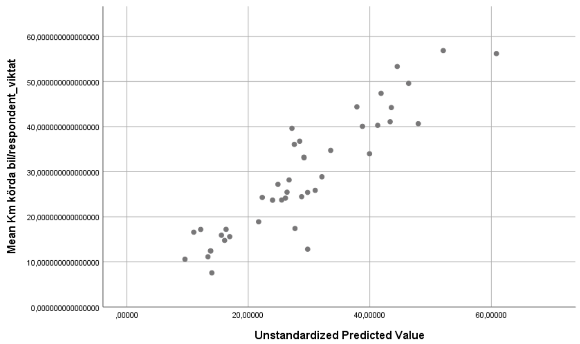
LOCATION INDICATORS FOR DRIVING DISTANCE BY MOTOR VEHICLE PER PERSON

The difference in journey distances by motor vehicles within the RVU area is very large. The residents of Åsa/Frillesås in Kungsbacka Municipality and the residents of Orust municipality drive the furthest. The distance travelled per person in Gothenburg is the shortest followed by Alingsås. A pattern can be discerned where journey length by motor vehicle increases with distance to central Gothenburg up to a certain distance and then decrease again near the larger urban areas on the outer edges of the RVU area.

The statistical analysis shows that the proximity to larger urban areas (over 25,000 inhabitants), proximity to regional centres, low proportion of single-family houses and short street lengths per person generate shorter driven distances per person.

The identified location indicators for journey length by motor vehicle are the same as for motor vehicle ownership but with the addition that even proximity to larger urban areas is important. For example, a 50 percent higher proportion of single-family houses would result in driving distances by motor vehicle increasing by 7.5 km per person and day.

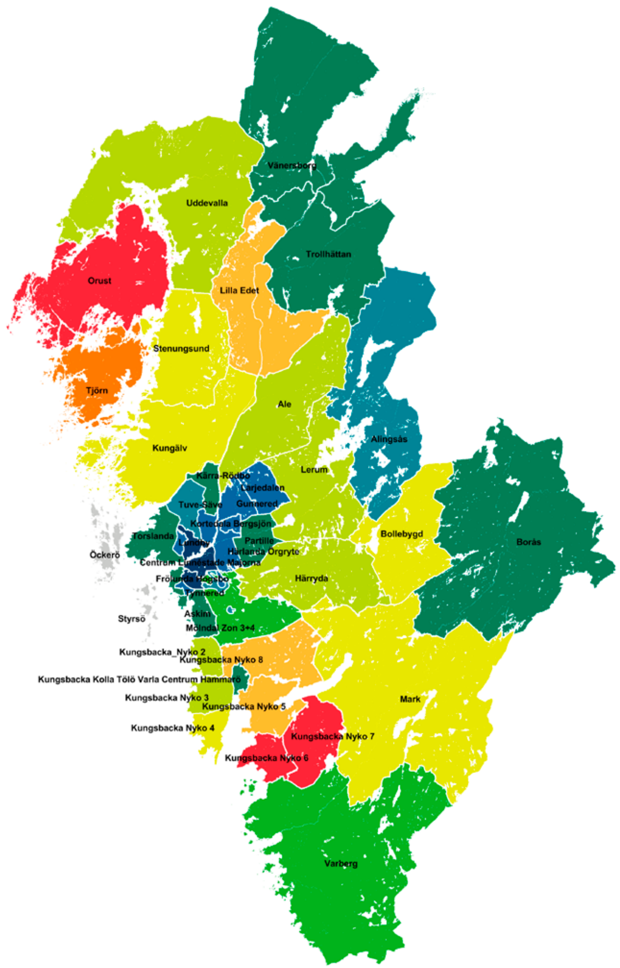
Distance to major urban area (+)
Proportion single-family houses (+)
Street length per person (+)
Distance to regional centre (+)



REGRESSION MODEL EXPLAINS 82% OF THE VARIATION IN JOURNEY LENGTH BY MOTOR VEHICLE

The regression model with the two location indicators and a control variable has an adjusted r2 value: 0.82. The model contains 42 areas. All explanatory variables without proximity to the regional centre have a significance level of below 5%. Proximity to the regional centre has a significance level of 7.5%. All VIF values are below 3, which indicates that the independent variables in the model do not covariate. Overall, the model has nevertheless been judged plausible based on statistical requirements.

Regression formula: y = 7.564 + (distance to regional centre in metres * 0.0000832) + (proportion of single-family houses * 14.99) + (street length per person within 1 km * 0.145) + (distance to cities over 25,000 inhabitants * 0.00106)



MAP: KM MOTOR VEHICLE JOURNEYS/PERSON/DAY

>53 53 47.8 42.6 37.4 32.2 27.6 22.4 17.2 12 < 12

LOCATION INDICATORS FOR NUMBER OF MOTOR VEHICLE JOURNEYS PER PERSON

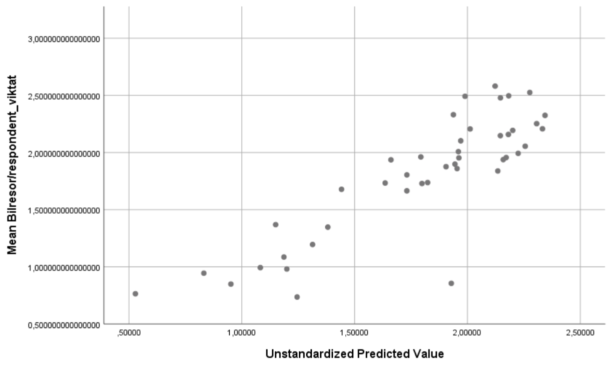
Number of motor vehicle journeys per person follows a similar pattern as driving distance by motor vehicle. The least number of motor vehicle journeys per person is in the central parts of Gothenburg and the highest number of journeys in southern Kungsbacka, Lerum and Stenungssund.

The statistical analysis shows that the number of motor vehicle journeys per person has a strong corelation with proximity to the regional centre and crossing density together with the median income control variable. The farther away from Gothenburg and the farther it is between crossings in the street network, the higher the number of motor vehicle journeys generated.

Proximity to the regional centre tends to be of a great significance in the inner part of the RVU area, which can be used as a common labour market and where motor vehicle commuting to Gothenburg is common.

If proximity to the regional centre reflects to some extent the competitiveness of public transport and access to destinations within walking and cycling distances, high crossing densities may reflect an urban environment that more prioritises pedestrians and cyclists above motor vehicle traffic. One example of this is Alingsås. An increase of 10 crossings within 1 km walking distance reduces the number of car journeys by 18 percent. An increase in median income by SEK 10,000 increases the number of motor vehicle journeys by 10 percent. 1 km distance from the regional centre increases the number of motor vehicle journeys by 1 percent.

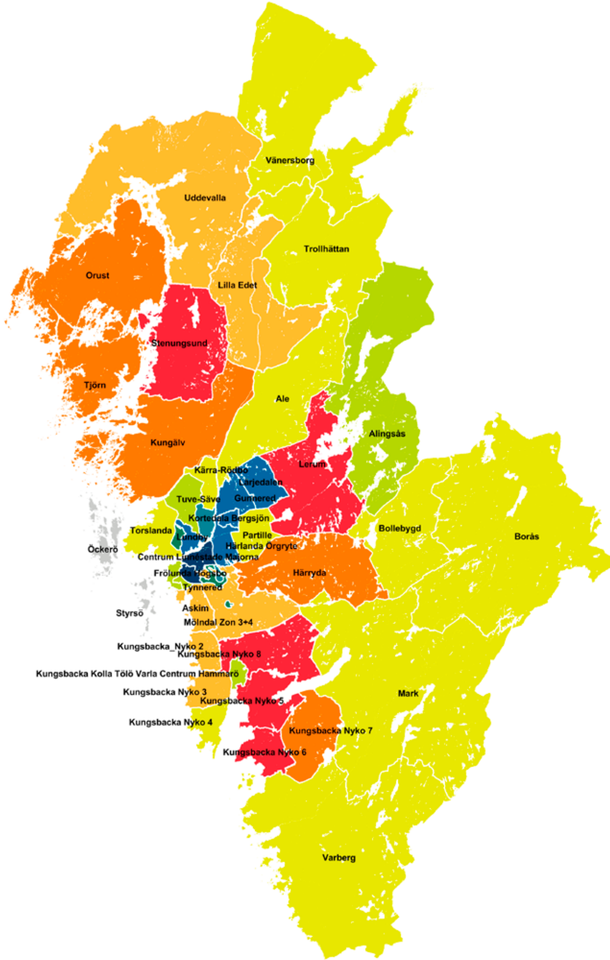
Distance to regional centre (+)
Crossing density within 1 km (–)
Control variable: Median income (+)



REGRESSION MODEL EXPLAINS 72% OF THE VARIATION IN NUMBER OF JOURNEYS PER PERSON WITH MOTOR VEHICLE

The regression model with the two location indicators and a control variable has an adjusted r2 value: 0.72. The model contains 42 areas. All explanatory variables have a significance level of below 1%. All VIF values are below 2, which indicates that the independent variables in the model do not covariate. Overall, this model meets the statistical requirements.

Regression formula: y = 0.146 + (walking distance to regional centre * 0.000012) + (median income * 0.0000062) + (crossings within 1 km * -0.019)



MAP: NUMBER OF MOTOR VEHICLE JOURNEYS PER PERSON

>2.4 ■ 2.4 ■ 2.2 ■ 2 ■ 1.8 ■ 1.6 ■ 1.4 ■ 1.2 ■ 1 ■ 0.8 ■ < 0.8

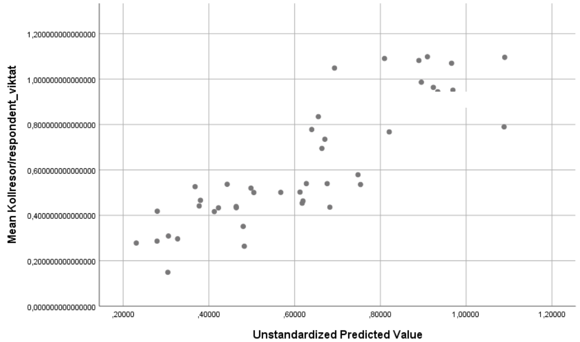
LOCATION INDICATORS FOR NUMBER OF JOURNEYS WITH PUBLIC TRANSPORT PER PERSON

Most journeys with public transport are made by the residents just north of Gothenburg city centre, followed by the inner city and other local suburbs and then Askim. The northern parts of Hisingen and Ale also have relatively many journeys by public transport. The least number of public transport journeys is made on Orust as well as Vänersborg and Fjärås in Kungsbacka Municipality, on Tjörn and Stenungsund.

Proximity to the regional centre and access to regional public transport, more specifically the rail station or express bus with more than 100 departures per day within 1 km, is of great importance for the number of public transport journeys. Median income is also significant. A higher median income favours motor vehicle traffic and a lower favours public transport.

This result can be interpreted as public transport being more competitive the closer to central Gothenburg you live. 1 km closer to the regional centre increases the number of public transport journeys by just under 1 percent. This result also shows that it is not the closeness to any form of public transport that is of weight. It is rapid and frequent public transport that makes a difference when it comes to choosing means of transport. Access to either a rail station or express bus (with over 100 departures per day) means an increase in the number of public transport journeys of 23 percent. An increase in median income of SEK 10,000 leads to a reduction of 2 percent in the number of public transport journeys.

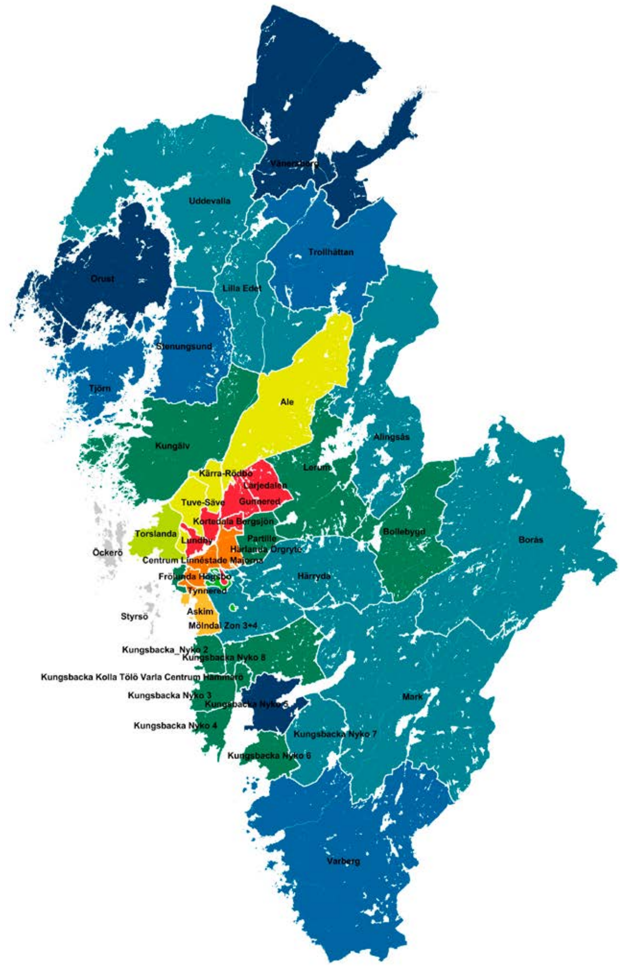
Distance to regional centre (–)
Access to regional public transport (+)
Control variable: Median income (–)



REGRESSION MODEL EXPLAINS 71% OF THE VARIATION IN NUMBER OF JOURNEYS PER PERSON WITH PUBLIC TRANSPORT

The regression model with the two location indicators and a control variable has an adjusted r2 value of 0.71. The model contains 42 areas. All explanatory variables have a significance level below 5% and all VIF values are below 2, which indicates that the independent variables in the model do not covariate. Overall, this model meets the statistical requirements.

Regression formula: y = 1.26 + (walking distance to regional centre *-0.000007 + median income *-0.0000019) + (train station or express bus with more than 100 departures per day within 1 km walking distance * 0.227)



MAP: PUBLIC TRANSPORT JOURNEYS PER PERSON

>1 1 0.91 0,82 0.73 0.64 0.55 0.46 0,37 0.28 <0.28

LOCATION INDICATORS FOR NUMBER OF BICYCLE JOURNEYS PER PERSON

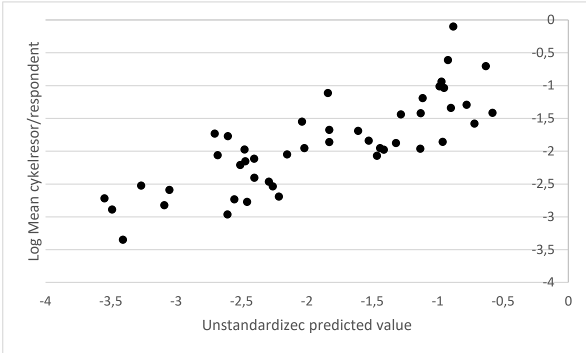
Most bicycle journeys are made today in the most central parts of Gothenburg. Outside Gothenburg, Trollhättan is the municipality with the highest number of bicycle journeys per person. The fewest journeys by bicycle take place in the eastern parts of Kungsbacka and Orust.

The local crossing density and the distance to major urban areas above 25,000 inhabitants have a significant impact on the number of bicycle journeys. Crossing density increases the number of bicycle journeys and distance to urban areas reduces the number of journeys per person.

Statistical analyses indicate a logarithmic correlation between the two location indicators and the number of bicycle journeys per person. This could be interpreted so that it is above all a short distance to major urban areas and a high crossing density that is of great significance for the number of bicycle journeys.

These effect relationships show that 1 km closer to a major urban area leads to 5 percent more bicycle journeys per person. If the crossing density increases by 10 within a 1 km walking distance, it will lead to a 30 percent increase in bicycling according to the model. Probably more than just crossing density are needed to create a more bicycle-friendly urban environment. But the strong effect relationship may be due to the fact that the urban environments in the region that have a high crossing density are likely to also have other qualities associated with a bicycle-friendly urban environment. However, these qualities have not been measurable and evaluated within the scope of this study.

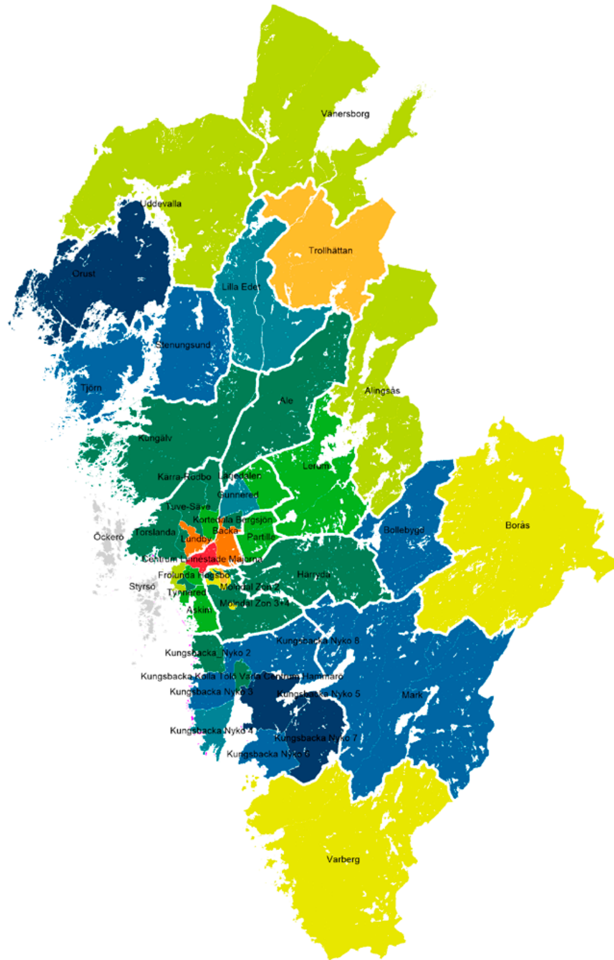
Crossing density (+)
Distance to major urban areas (–)



REGRESSION MODEL WITH LOGARITHMISED NUMBER OF BICYCLE JOURNEYS EXPLAINS 64% OF THE VARIATION IN THE NUMBER OF JOURNEYS PER PERSON BY BICYCLE

The regression model with the two location indicators and a control variable has an adjusted r2 value of 0.64. The number of bicycle journeys in the model has been logarithmised where minus values occurred. There is a greater tendency for normally distributed values with a logarithmised value. The logarithmised model therefore also provides more plausible effect relationships. All explanatory variables have a significance level of below 1%. Overall, the logarithmised model meets the statistical requirements.

Regression formula: lnY = -2.16-(distance to urban areas over 25,000 inhabitants in metres * 0.00005) + (number of crossings within 1 km walking distance * 0.02774)



MAP: BICYCLE TRIPS PER PERSON

>0.45 ■ 0.45 ■ 0.4 ■ 0,35 ■ 0.3 ■ 0.25 ■ 0.2 ■ 0.15 ■ 0.1 ■ 0.05 ■ < 0.05

LOCATION INDICATORS FOR NUMBER OF PEDESTRIAN JOURNEYS

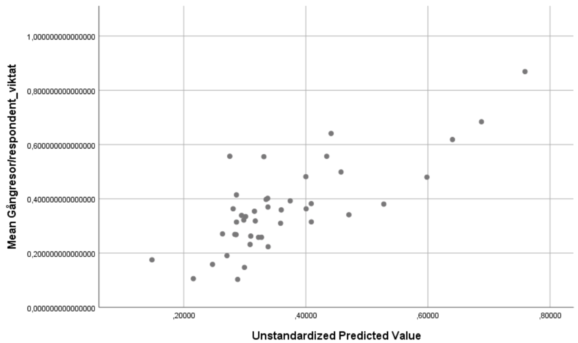
Most pedestrian journeys are made in the most central parts of Gothenburg. But Alingsås also has a large number of pedestrian journeys. The least pedestrian journeys per person takes place in large parts of Kungsbacka, Orust and Lärjedalen. The number of pedestrian and cycling journeys refers here to main journeys and not partial pedestrian and bicycle journeys, such as the way to a bus stop or car park.

The local crossing density and function mix have a positive effect particular on the number of pedestrian journeys. The crossing density is measured here by the total number of crossings in the street network within 1 km. Function mixing is measured with an index where a high mix between living and working gives a higher value. The proximity to the regional centre is also of general importance.

This result can be interpreted as a function mix and well-interconnected urban environments generate more pedestrian journeys. Function mix was also found among indicators in the aforementioned Stockholms study (Spacescape 2018).

The effect relationships show that the distance to the regional centre provide small but significant relationships. If the number of crossings increases with 10 within 1 km, the number of pedestrian journeys increases by 5 percent. Probably more than just crossing density are needed to create a more pedestrian-friendly urban environment. But the strong effect relationship may be due to the fact that the urban environments in the region that have high crossing density are likely to also have other qualities associated with a pedestrian-friendly urban environment. However, these qualities have not been measurable and evaluated within the scope of this study.

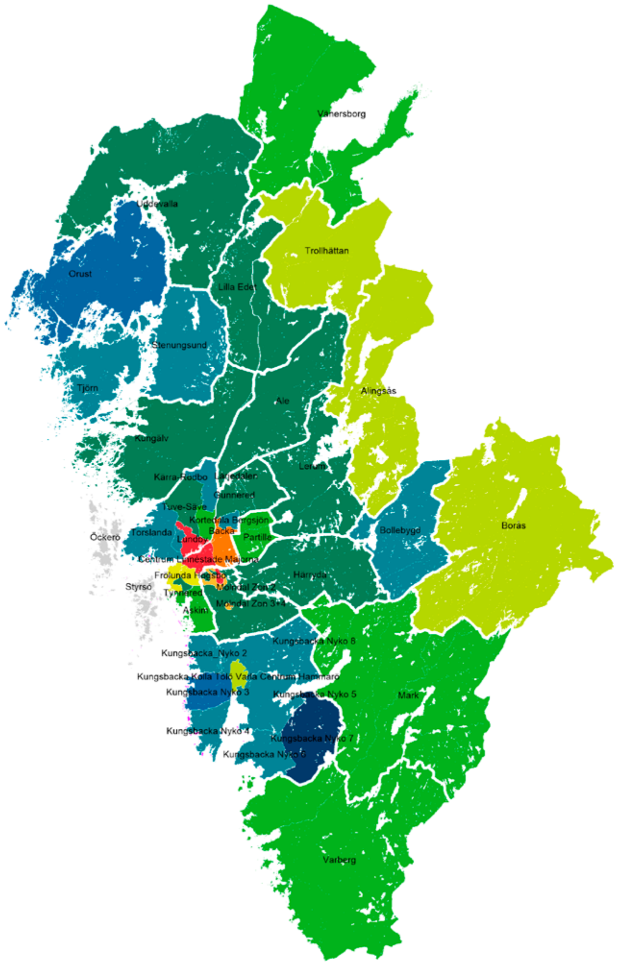
Crossing density (+)
Function mix (+)
Distance to regional centre (–)



REGRESSION MODEL EXPLAINS 57% OF THE VARIATION IN NUMBER OF JOURNEYS PER PERSON WITH PUBLIC TRANSPORT

The regression model with the two location indicators and a control variable has an adjusted r2 value of 0.57. The model contains 42 areas. All explanatory variables have a significance level of below 5%. All VIF values are below 3, which indicates that the independent variables in the model do not covariate. Overall, this model meets the statistical requirements.

Regression formula: y = 0.093 + (walking distance to regional centre *-0.0000016) + (number of crossings within 1 km walking distance * 0.005) + (mix of residents and working (indexes where higher mix yields higher value) * 0.563)



MAP: PEDESTRIAN JOURNEYS PER PERSON

>0.6 0.6 0.55 0,5 0.45 0.4 0.35 0.3 0.25 0.2 <0.2

4. MODELLED TRAVEL HABITS AND MOTOR VEHICLE OWNERSHIP IN STATION SOCIETIES

METHOD

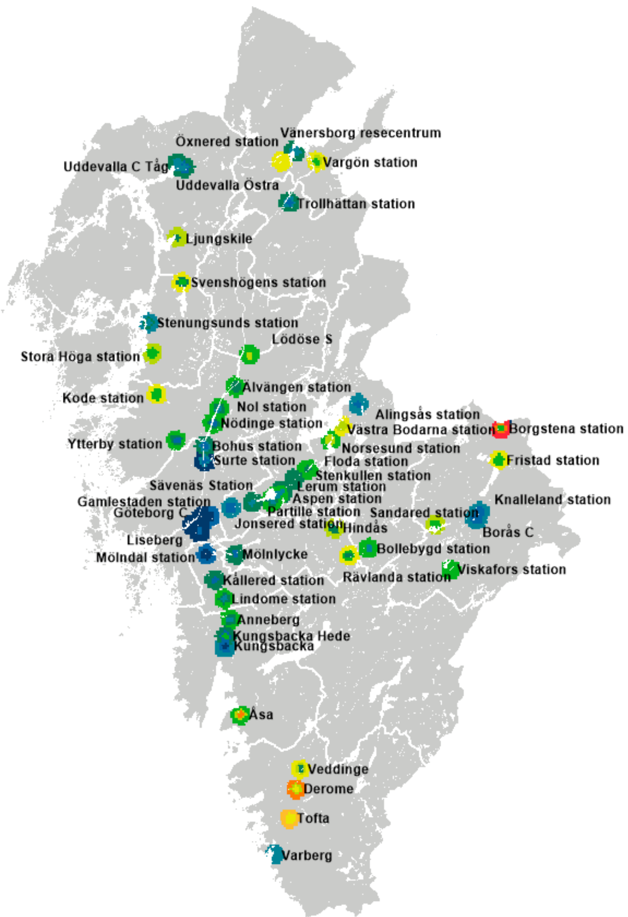
With the help of developed regression formulas, travel habits, driving distance with motor vehicle and motor vehicle ownership have been modelled within 500 metres and 1 km from each station society.

MODELLED MOTOR VEHICLE OWNERSHIP

Modelled motor vehicle ownership shows a clear pattern where proximity to the regional centre is of great significance but where there are also significant differences between the nearby areas around stations.

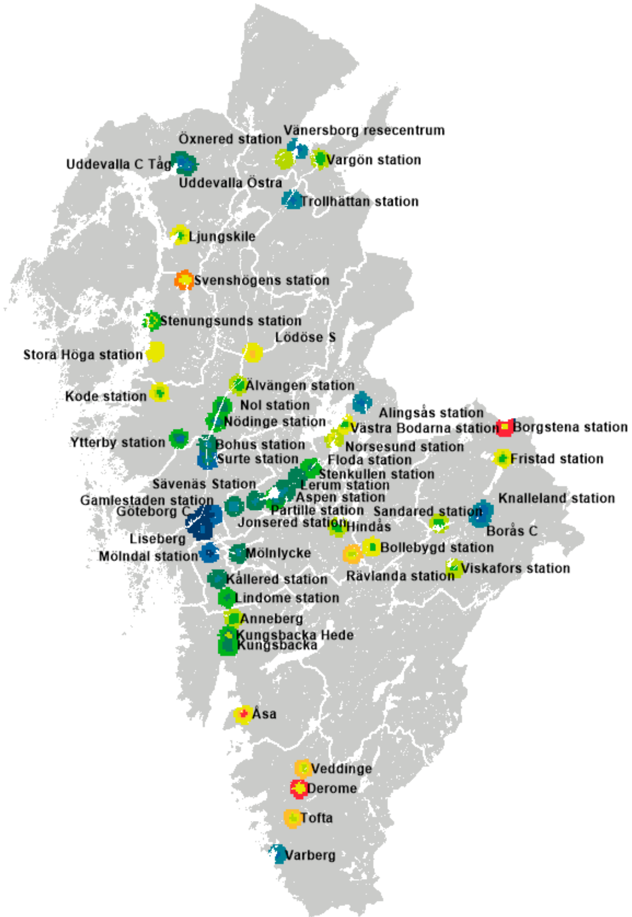
MODELLED JOURNEY DISTANCE BY MOTOR VEHICLE

The highly modelled journey distance by motor vehicle can be found in areas a little further away from the stations in Kode (Kungälv), Borgstena (Borås) and Tofta (Varberg). At the other end of the spectrum, we see that it is not only the regional centre that gets low modelled journey distances by motor vehicle, the same goes for the most central parts of Vänersborg, Trollhättan, Uddevalla, Stenungsund, Alingsås, Borås and Varberg.



MAP: MODELLED MOTOR VEHICLE OWNERSHIP PER PERSON

>0.71 0.71 0.66 0,61 0.56 0.51 0.46 0.41 0.36 0.31 <0.31



MAP: MODELLED JOURNEY DISTANCE WITH MOTOR VEHICLE KM/PERSON/DAY

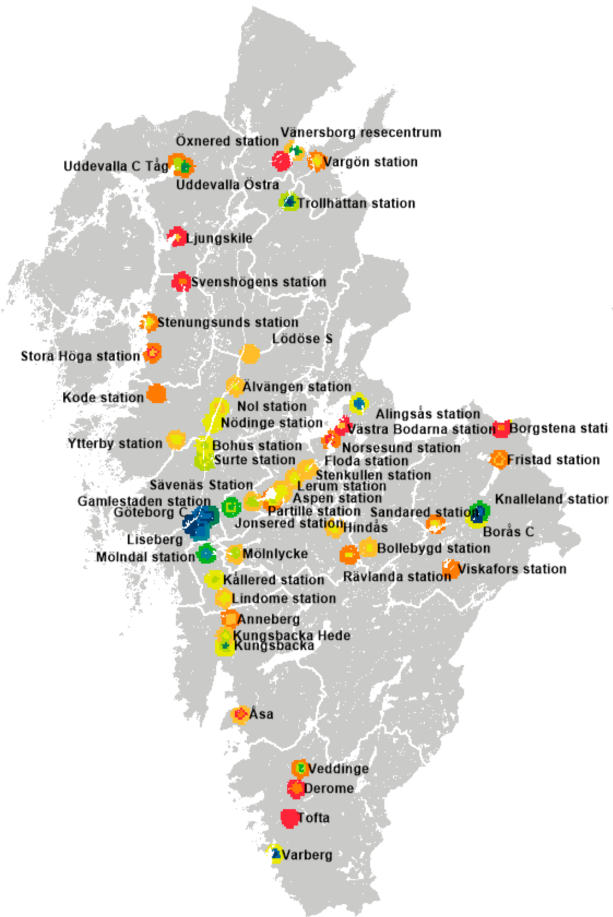
>53 53 47.8 42.6 37.4 32.2 27.6 22.4 17.2 12 < 12

MODELLED NUMBER OF MOTOR VEHICLE JOURNEYS

Areas in central Gothenburg have the lowest number of modelled motor vehicle journeys and have slightly lower values than most station-near locations in Mölndal, Borås, Varberg, Vänersborg, Trollhättan and Alingsås. Although it is clear that the distance to the regional centre is shown in the map image, we also see that crossing density within 1 km makes a big impact. In Alingsås, Borås and central Kungsbacka amongst other places.

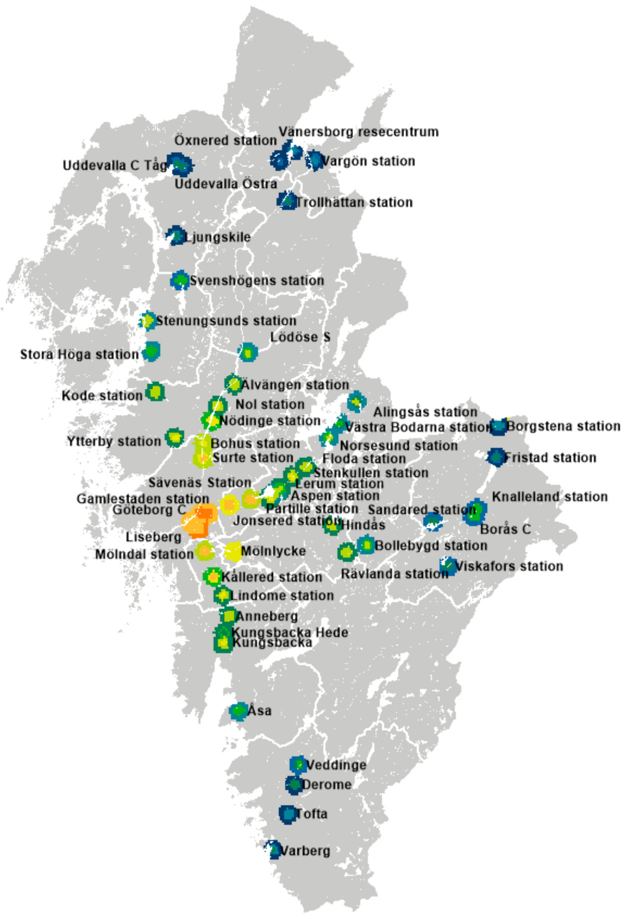
MODELLED NUMBER OF PUBLIC TRANSPORT JOURNEYS

As regards the number of public transport journeys, the map shows approximately the opposite pattern. The highest number of modelled trips is in central Gothenburg. However, there are also other differences in the number of motor vehicle journeys as the average distance to express public transport is a location indicator for public transport. This is reflected, among other things, in Surte and Rävlanda having a high number of modelled public transport journeys per person compared to many other station communities a corresponding distance away from the regional centre.



MAP: MODELLED NUMBER OF MOTOR VEHICLE JOURNEYS/ PERSON

>2.4 ■ 2.4 ■ 2.2 ■ 2 ■ 1.8 ■ 1.6 ■ 1.4 ■ 1.2 ■ 1 ■ 0.8 ■ < 0.8



MAP: MODELLED NUMBER OF PUBLIC TRANSPORT JOURNEYS/PERSON

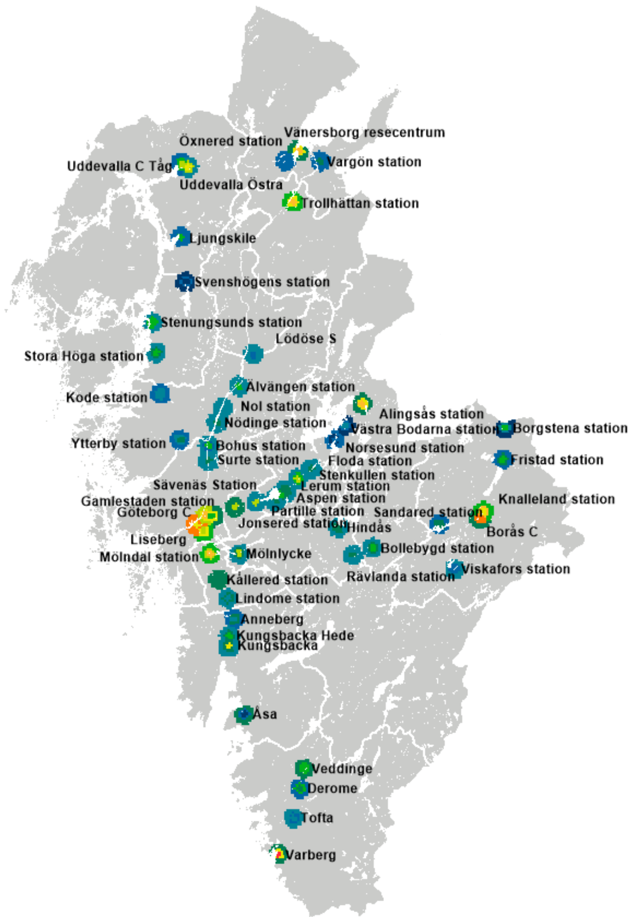
>1 ■ 1 ■ 0.91 ■ 0,82 ■ 0.73 ■ 0.64 ■ 0.55 ■ 0.46 ■ 0,37 ■ 0.28 ■ <0.28

MODELLED NUMBER OF PEDESTRIAN JOURNEYS

The map of modelled pedestrian journeys distinguishes itself from previous maps by incorporating many low-value areas and only a few places with high-rated pedestrian/bicycle journeys. In addition to central Gothenburg, we see high rated values in Alingsås, Borås, Uddevalla and Trollhättan in particular.

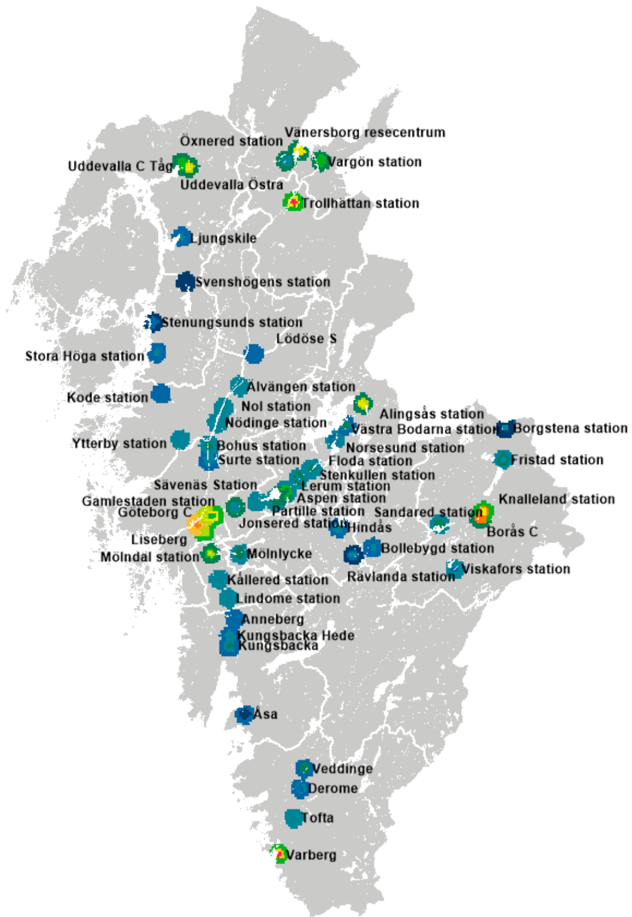
MODELLED NUMBER OF BICYCLE JOURNEYS

To model the number of bicycle journeys simply, a linear regression formula has been used, unlike the logarithmic formula previously proposed to better estimate the effect relationship (y = 0.117 + distance to cities over 25,000 inhabitants *-6.941 + the number of crossings within 1 km walking distance * 0.006).



MAP: MODELLED NUMBER OF PEDESTRIAN JOURNEYS/PERSON

>1.2 ■ 1.2 ■ 1.09 ■ 0,98 ■ 0.87 ■ 0.76 ■ 0.65 ■ 0.54 ■ 0.43 ■ 0.32 ■ <0.32



MAP: MODELLED NUMBER OF BICYCLE JOURNEYS/PERSON

>1.2 ■ 1.2 ■ 1.09 ■ 0,98 ■ 0.87 ■ 0.76 ■ 0.65 ■ 0.54 ■ 0.43 ■ 0.32 ■ <0.32

5. CONCLUSIONS

CONCLUSIONS

DETECTED LOCATION INDICATORS ARE FIRMLY ANCHORED IN RESEARCH AND EASY TO IDENTIFY

Of the identified location indicators, proximity to the regional centre has consistently been of great significance for the balance between motor vehicle journeys and other modes of transport. The distance to the regional centre increases motor vehicle ownership and motor vehicle journeys, while the proximity to the regional centre instead increases the number of public transport journeys and pedestrian journeys. Proximity to the regional centre is also a location indicator as Petter Naess in his meta analyses "Urban Form and Travel Behavior: Experience from a Nordic Context" identified as being of fundamental importance to which distribution of transport modes is generated (Naess 2012). Proximity to the regional centre can also be said to be included in Ewing & Cervero's "5 Ds" (destination availability). The proximity of the regional centre is likely to be a location indicator that accommodates many dimensions of significance. An increased distance can, for many, mean an increased commuting distance since many in the region work or study in the regional centre, after all. With increased commuting distance, the competitiveness of the motor vehicle may well increase. But the distance can also affect the general availability of pedestrian/bicycle and public transport to other forms of everyday destinations, which also Naess points out. Possibly, access to car parks can also be better and cheaper the further away from the regional centre you get. Access to parking has not been possible to compile for the various areas.

Even proximity to larger urban areas proved to be a valuable location indicator. With proximity to larger urban areas, bicycle journeys increase while the number of kilometres ridden per year decreases.

A location indicator that neither Naess nor Ewing & Cervero previously identified but which here has been shown to have great significance for motor vehicle ownership number of kilometres driven per year is the proportion of single-family houses. The proportion of single-family houses also proved to be important in explaining motor vehicle ownership in the Stockholm region. With a high proportion of single-family houses, parking is likely to be good. It is also possible that areas of single-family houses are usually situated in places that favour motor vehicle traffic in terms of how the streets and the surrounding urban environment are laid out. Or that single-family house ownership itself increases motor vehicle journeys due to own repairs, etc. Based on the theory of the significance of the 5 Ds, the proportion of single-family houses could possibly be included in "density" or "design" but has no obvious affiliation in the model, as the concept of "design" mainly refers to the distribution and form of the street network. The proportion of single-family houses is not density either, since it is more about settlement typology. Areas of single-family houses can in some cases have a higher area exploitation than areas dominated by flats.

A location indicator that has not previously appeared in either Naess or Ewing & Cervero's meta analyses is the street length per person. The location indicator is important for both motor vehicle ownership and km per year. Street length per person can be said to be a measure of "sprawl" comprising the two aforementioned "Ds" "density"and "design". One theory may be that areas with a high street length per person favour motor vehicle traffic as accessibility is likely to be high, while it becomes harder to supply areas with a high street length per person with competitive public transport.

Crossing density also appeared to be significant for the number of motor vehicle journeys, pedestrian journeys and bicycle journeys. A high crossing density favours pedestrian and bicycling journeys, while a low crossing density increases the number of motor vehicle journeys. The crossing density can therefore be said to be an appropriate indicator for describing pedestrian and bicycle-friendly urban environments. It is plausible that it is easier to walk and cycle if there are many different route options. With shorter distances between crossings, the overall competitiveness of the motor vehicle can also be reduced as the difference in speed between transport modes is evened out. According to the theory of the 5 Ds, crossing density is a "design variable".

Proximity to fast public transport is proving to increase the number of public transport journeys. Interestingly, it was only the combination of a rail station or express bus with more than 100 departures per day within 1 km that was clearly significant for travel habits. Proximity in metres had no significance given the area boundary and travel survey data studied here. Neither did rail stations or a combination of rail stations and all the express bus stops. It is therefore seems that accessibility to the express bus stop within walking distance is only significant provided the frequency is high enough. Here, an in-depth study of the importance of service frequency for the number of public transport journeys could be interesting. Proximity to fast public transport can be said to be included in the 5 Ds with "distance to public transport" and in the Stockholm region had importance to both few motor vehicle journeys and a higher number of public transport journeys.

Mixing residents and workers within 1 km proves to be of great significance for the number of pedestrian journeys. A high mix gives more pedestrian journeys. This correlation was also shown to exist in the Ewing & Cervero meta analysis. One possible explanation may be that if the mix is high, and given all other variables are equal, the probability is also higher that residents have their place of work within close walking distance and therefore walk more. Another explanation could be that mixed urban environments have a generally greater diversity of services within walking distance, which in turn could explain the number of pedestrian journeys. In the categorisation of the 5 Ds influencing traffic, a mix of residents and workers is a commonly used indicator of "diversity".

Of the socio-economic control variables tested, median income was the only one that proved to have a significant impact on traffic generation. A higher median income increases the number of motor vehicle journeys and reduces the number of public transport journeys.

Summated, all models show a degree of explanation between 57 percent and 95 percent. Especially the models for motor vehicle ownership (95%) and driving distance (82%) have a high degree of explanation with three or four different location indicators. This probably gives the models a high use potential for further analysis of motor vehicle dependence and CO_2 emissions.

The found location indicators also confirm recognised research findings and show the significance of all the "5 Ds" (density, diversity, design, destination availability, distance to public transport). At the same time, the "proportion of single-family houses" location indicator is added as an additional significant location indicator. Interestingly, also the street length per person location indicator does not appear to have been used in previous studies but is important in both the Gothenburg region and the Stockholm region.

WHAT CAN BE REACHED WITHIN 1 KM WALKING DISTANCE HAS CRUCIAL IMPORTANCE FOR TRAVEL HABITS

Consistently, the study shows that a walking distance of 1 km is a significant range. It is mainly within 1 km that functional mixing, crossing density, street length per person and access to fast public transport affect travel habits. The other tested ranges (within 500-metre squares, 3 km and 5 km) have a significantly weaker connection with travel habits. The result also corresponds well with a previous study in the Stockholm region (Spacescape 2018).

THE INDIRECT SIGNIFICANCE OF DENSITY FOR TRAVEL HABITS

Density is a commonly used indicator of transport habits. In this study, density did not appear to be significant as an individual location indicator. At the same time, many of the found location indicators require a certain degree of density in order to exist. Nevertheless, a certain density is required in order for a frequent public transport service to function. The conclusion is probably rather that density itself is not enough. It must also be mixed, close to public transport and seamless.

RECOMMENDATIONS FOR FURTHER URBAN PLANNING

Presuming targets are set for reduced energy consumption, the following seven recommendations can be given for further urban planning:

1. Prioritise expansion near the regional centre

2. Prioritise expansion within 1 km from rail station or express bus stop with high frequency service

3. Construct residences where there are premises and construct premises where there are residences

4. Transform roads into streets

5. Limit the proportion of single-family houses

6. Increase the service frequency of express buses in suitable station communities

MODELS AND LOCATION INDICATORS TO EXPLAIN TRAFFIC GENERATION

MODELS	MOTOR VEHICLE OWNERSHIP	KM DRIVE BY MOTOR VEHICLE	NUMBER OF MOTOR VEHICLE JOURNEYS	NUMBER OF PUBLIC TRANSPORT JOURNEYS	NUMBER OF BICYCLE JOURNEYS	NUMBER OF PEDES-TRIAN JOURNEYS
DEGREE OF EXPLANATION	95%	82%	74%	71%	60%	57%
Proximity of regional centre	–	–	–	+		+
Proportion single-family houses	+	+				
Street length per person	+	+				
Distance to major urban areas		–			+	+
Crossing density			–		+	
Proximity to regional public transport				+		
Mix of residents and employed						+

FIG. SUMMATIVE MATRIX

The matrix presents location indicators and their impact on various types of journeys, km driven by motor vehicle and motor vehicle ownership.

AREAS OF USE OF THE LOCATION INDICATORS

1. KNOWLEDGE SUPPORT

Explains the connection between urban planning and travel habits and what it takes to increase the proportion of sustainable transport and reduce journey lengths by motor vehicle.

2. INTERACTION

Location indicators can provide a basis for increased cooperation between municipal transport and city building offices, and provide support common guidelines.

3. FOLLOW-UP

The location indicators can be used to support the follow-up of how conditions for sustainable travel habits change over time, for example in structure plans.

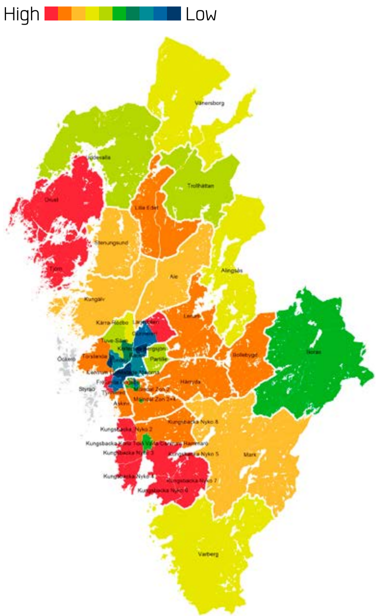
4. GUIDELINES

The indicators can be used as input to regional and municipal guidelines for development planning.

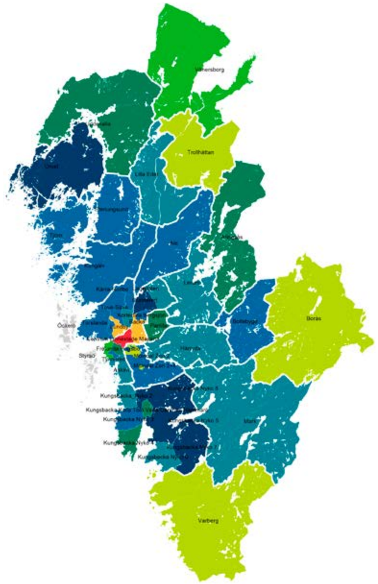
5. PLAN ANALYSIS

Travel habits and CO_2 emissions could be modelled by experimenting with alternative development scenarios or development plans in a structured GIS model.

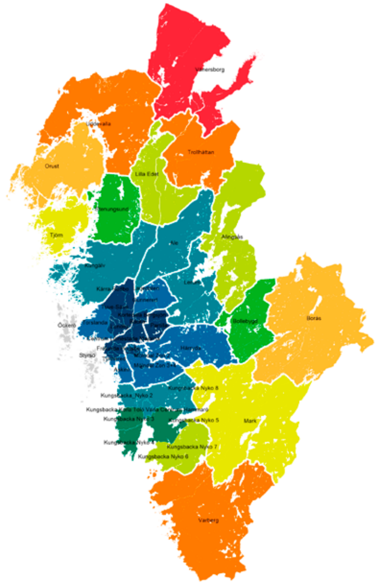
6. MAPPING OF LOCATION INDICATORS



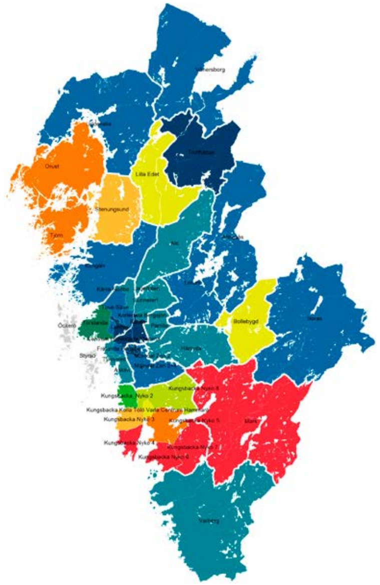
PROPORTION SINGLE-FAMILY HOUSES



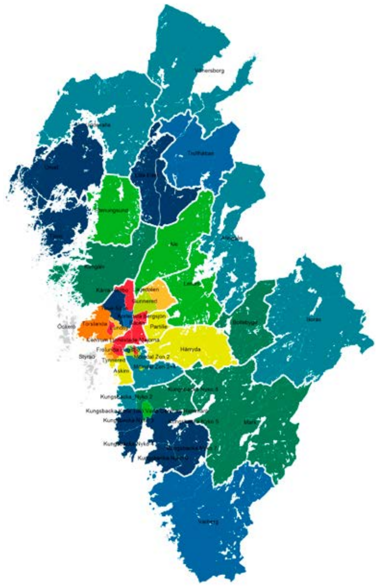
NUMBER OF STREET CROSSINGS WITHIN 1 KM WALKING DISTANCE



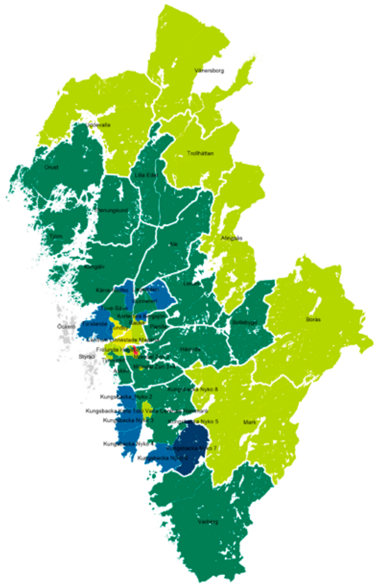
DISTANCE TO REGIONAL CENTRE



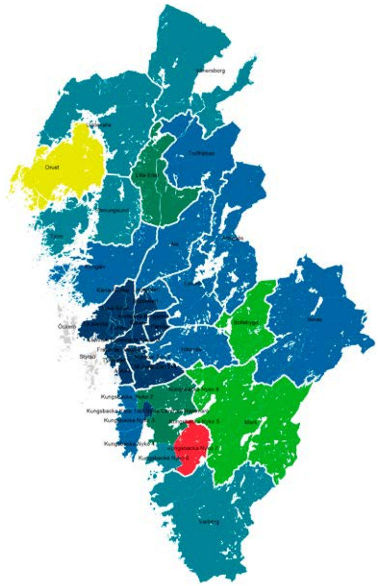
DISTANCE TO MAJOR URBAN AREAS (OVER 25000 INHABITANTS)



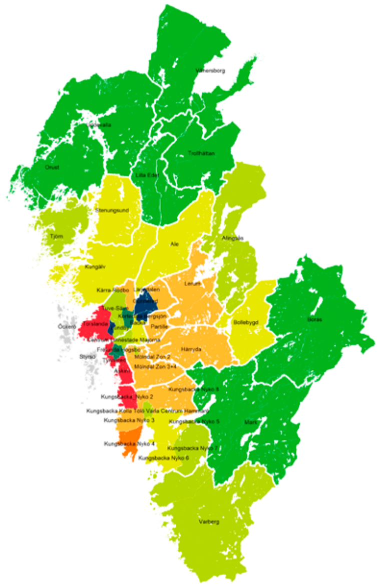
ACCESS TO A RAIL STATION OR EXPRESS BUS (WITH MORE THAN 100 DEPARTURES PER DAY) WITHIN 1 KM WALKING DISTANCE



FUNCTIONAL MIX WITHIN 1 KM WALKING DISTANCE



STREET LENGTH PER PERSON WITHIN 1 KM WALKING DISTANCE



MEDIAN INCOME

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