1. INTRODUCTION

1.1 Background

The transport sector faces big challenges regarding their contribution to climate goals. There are high expectations on the contribution from technological development of vehicles, and the development of alternative fuels and transport concepts to meet the ambitious targets. However, several studies conclude that although the technological development of vehicles and fuels can and must contribute to a large extent, this will not be enough. To achieve the climate goal a change towards a more transport efficient society will also be necessary. Generally, a ‘transport efficient society’ will require several means and measures that increase accessibility and attractiveness of walking, cycling and public transport, thereby reducing car use. A ‘transport efficient society’ also implies more efficient goods logistics and a modal shift towards rail and sea transport.

The initial basis for our study is an assessment performed by the Swedish Transport Administration showing a plan for how the Swedish transport system could and would need to develop to meet climate goals. An important basis for this climate plan was the climate goals set by the Swedish government and parliament. According to those goals Sweden should be climate neutral by 2050, implying that the emissions of greenhouse gases (GHG) from the transport sector, too, should be close to zero. It is also stated that the vehicle fleet should be ‘fossil independent’ by 2030. The meaning of this goal is unclear, but the Transport Administration has interpreted it as a reduction of at least 80 per cent in the use of fossil fuels used for road transport from 2004 to 2030. The same interpretation has later been used also by the Swedish Commission on Fossil Free Road Transport (2013).

Transport Administration (2010) finds that if the transport sector is to achieve these goals, it will require not only ambitious technical development for vehicles and fuels, but also changes in planning policies and the use of active measures and instruments that promote transportation patterns in which car is used less, goods logistics is improved and alternative transport modes are used more. In their analysis, the Transport Administration presents an estimation of possible reduction of GHG due to technical development of vehicles and fuels. Given the overall targets, they conclude the following limits for the development of vehicle mileage between 2010 and 2030:

- Vehicle mileage for cars 2030 has to decrease by 20 percent. This is in sharp contrast to a predicted increase by about 33 percent under BAU
(Business-as-usual, ie official traffic forecasts for 2030, based on already approved measures). Thus, the ‘climate scenario’ for 2030 corresponds to a 48 percent reduction compared to BAU 2030.

- Truck traffic volume for 2030 has to remain stable at 2010 volumes, instead of increasing by about 30 percent as forecasted under BAU

Based on this overall picture, the report then suggests a package of possible measures including a suggested quantified reduction for each measure, table 1 and 2.

The potentials described in table 1 and 2, were presented in the Transport Administration’s Climate Plan in 2010. Recently, an update has been made, incorporating results from the Swedish Commission on fossil free road transport (reported to the Government in late 2013). The Commission assessed a higher potential for biofuels and electricity than the report from 2010. With this higher potential taken into account, the required reduction of VKT for car traffic until 2030 is smaller (-12 percent instead of -19 percent). This will allow for modifications of the different targets in table 1 and table 2.

For the study reported in this paper, however, the analyses are based on the conclusions from Transport Administration (2010), as given by Table 1 and Table 2.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Package of measures for reducing car traffic growth suggested by the Transport administration (2010). Car traffic (VKT, vehicle km) reduction potential for each measure.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduction of VKT growth Assigned potential (vs BAU)</td>
</tr>
<tr>
<td>---------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Year 2030</td>
</tr>
<tr>
<td>Urban planning for reduction of car VKT (vehicle kilometer travelled)</td>
<td>-10%</td>
</tr>
<tr>
<td>Improved public transport (doubling/tripling of frequency)</td>
<td>-6%</td>
</tr>
<tr>
<td>Improved facilities for walking and cycling</td>
<td>-2%</td>
</tr>
<tr>
<td>Car sharing</td>
<td>-5%</td>
</tr>
<tr>
<td>Telework and internet shopping</td>
<td>-3%</td>
</tr>
<tr>
<td>Parking policies and road pricing</td>
<td>-5%</td>
</tr>
<tr>
<td>General reduction of speed limits</td>
<td>-3%</td>
</tr>
<tr>
<td>Increased transport cost (Fuel tax, fuel price etc. + 50 %)</td>
<td>-15%</td>
</tr>
<tr>
<td><strong>Total car traffic volume compared to BAU 2030</strong></td>
<td>-40%</td>
</tr>
<tr>
<td><strong>Traffic volume of cars as compared to 2011</strong></td>
<td>-19%</td>
</tr>
</tbody>
</table>
Table 2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modal shift to rail and waterborne</td>
<td>-13%</td>
<td>-21%</td>
</tr>
<tr>
<td>Improved city logistics</td>
<td>-3%</td>
<td>-5%</td>
</tr>
<tr>
<td>Less empty running</td>
<td>-2%</td>
<td>-4%</td>
</tr>
<tr>
<td>Route planning</td>
<td>-5%</td>
<td>-7%</td>
</tr>
<tr>
<td>Longer vehicles</td>
<td>-4%</td>
<td>-10%</td>
</tr>
<tr>
<td>Consumer and production patterns</td>
<td>-1%</td>
<td>-1%</td>
</tr>
<tr>
<td><strong>Total traffic volume of trucks as compared to BAU 2030</strong></td>
<td><strong>-25%</strong></td>
<td><strong>-41%</strong></td>
</tr>
<tr>
<td><strong>Traffic volume of trucks compared to 2011</strong></td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

1.2 Previous studies that form the basis for the paper

In three consecutive studies the results from the analysis from the Swedish Transport Administration (2010), Table 1 and Table 2, was stepwise concretized (WSP 2011, 2013a and 2013b).

In Study I, a back-casting analysis was performed based on the assumption that the package of measures had been implemented to its full potential in 2030. The aim was to describe how car travelling would then have changed from 2010 to 2030 in different parts of the transport sector: different types of regions, for trips of different lengths and for different travel purposes. The study included a stakeholder workshop with representatives from industry, government, governmental administrations and municipalities.

Study II, was focused specifically on those measures that related to urban planning. The study aimed at quantifying to what intensity and extent each measure would have to be implemented in order to obtain car traffic reductions corresponding to the potential traffic reductions assigned to it in table 3.
Table 3  Measures and their targeted car traffic reductions that were analysed in Study II with focus on required implementation intensity and extent.

<table>
<thead>
<tr>
<th>Measure (only measures in built-up areas)</th>
<th>Target for car traffic reduction as compared to BAU 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denser and greener cities</td>
<td>-3%</td>
</tr>
<tr>
<td>Functional land use mix especially commercial services</td>
<td>-2%</td>
</tr>
<tr>
<td>Street design and speed regulation prioritising pedestrians and cyclists</td>
<td>-3%</td>
</tr>
<tr>
<td>Improved accessibility for public transport trips</td>
<td>-4%</td>
</tr>
<tr>
<td>Parking: availability and price</td>
<td>-2%</td>
</tr>
<tr>
<td><strong>Total reduction</strong></td>
<td><strong>-14%</strong></td>
</tr>
</tbody>
</table>

Study III, examined the comprehensive planning in five Swedish municipalities. In this study, we analysed how the municipalities meet the need for measures and actions indicated by Study I and II. The analysis was based on (i) a review of the comprehensive plans for the municipalities (ii) a workshop with representatives from the municipalities.

The aim was to understand the barriers that prevented the measures to be implemented to the intensity and extent that would be necessary to reach the goal (14 % reduction of car traffic in 2030 compared to BAU 2030). Another aim was to examine what kind of overall support or incentives the municipalities would need to overcome those barriers.

The three studies thus cover the concretization and quantification of a package of several measures. The present paper focuses on one of those measures: urban planning, with a particular emphasis on urban density. Previous research has shown that high urban density provides a structure that is an important pre-requisite for the provision of high accessibility for pedestrians, cyclists and public transport users.

It is often stated in general terms that cities needs to be built denser, and in particular that urban sprawl should be avoided to reduce car mileage. But how much denser would the cities need to be in fifteen to twenty years’ time? And would that be possible? We are focusing on those issues in a Swedish context, and basing the analysis on the density 2010 and the current trend for the development of density in Swedish cities.
2. AIM

2.1 Aggregated study of densification – trend, requirement and achievability

According to the preconditions for the study (Table 3) urban density would have to increase enough to decrease car traffic on the overall national level with 3% as compared to BAU 2030.

The aim was to investigate if such increase of density would be possible given 1) current state, on-going trend and predictions of population growth 2) availability of land in built-up generally. On an aggregate level the following questions were raised.

Would the required densification of built-up areas be possible, given:

- Relationships between density and car travelling given in literature?
- Current state of density?
- Ongoing trend concerning densification/urban sprawl in Sweden?
- Predicted population growth until 2030?

Further, 3) Could the required densification take place even without the exploitation of important green structures and parks?

Finally, 4) how much more would vehicle mileage decrease if we would not only densify, but also centralize within urban areas. That is, if new dwellings in urban areas are located closer to city centres than what is typical?

In the aggregated study we separate between three region types: metropolitan areas, cities regions of medium density and cities in sparsely populated areas.

2.2 Feasibility study on municipality level

On a more detailed level we studied practical feasibility of the densification scenario in five Swedish municipalities. This part of the study aimed at the following issues:

1) What are the density trends in the five municipalities?
2) How are densification issues handled in the comprehensive plans? Are they in line with the targets set by the densification scenario?
3) How do the municipalities look at the gap between their current intentions and plans, and the requirements set by national climat goals? Which are the main obstacles for a densification in line with our densification scenario: no (or very limited) expansion outside the current borders of built-up areas?
4) What kind of overall support or incentives would the municipalities need to overcome those obstacles?
3. METHOD

3.1 Aggregated study of densification

The analysis was performed based on a literature review on the overall relation between urban density and car traffic volumes, and official data from Statistics Sweden concerning current state and land use trends and expected population growth until 2030. Current densification trend was extrapolated to form BAU 2030 (a business as usual scenario for density and car traffic volumes 2030). A densification scenario was then created based on an assumption that the whole expected population growth until 2030 would be contained within today’s city borders. Altogether this formed a framework for estimation how increased urban density in cities – the densification scenario - would affect future car traffic in Sweden. Calculations were made based on relationships from literature and the results were compared with the set up target for national decrease in car traffic due to densification.

The literature review also showed results concerning the effect that more centralized localization patterns would have on car traffic volumes. We used those relations to estimate the effect of changes in spatial distribution within cities. We could thereby estimate the effect on car traffic that would occur from localizing future new dwellings, not only within, but also centrally in, built-up areas.

Further, on an overall level the study explores occurrences of “available” land within the borders of today’s built-up areas. Here we refer to brownfields and other exploitable land that could be used without having to exploit parks and other green spaces in the cities.

3.2 Feasibility study on municipality level

To illustrate the density trend for the participating five municipalities we used official population and land use data from Statistics Sweden.

The municipalities’ comprehensive plans and policy documents regarding future development were reviewed and compared with the requirements set by the targets from the aggregated study.

In order to understand the views and needs at the municipality level a workshop was held with local planners and politicians. On the workshop the analysis was presented and further discussed.

4. AGGREGATED STUDY – RESULTS

4.1 Relation between change in density and car traffic volumes

The literature review on relation between change in urban density and car traffic volumes (vkt by car per inhabitant) was focused on studies from the Scandinavian countries.
Engebretsen et al (2011) presents the following relationships between urban density and regional car travelling (car trips <10 km) from a study of Norwegian cities:

- **For cities > 100 000 inhabitants**
  - Cities with 15-20 inhabitants/ha: 20 km car travelling/day
  - Cities with 20-25 inhabitants/ha: 15 km car travelling/day
  - Cities with 25- inhabitants/ha: 12 km car travelling/day

- **For cities of 50 000 – 100 000 inhabitants**
  - Cities with 10-15 inhabitants/ha: 19 km car travelling/day
  - Cities with 15-20 inhabitants/ha: 22 km car travelling/day
  - Cities with 20-25 inhabitants/ha: 15 km car travelling/day

- **For cities with less than 50 000 inhabitants**
  Engebretsen not find any clear relation between density and amount of travelling by car.

In summary, Engebretsen et al (2011) thus indicate that increasing population density with an extra inhabitant per hectare would reduce car travel per person by 5% in large cities (>100 000 inh), by 2.5% in medium cities (50 000 inh) but not at all in small cities.

In another study, Swedish transport administration (2012) presents an investigation of car related energy consumption for a number of average sized Swedish cities with low commuting, Figure 1. From this figure was extracted a relationship between car travelling and urban density.

**Figure 1** Relationship between car related energy consumption and density (inhabitants per hectare) for Swedish average sized cities (Swedish transport administration 2012)
According to figure 1 we assume a linear relationship between density (inhabitants/hectare) and car related energy consumption (here used as a proxy for car traffic volumes). This implies that the relative effect of increased density will be larger in more dense cities, which is similar to Engelbretsen (2011) findings.

Figure 1 indicates that when density increases with an extra inhabitant per hectare, car travel would be reduced by 2 – 4 percent in the studied cities. The lower figure would be expected for cities with density around 10 inhabitants/ha, while the larger effect would be expected for cities with density around 20 inhabitants/ha.

A sensitivity analysis showed that the relation found by Engebretsen and the relation found by Swedish transport administration resulted in roughly the same effects when applied city-by-city to Swedish data of population and land use. In the continued study we used a combination of the two findings: The relation found by Engebretsen was used for metropolitan areas while the relation found by the Transport Road Administration was used for cities in medium and sparsely populated regions.

4.2 Relation between car travelling and centrality

According to the literature there is a strong relationship between amount of car travel a person does, and how centrally her residence is located. In our densification scenario, we assume that all new dwellings will be located within current borders of the built-up areas. However, the spatial distribution of new builds over regions, and within cities/towns, is assumed to follow the same pattern as before. However, if new housing is “pushed” closer to the city center than what is common, that would possibly give an additional impact on traffic reduction.

Naess (2012) summarised a number of studies and found the following relations between proximity to city center and motorised travel:

- Copenhagen (Denmark) and Oslo (Norway): 1 km closer to city center results in 6% less motorised travel.
- Fredrikshavn (Denmark): 1 km closer to city center results in 8% less motorised travel.

In our analyses we used the relation from the Copenhagen study for metropolitan areas and the relation from Fredrikshavn for cities in medium and sparsely populated regions.

Densification in general would have an impact on propensity to car use for the total population. Everyone would benefit from higher accessibility, and thus use car less, if cities became more dense. In this respect the effect of centralization is different: it is only the inhabitants of new dwellings that change their travel behaviour when those dwellings are located closer to city centers. The centralization scenario would therefore have a smaller total effect on car traffic, even if the effect per person seems to be strong.
4.3 Density trends and expected population growth in Sweden

Trend - Sweden becomes denser
Official statistics for the development of population within and outside built-up areas and the areal size of built-up areas for 1990, 2000 and 2010 was used to aggregate the density trend.

Figure 2 show the development of density in Swedish built up areas between two periods of time: 1990-2000 as compared with 2000-2010 for three types of regions. The analysis shows a trend of increasing density. In the metropolitan areas the population density was increasing 1990-2000 already and the trend was even more pronounced during 2000-2010. For cities in medium populated regions there was almost no change in population density in the period 1990-2000, but density increases 2000-2010. For sparsely populated areas there was a decrease in population and density is reduced during both periods. However this tendency (reduced density) is less pronounced 2000-2010 (-2 %) compared to 1990-2000 (-6%).

Figure 2 Relative change in density as a function of the relative change in population between 1990-2000 and 2000-2010 aggregated over cities in three types of regions in Sweden. The arrows (→) shows the development from 1990-2000 (at the arrow base) to 2000-2010 (at the arrowhead point).
4.4 Estimated effects on car traffic

BAU-scenario: Densification trend continuous until 2030.
The bases for the BAU 2030 scenario assumes:

- 10% increase in population nationwide until 2030 (official national forecast)
- Regional distribution of population increase follows official forecasts: metropolitan areas +18 %, medium populated regions +8% and sparsely populated regions -3%.
- The identified ongoing densification trend continues.

Densification scenario: Population growth only in built-up areas
The possibilities and limits for future densification are depending on expected population growth. A scenario was chosen to explore how much a strong, but (theoretical) possible, densification scenario would affect car traffic in 2030. The scenario assumes that population growth will have the same distribution over regions and cities as in BAU 2030, but take place only within the borders of today’s built up areas. That is, all new housing would need to be inserted at left over areas within cities or added to existing residential areas. No new land outside the cities would be taken into account.

In table 4 we present the estimated effects on car traffic for the densification scenario as compared to the BAU scenario.

Table 4

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>Scenario BAU 2030</th>
<th>Densification scenario</th>
<th>Relative effects</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Car traffic (pkt)</td>
<td>Car traffic 2030 (pkt)</td>
<td>Car traffic 2030 (pkt)</td>
<td>Effect on car traffic compared to 2010</td>
<td>Effect on car traffic compared to BAU 2030</td>
<td></td>
</tr>
<tr>
<td>Metropolitan areas</td>
<td>21 300</td>
<td>22 400</td>
<td>19 100</td>
<td>-10%</td>
<td>-15%</td>
<td></td>
</tr>
<tr>
<td>Medium populated</td>
<td>45 700</td>
<td>49 000</td>
<td>48 300</td>
<td>6%</td>
<td>-1%</td>
<td></td>
</tr>
<tr>
<td>regions</td>
<td>17 100</td>
<td>16 500</td>
<td>16 700</td>
<td>-2%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Sparsely populated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>regions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total effect on</td>
<td>84 100</td>
<td>87 900</td>
<td>84 000</td>
<td>0%</td>
<td>-4%</td>
<td></td>
</tr>
<tr>
<td>country level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The result showed that such a scenario reduces car traffic by 4 percent nationwide compared to BAU. This is more than the targeted decrease of 3 percent.

Possible added effect of greater centralization within cities

Literature suggests that a stronger centralization of new dwellings towards city center would mean an additional decrease in car traffic. In this scenario we have the same assumption about population growth as in the densification scenario (growth in built-up areas only) but now we explore how much further centralization of new inhabitants would mean in terms of decrease in traffic growth.

For metropolitan areas we assume that new inhabitants until 2030 on the average will be located two kilometer closer to city centers as compared to “default” (the distribution of new inhabitants over the built-up areas without a specific centralisation target). For newcomers in medium populated regions the distance would decrease with one kilometer and in sparsely populated areas half a kilometer. Using relations between proximity to city center and motorised travel by Naess (2012) we found a possible additional decrease in car traffic with one percent nationwide on top of what was predicted for the densification scenario alone, see table 5. In total the analysis shows densification and centralization can reduce car traffic with 5 % to 2030 compared to BAU.

Table 5 Added effect on car traffic if the densification scenario would be focused towards stronger centralisation of new dwellings.

<table>
<thead>
<tr>
<th></th>
<th>Decrease in average distance to city center</th>
<th>Decrease in car travelling (pkt) for added population</th>
<th>Resulting decrease in pkt in built-up areas</th>
<th>Relative total effect of a more centralised localisation within built-up areas (% of total pkt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metropolitan areas</strong></td>
<td>2</td>
<td>12%</td>
<td>-417 600</td>
<td>-2%</td>
</tr>
<tr>
<td><strong>Medium populated regions</strong></td>
<td>1</td>
<td>8%</td>
<td>-305 500</td>
<td>-1%</td>
</tr>
<tr>
<td><strong>Sparsely populated regions</strong></td>
<td>0,5</td>
<td>4%</td>
<td>-21 600</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total effect on country level</strong></td>
<td>0,5</td>
<td>4%</td>
<td>701 500</td>
<td>-1%</td>
</tr>
</tbody>
</table>

4.5 Are there enough available land to densify todays built up areas?

The densification scenarios are far-reaching, and it is natural to ask questions about whether this is possible and what it would mean. What kinds of areas are available to expanded settlements within today's built-up areas? Does the scenario mean that green spaces and parks would need to be utilized? What degree of exploitation would the scenario lead to?
To start to investigate this on an overall level the study explored occurrence of “available” land in today’s built-up areas. In order not to take recreational green spaces into account for exploitation we searched for statistics of available “waste land” or brownfields. Such could be e.g. former industrial ground plots and left over land between developments. Unfortunately there is no aggregated data that describes the amount of urban land of this kind. Instead, we combined different national statistics for land use in Swedish cities to get an approximate idea of the amount of “available” land. In overall statistics, a large share of land use was categorised as “undeveloped green space”. This wide category includes both parks and greenery within the built environments, but also a lot of other areas that are not exploited or used for any recreational purposes. An overall analysis for a sample of cities and towns indicated that about 32 percent of the area under the label “undeveloped green space” constitutes what could be characterised as “waste land” rather than recreational space.

For the final analysis we then used data concerning urban land use for Swedish cities, and assumed (based on our study of sampled cities/towns) that 32% “undeveloped green space” could be regarded as wasteland, and that half of the estimated “waste land” in each city could be taken into account for residential developments until 2030. For the calculation we assumed that new developments would be high-density (60 inhabitants per hectare). For cities that already have an overall average density of more than 60 inhabitants per hectare, we assumed that the same high density would apply to new developments as well.

For all cities we then calculated whether expected population growth could be contained within half of the estimated area of available brownfields or “waste land” (assuming the above mentioned degree of exploitation). If not, we assumed that overlapping population had to be inserted in existing residential areas through complementing existing housing developments, thereby increasing density. In both cases the resulting degree of exploitation was calculated, see table 6.

Table 6 shows that if all additional population until 2030 would be localised within the borders of today’s built-up areas, it would mean that for most cities in metropolitan regions, it would not be sufficient to use fifty percent on the “waste land”. Further densification through complementation within existing developments would be necessary. The average number of inhabitants per hectare in those cities would increase from 53 to 58.

In medium and sparsely populated regions, however, building on fifty percent of the “waste land” or brownfields would be enough to contain expected population growth for most cities.
Table 6  
Exploration of possibilities to contain the forecasted population growth within the borders of built-up areas 2010. For how many cities would the use of half of the available brown fields be enough and for how many cities will there be further need for densification of existing housing areas? The current and expected density on built-up land is as well reported.

<table>
<thead>
<tr>
<th>Metropolitan regions</th>
<th>Cities in which half of the estimated &quot;waste land&quot; would be enough to contain the population growth until 2030</th>
<th>Cities in which further densification in existing developments would be needed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of built-up areas &gt; 10000 inhab.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Population 2010</td>
<td>48 400</td>
</tr>
<tr>
<td></td>
<td>Population 2030</td>
<td>49 600</td>
</tr>
<tr>
<td></td>
<td>Average inhab/ha on developed areas 2010</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Average inhab/ha on developed areas 2030</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Medium populated regions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of built-up areas &gt; 10000 inhab.</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Population 2010</td>
<td>1 354 800</td>
</tr>
<tr>
<td></td>
<td>Population 2030</td>
<td>1 442 300</td>
</tr>
<tr>
<td></td>
<td>Average inhab/ha on developed areas 2010</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Average inhab/ha on developed areas 2030</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Sparsley populated regions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of built-up areas &gt; 10000 inhab.</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Population 2010</td>
<td>407 100</td>
</tr>
<tr>
<td></td>
<td>Population 2030</td>
<td>408 500</td>
</tr>
<tr>
<td></td>
<td>Average inhab/ha on developed areas 2010</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Average inhab/ha on developed areas 2030</td>
<td>21</td>
</tr>
</tbody>
</table>

4.6 Other measures except for densifications that were analysed

In the overall study all five measures mentioned in Table 3 were analysed. Their required intensity and extent if to meet their respective targets to reduce car traffic was quantified and the results were discussed on the workshop with municipalities. The method and results are not presented in detail in this paper. The overall result showed:

Functional land use mix especially commercial service

The number of external business establishments in Sweden would be reduced by about a quarter by 2030 to achieve a reduction of the national road traffic work by 1% compared to BAU by 2030. To reach the goal of 2% car traffic
reduction due to better land use mix other measures would need to be taken as well.

Street design and speed limitsadapted for the prioritization of pedestrians and cyclists
We have assumed that one-quarter of the neighborhoods in Sweden are already planned according to “pedestrian-/cyclist-friendly” principles. If the remaining three-quarters of neighborhoods are transformed to a magnitude corresponding to going from being totally automobile-oriented to completely pedestrian and bicycle oriented to achieve an effect of the 3% reduction in car traffic nationally compared to BAU by 2030.

Improved accessibility for travelling with public transport
Public transport in urban area (approximated by all public transport journeys <30 km) needs improvement equivalent to an increase of nearly 245% of the supply today. This represents a reduction of the generalized travel cost of approximately SEK 4.70 (about 0.5 Euro). Can also be achieved by door-to-door travel time is reduced by 7 minutes on average.

Parking policies – availability and price
Example effect of price on parking: An average increase in parking cost of SEK 10 per day (about 1 Euro) at all its workplaces (including work outside urban areas) would provide a national car traffic reduction of about 1.5%

Example effect of parking supply: Halving the supply of parking spaces at both at home and at other destinations (outside and inside urban areas) in a way that walking distance per trip on the average would increases by 30 meters would result in total national traffic reduction of about 0.5%.

The four measures were also included in the practical feasibility study.

5. STUDY OF PRACTICAL FEASIBILITY - RESULTS

5.1 Densification trends in five Swedish municipalities

Five cities were studied in more detail. In the first step data for the local density trends were analysed. As was the case for the aggregated study all five cities showed a trend towards higher density, see figure 3, though in different pace and from different starting points. The city of Malmö, Sweden’s third city, showed the most significant densification trend. Malmö is according to the study the city with the highest density in Sweden. Gothenburg, Sweden’s second largest city, shows on the other hand a relatively low density as compared to average density in larger cities in Sweden. Also, Gothenburg show a densification trend over the last twenty years.
The preliminary idea was to study to what degree local growth plans for the cities would meet the overall density scenario in which total population growth would happen within the borders of the built-up areas. For each city, the overall achievability for such densification was preliminary estimated. The estimation was based on national forecasts for population growth in each city and the overall estimate of available “waste land” per city according to the aggregated study. The analysis showed that for Gothenburg and Malmö it would not be enough to develop half of available “waste land” to contain the expected population growth. Further densification e.g. completion of existing developments would be needed. Lerum, Eskilstuna and Täby could according to the calculation be able to comprise the (nationally) foreseen population growth through taking into account half of the waste land within the city bounders.

5.2 Municipalities development plans does not reach the goal

The analysis of the municipality’s comprehensive plans and policy documents for future development were reviewed and compared with the need according to the density scenario from the aggregated study. The first conclusion was that it was not possible to actually compare the cities future density with the preliminary estimations from the aggregated study. The reason was that the aggregated estimations were made based on national population forecasts for the municipalities. However, it turned out that all cities plan for much higher
population growth as compared with the national figures (10-60% higher population growth). Thus the basic assumption was not really comparable. Further the comprehensive plans appoints areas for new housing but they generally do not subscribe what kind of housing which makes it impossible to estimate inhabitants per hectare.

All, both large and small municipalities strive to become denser within urban areas. The focus on the densification varied between starting from the city center or from the outskirts going towards the center. Since growth plans are so vast and since density in future housing areas is not specified it was not possible to quantify the densification ambitions. On the one hand the municipalities strive to become denser but no one excludes expansion outside urban areas completely.

5.3 Obstacles for reaching a high densification

The target to only grow within the built-up areas would off course require extremely strict planning and control concerning future developments and it is not likely that this would be met to hundred percent. To approach such goal attainment it would probably require sharp instruments and incentives. To better understand the problem a workshop with the participating municipalities was organized. At the workshop all the measures mentioned in table 3 was discussed (and had been analysed). Concerning densification we wanted to raise questions of what major obstacles municipalities see to approach a higher degree of densification.

On the workshop civil servants and a few local politicians participated. We presented our results on what would be needed to meet climate goals and how their comprehensive planning meets those needs. The participants worked in groups discussing questions concerning obstacles for a higher degree of densification and need for overall incentives to approach the goal. Their conclusions were documented. The major obstacles for a high degree of densification according to the participating municipalities were:

Public acceptance
There are a lot of negative images of densification and what it means in the public conscious and plans for dense and / or high buildings may frequently result in complaints from local residents.

Competition and pressure from stakeholders
Existing housing shortage makes it difficult to say no to private developers or put claims, e.g. on location and density, on new developments. Also negative competition between municipalities to attract new inhabitants sometimes influence the will to stop urban sprawl.

Environmental Laws and Limits
Noise and air quality is sometime expected to cause problems at dense areas. The municipalities see a goal conflict between legal limits for noise and air quality on the one hand and a wish for densification in order to decrease
motorized transport on the other. Also legal protection for cultural aspects may govern what kind of buildings that are permitted in a city area.

Overall planning law
In Swedish law for planning and building houses there is no support for stopping new housing outside the detailed plan areas as far as it does not result in bad or unhealthy living space for the residents.

Financing and costs
The municipalities see risks for large costs for the remediation of brownfield sites in order to make them suitable for housing.

5.4 What incentives would overcome the obstacles?
The municipalities discussed what new or existing policy instruments that would facilitate implementation of densification. The discussion was divided into instruments such as the municipality itself has control over, and overall instrument that the State could take. Examples of instruments that were proposed are presented below.

Instruments and measures on municipality level

Make use of municipality right of decision
- Ease the noise requirements in certain situations as the municipalities have the right to do this. However the decision risk to be appealed to the country board.
- Produce better and more correct impact analyses concerning noise and air quality.
- Implement monitoring of expected travel time quotas for different transport modes as a base for decisions concerning physical and traffic planning.
- Start a continuous monitoring of plan indicators that mirror e.g densification trend.
- Financial contribution to soil remediation on former industrial sites
- Implement green structure plans that include quality assessments on existing parks and other green spaces. Such plan could provide a basis for prioritization of where to build new housing.
- Changed parking standards and perform dialogue with citizens and property owners on reduced car parking
- Enhanced requirement on tight density of central exploitations
- Stronger guidelines for the authorization of concentration in the outer areas
Dialog and consensus
- Helping to create a consensus on what is the most priority in physical planning on municipality level.
- Improved dialog with property owners before and during exploitation

Need for instruments and measures outside the municipality level

Need for changes in rules and planning instruments
- Introduce planning according SUMP (Sustainable Urban Mobility Plans). SUMP is a type of integrated transport plan, including both physical planning and infrastructure planning together with soft measures to affect the travel habits of the population. They are used, among other things in France (Plan de déplacement Urbain) and the United Kingdom.
- Overall adjustment of physical and transport planning to meet the demand for action created by the climate threat. The national (and international) level must take the lead and make overall changes.
- Introduction of a regional planning level.

Environmental Legislation
- More uniform noise rules are needed. Today, there are differences between the noise recommendations from different national bodies. Furthermore, unify recommendations for noise of various origins such as traffic noise and industrial noise.

Increased opportunities for using Mobility Management
- Introduction of systems for “mobility budget” (used for example in the Netherlands) at work places. Mobility budget is a generic term for a system in which the employees will be responsible for an overall budget covering both commuting and business travel. Reimbursement for different modes is set so that employees have an economic incentive to use those travel modes that the employer chooses to promote.
- Possibility for municipals to require transportation plans from companies that are to establish transport intensive activities or businesses, such possibilities are in place in Switzerland for example.

Economic instruments
- Changes in the taxation law towards reduced possibilities to deduce the taxable income due to travel expenses for commuting to work by car.
- Design instruments that would make it possible for municipalities to impose tax on parking (also parking lots at private land) in a similar way as is done in Nottingham in the UK.
- Stately funding for converting / decontaminate industrial land for new functions e.g residential housing.
- Investing in better public transport
Other instruments

- Prohibit the possibility to include parking cost in the rent for apartment buildings.
- Relax the requirement for installing a lift when adding a penthouse apartment in existing buildings.

6. CONCLUSIONS

The study revealed an ongoing densification of Swedish cities and towns. This would, if the trend is sustained, partly suppress the foreseen growth in car traffic for 2030. However, to reach the postulated traffic reduction, it would not be sufficient to extrapolate the present trend. Further densification would be needed. If population growth until 2030 solely would happen within the borders of today’s built-up areas, 4% less car traffic compared to BAU 2030 could be reached. Further, if dwellings would be localized closer to the city centre than today car traffic could decrease with yet an additional 1%. On an overall level the predicted population growth could be contained without using additional land outside today’s city borders. However, the realization would request strict planning of all new developments. In the workshop with municipalities the need for increased overall control measures aiming towards the climate goals was stressed.

The study have clarified what changes is needed in travel behavior and planning of cities, towns and infrastructure to reach the climate objectives. How these changes can be achieved is however not discussed in the study. To make this possible new policy instruments will be needed, both directed towards the users of the transport system and also directed towards those who plan the cities and infrastructure – primarily municipalities. The Swedish Commission on Fossil Free Road Transport has recently presented a number of policy instruments that if implemented could lead in that direction. Even though the focus of the study have been to understand the measures needed to reach the climate objective, the described development has a large number of other advantages. Less traffic means less congestion, better air quality and lower noise levels. Lower speeds and a higher share of electric vehicles will reduce noise levels further. Lower speeds and reduced truck traffic will also improve road safety. Use of green space on the outskirts of urban areas is curbed by denser settlement. Significant increases in cycling and walking contribute to improved public health. Accessibility will be enhanced for all by improving public transport. There is also evidence that compact urban development increases gender equality, reduces social exclusion and curtails the number of violent crimes due to more people out walking. In general, compact cities are attractive for people to live in. The compact city concept is suited to meet many objectives and needs, as has recently been highlighted by a number of organizations, including the IEA (2012), OECD (2010, 2012), UN Habitat 2009, UNEP (2011), the World Bank (2010), and the World Health Organization (2011).
7. BIBLIOGRAPHY


