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Sustainable Mobility in Swedish Cities

A Comparative International Assessment of Urban Transport Indicators in Sweden's Five Most Populous Urban Regions

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Preface

This report seeks to provide a perspective on the passenger transport and related characteristics of Swedish urban regions in comparison to each other and in contrast to other regional groupings of cities, namely American, Australian, Canadian, European and Asian (Singapore and Hong Kong). Understanding how cities works and what their relative strengths and weaknesses are, especially in relation to the sustainability of their transport systems, is important in formulating critical policies in the future.

The indicators assembled in this report follow the core indicators that I have used for over 40 years in comparing cities. While no single study or database can lay claim to measuring every factor that is important in understanding the transport infrastructure and mobility patterns of cities, those assembled here do provide quite a detailed insight, on an aggregate level and as a snapshot for 2015, of some key characteristics of passenger transport in Swedish cities. The study has a focus on public transport, but also covers private transport, non-motorised transport and other matters.

It is hoped that if nothing more, it generates productive discussions about how to improve the sustainability of transport in urban Sweden. And perhaps even more importantly, it also helps to simulate thought about how the availability of basic data in Sweden on so many factors may be streamlined in the future. Presently it is not an easy task in Sweden to piece together these data.

Such a wide ranging study could not have been achieved without the generous support of so many people, especially those in government agencies in the five regions whose responses to all my persistent questions over two years, were simply remarkable. And this help was needed because many of the factors provided in this report were difficult to assemble and yet they are quite basic in trying to understand urban transport systems.

All these individuals are too many to name, but a handful are highlighted in the acknowledgements at the end of this report. For all the many others, and they know who they are, I am very grateful for your generous support in this project. I hope in the results, that you will find something useful for your own city.

Frankfurt, February 2019

Jeffrey Kenworthy

Author

Summary

This final report presents the results of 124 urban transport related indicators for 2015 for Sweden's five most populous urban regions and compares them with each other and against cities in the USA, Australia, Canada, Europe and two large cities in Asia (Singapore and Hong Kong). Results indicate that Swedish cities are atypically low in density, and high in roads and freeways compared to most other European cities. Partly resulting from these conditions, Swedish cities on average have much lower public transport boardings than typical European cities (roughly half), but at the same time they are much better than in the more auto-dependent regions in the USA, Australia and Canada where densities are also low. Notwithstanding their moderate public transport use, their normalised farebox and operating costs data are relatively similar to the other cities in the study. Public transport use measured by passenger kilometres is closer to European levels due to the longer distances travelled by public transport in Swedish cities. Modal split of daily trips is also just under 50% for public transport, walking and cycling combined, meaning that modal share in these five Swedish urban regions is pivoted rather equitably between the more sustainable and less sustainable modes. Car use per person (vehicle kilometres) is only a little higher in the Swedish cities and passenger kilometres per person in cars are about the same compared to typical European cities. The percentage of total motorised passenger kilometres accounted for by public transport is much higher than in the USA, Canada and Australia, but less than in other European and in Asia cities. Energy use in private motorised passenger transport is, due to comparable car use levels, like that in other European cities and very much lower than in the auto-cities of North America and Australia. The Swedish cities excel in their extremely low transport emissions per capita and low spatial intensity of emissions (per hectare) compared to every other region in the world and even the worst Swedish cities are better than the best of the other cities. Likewise, in transport fatalities, Swedish cities are the lowest in the world.

Some factors that seem to contribute to the above sometimes paradoxical situations are that:

a. Swedish cities have significantly lower car ownership than might be expected, lower even than other European cities and average wealth levels in 2015, as measured by metropolitan GDP are below typical European levels (though comparable to 2005/6 levels Australian and Canadian cities).
b. These five Swedish cities have comparatively low parking supply in their CBDs and a relatively high proportion of metropolitan jobs located in the CBDs, which assists public transport in the journey-to-work.
c. despite low densities, Swedish cities have developed relatively well-performing and more extensive public transport systems than many comparable lower density cities – they have healthy levels of service in terms of seat kilometres per capita, only eclipsed by other European cities and the Asian cities. However, seat

occupancy is comparatively low, indicating generous levels of spare capacity that could be utilised through better urban planning to create back-loading of passengers.

d. Swedish cities have the highest level of public transport line length per persons, as well as high levels of reserved public transport route per person, although they are also well-endowed with freeways, which tends to undercut this advantage.
e. average operating speeds for public transport in Sweden seem to be higher than most other cities and public transport overall enjoys a modest speed advantage over car speeds.
f. Swedish cities spend relatively generous amounts of money operating their public transport systems, on average about 1.34% of their local GDPs, which significantly exceeds that of the auto-dependent regions, and is close to the other European cities (1.50%).
g. cost recovery from fares of public transport operating costs is on average a bit less than 50% and less on average that the other global cities. This may be partly indicative of a recognition in Sweden of the proven value of public transport systems in helping to create urban regions that are only moderately car dependent by developed world standards, despite lower densities, because farebox recovery takes no account of public transport's broader economic benefits and
h. Swedish cities have significant areas of urban fabric that are supportive of non-motorised modes and where walking and cycling is high, leading to over 27% of daily trips in Swedish cities by these modes, despite a very cold climate.

Three key weaknesses that have emerged in Swedish cities are: (a) their overall low density that would benefit from targeted increases in higher density development, especially linked to expanded and improved public transport, especially rail. Stockholm is by far the best of the Swedish cities in sustainable transport and although it is still overall a relatively low-density region, it is bound together by strong urban rail networks around which very high density, mixed use centres have been built; (b) the need to restrict further development of already abundant freeway systems in all five of the Swedish cities and (c) an over-reliance on bus systems and the need for more extensive urban rail networks. A major difference between Swedish and European cities generally is that European cities have three times higher rail use and this is a critical distinguishing feature in the lower public transport use in Swedish cities.

1. Introduction

Comparing cities to better understand their transport and land use patterns, to gain insights into their strengths and weaknesses and to deliver policies about how to reduce automobile dependence and improve transport sustainability, has a long history in the academic literature (e.g. Newman and Kenworthy, 1989a, b,1991, 1999a, 2015; Kenworthy and Laube, 1999, 2001; Schiller and Kenworthy, 2018).

The research here builds on this long tradition and seeks to add five of Sweden's most populous cities to Kenworthy's Global Cities Database. To do this, the report summarises the achievements and insights from a small K2 grant given in 2016, analysing urban transport indicators for the year 2015 for Stockholm (2,231,439), Göteborg (982,360), Malmö (695,430), Linköping (152,966) and Helsingborg (137,909). Appendix 1 contains a list of all the geographic definitions of each of these cities. Appendix 2 provides a detailed description of each of the 35 variables, most of which have been collected for the year 2015 (or the closest possible year to it, depending on data availability). Some data such as urban land use information and GDP, which were only available for earlier years at the time of the interim report on the study in February 2018, have since been systematically updated to 2015 to account for subsequent data releases by Statistics Sweden.

Contained in this report is a detailed insight into all the standardised variables for all five cities that have been calculated from the 35 primary variables listed in Appendix 1.

Two tables are provided with all the standardised variables for each individual Swedish city, as well as an average for the five Swedish cities and averages for another five groups of cities (USA, Australia, Canada, Europe and Asia), as well as an overall average for these other regions. A selected series of figures depicts these results visually for ease of appreciation of the differences. Comparisons are drawn to the averages for the same variables in a total of forty-one cities in other global regions (ten American, four Australian, five Canadian, twenty European and two large Asian cities – Singapore and Hong Kong). However, these data are for ten years earlier than the Swedish data (either 2005 or 2006) as these data have not yet been updated for any later years, because this work takes many years to complete. Most of the comparisons will still have a significant meaning. However, in some, which have been changing fast over recent years like emissions and transport deaths, the differences between Swedish cities and these other cities will have changed more (see later discussions).

2. Methodology

Details of the methodology in terms of geographic definitions of each city and definitions of each primary variable are provided in Appendices 1 and 2. All data have been collected using similar methodologies employed over the last 40 years of this international comparative work and are now provided in detail in Kenworthy (2017). Some data have been collected directly from Swedish sources, which have included online databases at a national level for different geographies (particularly Statistics Sweden). Data by municipality and county have been most useful. However, few items have been straightforward and most have required extensive and often repeat correspondence with a multitude of individuals, mostly in government agencies at different levels who have given freely of their time and expertise in satisfying all the requests for data. Once certain data have been collected, such as travel survey data, more work has always been required to extract what is needed. For this, help has been provided from within K2 or closely linked to K2 (see acknowledgments at the end). Thus this work is a time-consuming business, rather like trying to complete a complex jigsaw puzzle, the picture from which is not clear or reliable until all data are collected and reality-tested for reliability and plausibility, something often not sufficiently carried out in other work in this field.

3. Results

Tables 1 and 2 summarise the results for all the standardised comparative variables for each of the Swedish cities, an average for the five Swedish cities and the averages for cities in each of the other five regions, as well as a “global average” for those five regions.

Table 1. Comparative urban transport indicators for five Swedish urban regions compared to American, Australian, Canadian, European and Asian cities, Part I.

Variable	Units	Stockholm 2015	Malmö 2015	Göteborg 2015	Linköping 2015	Helsingborg 2015	SWE 2015	USA 2005	AUS 2006	CAN 2006	EUR 2005	ASIA 2005	ALL 2005
Urban density	persons/ha	23.5	20.0	19.7	13.8	21.9	**19.8**	15.4	14.0	25.8	47.9	217.3	42.2
Job density	jobs/ha	12.6	9.2	10.1	7.3	11.0	**10.0**	8.1	6.2	14.1	29.6	113.3	24.3
Activity density	persons+jobs/ha	36.1	29.2	29.8	21.1	32.9	**29.8**	23.6	20.3	39.9	77.5	330.6	66.5
Proportion of jobs in CBD	%	28.2%	7.8%	7.0%	18.9%	19.7%	**16.3%**	8.2%	12.7%	15.0%	18.3%	9.1%	14.5%
Metropolitan gross domestic product per capita	USD 1995	$49,271	$32,709	$40,808	$30,260	$28,917	**$36,393**	$44,455	$32,194	$31,263	$38,683	$21,201	$37,700
Length of road per person	m/ person	4.7	6.9	5.0	9.1	6.9	**6.5**	6.0	7.6	5.4	3.1	0.5	4.4
Length of freeway per person	m/ person	0.138	0.232	0.225	0.269	0.287	**0.230**	0.156	0.083	0.157	0.094	0.026	0.112
Length of road per urban hectare	m/ha	110.8	138.9	97.8	125.8	150.3	**124.7**	84.4	105.1	143.9	134.1	85.3	118.0
Length of freeway per urban hectare	m/ha	3.3	4.6	4.4	3.7	6.3	**4.5**	2.3	1.1	3.9	4.1	4.8	3.4
Parking spaces per 1000 CBD jobs	spaces/1000 jobs	125.3	236.8	160.0	224.6	483.5	**246.0**	487.2	297.8	319.4	248.0	121.2	313.7
Passenger cars per 1000 persons	units/1000 persons	398	442	405	432	435	**423**	640	647	522	463	78	512.3
Motor cycles per 1000 persons	units/1000 persons	24.3	29.1	35.0	29.8	30.3	**29.7**	16	21	15	41	19	28.5
Total length of public transport lines per 1000 persons	m/1000 persons	4,867	3,109	6,098	11,055	3,031	**5,632**	1,382	2,609	2,496	3,183	2,614	2,576
Total length of reserved public transport routes per 1000 persons	m/1000 persons	234	222	283	378	432	**310**	71.7	160.0	66.8	297.8	33.8	188.1
* Busway length per 1000 persons	m/1000 persons	42	43	92	37	80	**59**	12.1	10.5	15.1	20.8	2.3	16.1
* Minibus reserved route length per 1000 persons	m/1000 persons	0	0	0	0	0	**0**	0.0	0.0	0.0	0.0	0.0	-
* Segregated tram network length per 1000 persons	m/1000 persons	0	0	0	0	0	**0**	0.0	2.7	0.3	21.5	0.4	10.8
* Light rail network length per 1000 persons	m/1000 persons	54	0	86	22	0	**32**	5.8	0.3	10.5	15.5	6.0	10.6
* Metro network length per 1000 persons	m/1000 persons	48	0	0	0	0	**10**	14.6	0.2	10.7	30.4	19.2	20.7
* Suburban rail network length per 1000 persons	m/1000 persons	90	178	106	319	352	**209**	39.2	146.3	30.1	211.2	5.8	130.8
* Ferry network length per 1000 persons	m/1000 persons	0	0	0	0	0	**0**	0.00	0.0	0.0	0.0	0.0	0.0
Total length of reserved public transport routes per urban hectare	m/ha	5.49	4.44	5.57	3.17	9.47	**5.63**	1.21	2.3	1.7	14.1	7.4	8.0
* Busway length per urban hectare	m/ha	1.00	0.87	1.80	0.31	1.76	**1.15**	0.15	0.1	0.4	1.0	0.6	0.6
* Minibus reserved route length per urban hectare	m/ha	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.0	0.0	0.0	0.0	0.0
* Segregated tram network length per urban hectare	m/ha	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.0	0.0	1.2	0.1	0.6
* Light rail network length per urban hectare	m/ha	1.27	0.00	1.68	0.19	0.00	**0.63**	0.10	0.0	0.2	0.7	1.2	0.4
* Metro network length per urban hectare	m/ha	1.12	0.00	0.00	0.00	0.00	**0.22**	0.23	0.0	0.3	1.5	3.5	1.0
* Suburban rail network length per urban hectare	m/ha	2.10	3.57	2.09	2.67	7.71	**3.63**	0.72	2.1	0.8	9.9	2.0	5.4
* Ferry network length per urban hectare	m/ha	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.0	0.0	0.0	0.0	0.0
Total public transport vehicles per 1000 persons	units/1000 persons	1.31	1.06	1.37	0.80	2.31	**1.37**	0.76	0.93	0.92	1.51	1.50	1.2
* Buses per 1000 persons	units/1000 persons	0.95	0.79	0.95	0.65	1.02	**0.87**	0.39	0.64	0.76	0.77	0.93	0.7
* Minibuses per 1000 persons	units/1000 persons	0.00	0.00	0.00	0.00	0.00	**0.00**	0.22	0.00	0.00	0.00	0.32	0.1
* Tram units per 1000 persons	units/1000 persons	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.03	0.00	0.16	0.01	0.1
* Light rail units per 1000 persons	units/1000 persons	0.09	0.00	0.27	0.04	0.00	**0.08**	0.01	0.00	0.03	0.05	0.02	0.0
* Metro units per 1000 persons	units/1000 persons	0.20	0.00	0.00	0.00	0.00	**0.04**	0.10	0.00	0.09	0.23	0.17	0.2
* Suburban rail units per 1000 persons	units/1000 persons	0.06	0.27	0.13	0.10	1.29	**0.37**	0.04	0.25	0.03	0.30	0.05	0.2
* Ferry units per 1000 persons	units/1000 persons	0.01	0.00	0.03	0.03	0.00	**0.01**	0.00	0.00	0.00	0.00	0.00	0.0
Total public transport vehicle kilometres of service per capita	v.km/person	114.2	66.0	150.8	61.0	99.0	**98.2**	39.2	58.9	52.1	107.5	134.5	80.7
* Bus vehicle kilometres per capita	v.km/person	56.3	50.6	120.1	50.5	88.6	**73.2**	19.5	29.1	38.4	42.7	74.3	36.7
* Minibus vehicle kilometres per capita	v.km/person	-	-	-	-	-	**-**	6.0	0.0	0.0	0.0	28.4	2.9
* Tram wagon kilometres per capita	v.km/person	-	-	-	-	-	**-**	0.0	1.5	0.4	7.3	0.4	3.8
* Light rail wagon kilometres per capita	v.km/person	6.5	0.0	17.2	2.8	0.0	**5.3**	1.1	0.0	2.4	3.4	1.8	2.3
* Metro wagon kilometres per capita	v.km/person	43.0	0.0	0.0	0.0	0.0	**8.6**	9.9	0.0	9.7	21.1	20.4	14.9
* Suburban rail wagon kilometres per capita	v.km/person	7.8	15.4	12.8	7.5	10.3	**10.8**	2.7	28.1	1.2	32.9	9.0	20.0
* Ferry vessel kilometres per capita	v.km/person	0.5	0.0	0.7	0.2	0.0	**0.3**	0.0	0.2	0.0	0.1	0.2	0.1
Total public transport seat kilometres of service per capita	seat km/person	8,294	5,837	9,376	4,647	6,321	**6,895**	1,874	4,077	2,368	6,126	7,267	4,486
* Bus seat kilometres per capita	seat km/person	2,796	2,276	5,529	2,811	3,921	**3,467**	789	1,265	1,522	1,944	5,236	1,705
* Minibus seat kilometres per capita	seat km/person	0	0	0	0	0	**0**	66	0	0	0	455	38
* Tram seat kilometres per capita	seat km/person	0	0	0	0	0	**0**	1	77	20	352	20	183
* Light rail seat kilometres per capita	seat km/person	493	0	1,156	184	0	**367**	68	2	163	204	47	138
* Metro seat kilometres per capita	seat km/person	2,011	0	0	0	0	**402**	588	2	464	1,025	947	746
* Suburban rail seat kilometres per capita	seat km/person	2,905	3,561	2,590	1,649	2,401	**2,621**	349	2,682	194	2,575	466	1,649
* Ferry seat kilometres per capita	seat km/person	88	0	100	4	0	**38**	13	49	5	27	96	26
Percentage of total daily trip by non motorised modes	%	22.1%	31.2%	26.3%	33.0%	23.0%	**27.1%**	9.5%	14.2%	11.6%	34.5%	26.1%	23.2%
Percentage of total daily trip by motorised public modes	%	31.6%	17.6%	20.0%	9.7%	18.0%	**19.4%**	5.5%	7.5%	13.1%	22.4%	46.0%	16.8%
Percentage of total daily trip by motorised private modes	%	46.3%	51.1%	53.7%	57.2%	59.0%	**53.5%**	85.0%	78.3%	75.4%	43.1%	27.9%	59.9%
Passenger car vehicle kilometres per capita	v.km/person	5,100	5,343	5,068	5,180	5,279	**5,194**	13,100	8,698	6,519	4,937	1,333	7,312
Motorcycle vehicle kilometres per capita	v.km/person	54	58	77	55	63	**61**	76	72	53	123	242	104
Total private vehicle kilometres per person	v.km/person	5,155	5,401	5,144	5,235	5,342	**5,255**	13,176	8,770	6,572	5,060	1,575	7,416
Passenger car passenger kilometres per capita	p.km/person	6,630	6,839	6,689	6,734	6,862	**6,751**	18,703	12,447	8,495	6,817	1,975	10,234
Motor cycle passenger kilometres per capita	p.km/person	57	60	80	57	66	**64**	81	79	58	133	290	113
Total private passenger kilometres per capita	p.km/person	6,687	6,899	6,769	6,791	6,928	**6,815**	18,784	12,526	8,554	6,950	2,265	10,347

Each variable is examined in turn and selected graphic representations are made to enhance understanding of the data. The aim here is to communicate in a summarised, quick way, the potentially valuable research results which have emerged from this small K2 project. It contains some insights into their implications and occasionally some possible detailed reasons behind the results.

3.1. Urban density, job densities and activity densities

Density is critical in understanding the fundamentals of urban transport characteristics in any city. Low densities are associated with automobile dependence, higher densities are associated with less automobile dependence and a greater role for public transport, walking and cycling.

Swedish urban regions are low density, averaging less than the larger Canadian cities in 2005 (urban population density of 19.8/ha compared to 25.8/ha) and they are less than half the typical European urban density of 47.9/ha. The validity of these results has been checked in detailed with assistance from Statistics Sweden (e.g. see note at end of Appendix 2 and the footnote below).

The Stockholm region has the highest urban density (23.5/ha), job density (12.6 jobs/ha) and activity density (36.1/pop+jobs/ha), while Linköping has a typical US city urban density (13.8/ha). Across the full range of Swedish cities, unsurprisingly, job densities and activity densities follow a similar pattern to urban density, placing Swedish urban regions at the lower end of densities in cities globally (activity density in 2015 was only 26% more than the American cities and 47% higher than in Australian cities). These important results on density are referred to as discussions are presented of more variables below. Figure 1 summarises the results for the cities on urban density. Appendix 2 has some important notes about density at the end.

Table 2. Comparative urban transport indicators for five Swedish urban regions compared to American, Australian, Canadian, European and Asian cities, Part II.

Variable	Units	Stockholm 2015	Malmö 2015	Göteborg 2015	Linköping 2015	Helsingborg 2015	SWE 2015	USA 2005	AUS 2006	CAN 2006	EUR 2005	ASIA 2005	ALL 2005
Overall average speed of public transport	km/h	33.6	46.8	30.9	38.6	31.5	**36.3**	27.3	33.0	25.7	29.8	26.3	28.8
* Average speed of buses	km/h	24.8	27.8	28.0	31.3	23.6	**27.1**	19.9	23.4	22.4	21.9	19.4	21.5
* Average speed of minibuses	km/h	0.0	0.0	0.0	0.0	0.0	**0.0**	36.4	-	-	-	20.8	36.4
* Average speed of trams	km/h	0.0	0.0	0.0	0.0	0.0	**0.0**	5.2	16.0	14.0	16.9	11.1	15.4
* Average speed of light rail	km/h	30.5	0.0	23.0	16.2	0.0	**23.2**	26.0	18.0	34.8	25.9	22.6	26.1
* Average speed of metro	km/h	34.0	0.0	0.0	0.0	0.0	**34.0**	38.9	21.0	36.4	33.5	46.3	35.7
* Average speed of suburban rail	km/h	56.3	75.6	66.0	93.8	65.8	**71.5**	57.3	47.6	44.7	52.1	50.8	51.7
* Average speed of ferries	km/h	20.4	0.0	12.0	8.0	0.0	**13.5**	19.3	14.7	13.5	16.2	22.4	17.5
Average speed of the road network (24/)	km/h	37.1	41.0	39.0	30.5	39.1	**37.3**	50.4	42.8	45.4	34.3	30.6	40.2
Total public transport boardings per capita	boardings/person	358.6	111.4	284.7	64.0	158.4	**195.4**	66.7	95.6	150.7	386.3	450.4	254.4
* Bus boardings per capita	boardings/person	142.5	91.2	145.6	44.2	144.9	**113.7**	37.8	43.7	97.1	145.2	229.0	107.3
* Minibus boardings per capita	boardings/person	-	-	-	-	-	**-**	0.5	0.0	0.0	0.0	47.9	2.5
* Tram boardings per capita	boardings/person	-	-	-	-	-	**-**	0.2	10.0	3.6	59.2	6.4	30.6
* Light rail boardings per capita	boardings/person	22.2	0.0	115.0	12.0	0.0	**29.8**	3.3	0.2	11.6	24.1	12.9	14.6
* Metro boardings per capita	boardings/person	151.5	0.0	0.0	0.0	0.0	**30.3**	22.1	0.2	35.3	98.8	120.1	63.8
* Suburban rail boardings per capita	boardings/person	40.1	20.2	18.1	7.7	13.5	**19.9**	2.6	39.7	2.6	58.3	29.8	34.7
* Ferry boardings per capita	boardings/person	2.3	0.0	6.0	0.0	0.0	**1.7**	0.2	1.9	0.5	0.7	4.1	0.8
Total public transport passenger kilometres per capita	p.km/person	2,578.7	1,451.2	2,463.0	877.0	1,589.9	**1791.9**	571.1	1075.2	1030.9	2233.9	3786.1	#####
* Bus passenger kilometres per capita	p.km/person	822.3	520.7	1,281.4	533.7	969.6	**825.5**	214.4	349.1	620.4	632.9	1916.4	564.2
* Minibus passenger kilometres per capita	p.km/person	-	-	-	-	-	**-**	13.9	0.0	0.0	0.0	138.9	10.2
* Tram passenger kilometres per capita	p.km/person	-	-	-	-	-	**-**	0.3	36.0	21.6	131.5	10.1	70.9
* Light rail passenger kilometres per capita	p.km/person	130.4	0.0	517.6	38.2	0.0	**137.2**	24.6	0.5	101.3	100.7	46.8	69.8
* Metro passenger kilometres per capita	p.km/person	847.9	0.0	0.0	0.0	0.0	**169.6**	216.1	0.4	210.6	575.0	1154.2	415.2
* Suburban rail passenger kilometres per capita	p.km/person	760.0	930.5	645.4	304.7	620.3	**652.2**	100.1	676.3	73.9	789.7	492.4	508.6
* Ferry passenger kilometres per capita	p.km/person	18.0	0.0	18.6	0.4	0.0	**7.4**	1.8	12.9	3.1	4.0	27.2	5.4
Overall public transport vehicle occupancy	persons/unit	22.6	22.0	16.3	14.4	16.1	**18.3**	13.1	18.1	19.8	21.0	28.1	19.0
* Bus vehicle occupancy	persons/unit	14.6	10.3	10.7	10.6	10.9	**11.4**	10.9	11.7	16.1	15.0	25.3	14.3
* Minibus vehicle occupancy	persons/unit	-	-	-	-	-	**-**	2.2	-	-	-	4.9	2.4
* Tram wagon occupancy	persons/unit	-	-	-	-	-	**-**	19.6	23.3	51.6	22.1	22.6	26.5
* Light rail wagon occupancy	persons/unit	20.0	-	30.0	13.8	-	**21.3**	24.9	18.2	28.7	27.9	28.2	24.7
* Metro wagon occupancy	persons/unit	19.7	-	-	-	-	**19.7**	22.6	30.3	21.6	26.3	56.6	27.4
* Suburban rail wagon occupancy	persons/unit	97.8	60.4	50.4	40.5	60.0	**61.8**	38.5	24.7	51.8	30.8	55.0	34.1
* Ferry vessel occupancy	persons/unit	33.5	-	28.1	1.8	-	**21.1**	183.7	52.4	229.7	38.6	150.6	91.0
Overall public transport seat occupancy	%	31%	25%	26%	19%	25%	**25%**	29%	27%	44%	38.8%	52%	37%
* Bus seat occupancy	%	29%	23%	23%	19%	25%	**24%**	27%	27%	41%	35%	36%	33%
* Minibus seat occupancy	%	-	-	-	-	-	**-**	20%	-	-	-	31%	21%
* Tram seat occupancy	%	-	-	-	-	-	**-**	63%	47%	105%	45%	51%	55%
* Light rail seat occupancy	%	26%	-	45%	21%	-	**31%**	39%	25%	39%	48%	97%	44%
* Metro seat occupancy	%	42%	-	-	-	-	**42%**	39%	23%	48%	60%	122%	57%
* Suburban rail seat occupancy	%	26%	26%	25%	18%	26%	**24%**	30%	28%	30%	35%	106%	35%
* Ferry seat occupancy	%	21%	-	19%	10%	-	**16%**	13%	25%	57%	21%	28%	22%
Public transport operating cost recovery	%	64%	45%	48%	41%	33%	**46%**	31%	37%	57%	60%	121%	54%
Average public transport farebox revenue per boarding	USD/boarding	$0.89	$0.99	$0.91	$1.17	$0.77	**$0.94**	$ 0.75	$0.96	$0.67	$0.80	$0.48	$0.77
Average public transport farebox revenue per passenger kilometre	USD/pass. km	$0.12	$0.08	$0.10	$0.09	$0.08	**$0.09**	$ 0.09	$0.09	$0.10	$0.13	$0.06	$0.11
Average public transport farebox revenue per vehicle kilometre	USD/v.km	$2.79	$1.68	$1.71	$1.22	$1.23	**$1.73**	$ 1.23	$1.59	$1.91	$2.52	$1.62	$1.99
Public transport operating cost per vehicle kilometre	USD/v.km	$4.67	$4.14	$4.10	$3.40	$4.14	**$4.09**	$4.80	$2.62	$3.82	$5.05	$1.80	$4.44
Public transport operating cost per passenger kilometre	USD/pass. km	$0.21	$0.19	$0.25	$0.24	$0.26	**$0.23**	$0.37	$0.28	$0.20	$0.27	$0.06	$0.28
Public transport operating cost per capita	USD/person	$533	$273	$618	$604	$410	**$488**	$207	$308.59	$198.51	$560.16	$265.20	$390.91
Percentage of metropolitan GDP spent on public transport operating costs	%	1.08%	0.84%	1.52%	2.00%	1.42%	**1.34%**	0.44%	0.98%	0.65%	1.50%	1.35%	1.08%
Private passenger transport energy use per capita	MJ/person	12,051	15,670	15,905	18,124	17,681	**15,886**	53,441	35,972	30,804	15,795	6,076	28,301
Public transport energy use per capita	MJ/person	1,949	1,310	2,680	1,179	1,819	**1,787**	963	1,036	1,190	1,532	2,691	1,360
Total passenger transport energy use (private plus public)	MJ/person	14,000	16,980	18,585	19,304	19,500	**17,674**	54,403	37,008	31,994	17,326	8,768	29,661
Total emissions per capita	kg/person	17.6	17.5	17.5	20.6	16.2	**17.9**	185.1	143.6	164.6	34.9	34.1	97.9
* Emissions of CO per capita	kg/person	8.7	7.5	8.0	9.6	7.4	**8.2**	145.7	111.7	130.1	22.3	19.8	74.1
* Emissions of SO2 per capita	kg/person	0.1	0.0	0.1	0.1	0.1	**0.1**	1.7	0.5	0.6	0.1	0.7	0.6
* Emissions of VHC per capita	kg/person	5.0	5.5	4.3	5.5	3.8	**4.9**	13.4	12.8	11.4	4.9	2.1	8.4
* Emissions of NOx per capita	kg/person	3.7	4.4	4.9	5.4	4.9	**4.7**	24.3	18.6	22.5	7.6	11.5	14.7
Total emissions per urban hectare	kg/ha	413	349	344	284	355	**349**	2,673	1,996	4,084	1,718	5,401	2,446
Total emissions per total hectares	kg/ha	60	48	46	22	65	**48**	962	519	1,511	858	2,117	991
Total transport deaths per 100,000 people	deaths/100,000 persons	1.3	2.4	2.3	0.7	1.5	**1.6**	9.5	6.2	6.3	3.4	3.8	5.5
Proportion of total motorised passenger kilometres on public transport	%	27.8%	17.4%	26.7%	11.4%	18.7%	**20.4%**	3.2%	8.0%	11.3%	24.5%	62.9%	18.0%
Ratio of public versus private transport speeds	ratio	0.91	1.14	0.79	1.27	0.81	**0.98**	0.55	0.78	0.57	0.88	0.86	0.75
Ratio of segregated public transport infrastructure versus expressways	ratio	1.69	0.96	1.26	1.41	1.51	**1.36**	0.56	1.98	0.56	5.51	1.42	3.16

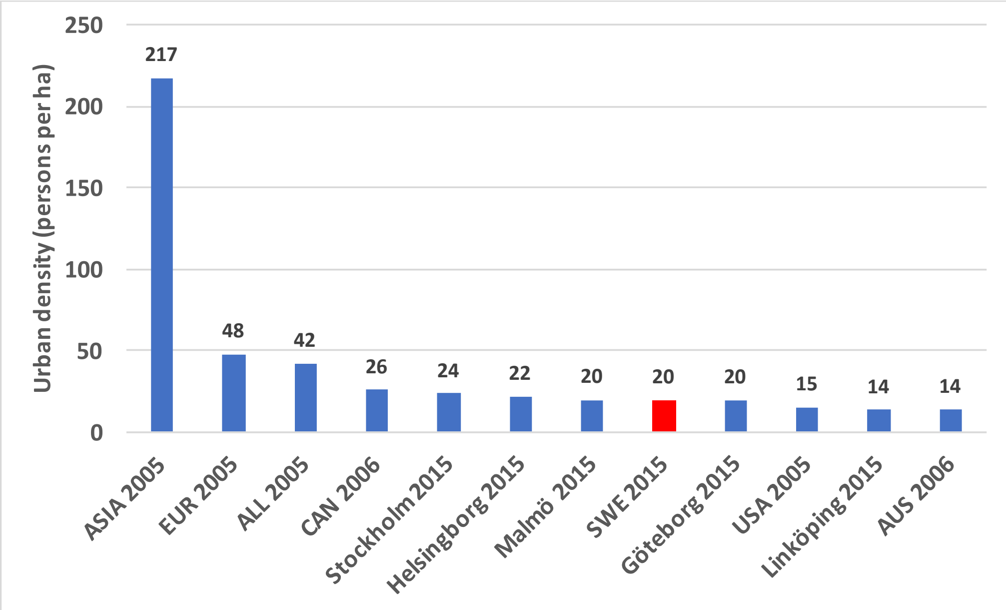

Figure 1. Urban density in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.2. Wealth

Wealth here is measured as metropolitan GDP per capita. The data are calculated for the commuter belt or labour market region of each city (see Appendix 2 explanation under this variable). Note that for the purposes of the international comparisons performed over many years using my global cities data, all financial data have been converted to *constant 1995 US dollars*.

In 2015, Swedish cities were moderately wealthy, averaging $36,393 per capita, which was more than both the Australian ($32,194) and Canadian cities ($31,263) were in 2006. However, the other European cities are generally higher in wealth ($38,683). The global sample in 2005 averaged $37,700. Stockholm, however, clearly stands out in wealth ($49,271) and in 2015 was higher than the US cities were in 2005, the wealthiest group in the global sample ($44,455). Helsingborg and Linköping, the two smaller Swedish cities in the sample, perhaps unsurprisingly, are the least wealthy of the five Swedish cities (averaging $29,588).

Of course, GDP is one of the variables that does change significantly over time. Therefore, the Australian, Canadian and European cities' GDP by 2015 could be expected to be significantly higher than Swedish cities in 2015, though the Asian cities are still likely to be less than in Sweden, but they are also likely to have caught up significantly.

3.3. Total roads

When all roads are considered from residential streets up to freeways/highways, the Swedish cities are well-endowed, averaging 6.5 m/person. This is less than in Australian cities (7.6 m/person), similar to US cities (6.0) and higher than in Canadian cities (5.4). It is also more than double the European cities with only 3.1 m/person, though this is somewhat to be expected, given the very significant lower densities of the Swedish cities (road length increases as densities decrease due to the commensurate longer roads needed to service development). Again, logically, Stockholm has the least roads (4.7 m/person), while Linköping, the least dense of the Swedish cities, has the most (9.1 m/person).

On a spatial basis, the length of road per urban hectare is not as high in comparative terms because of the low density of Swedish cities (it is less than in both Canada and the European cities), but still higher than the rest, even the American and Australian auto cities.

3.4. Freeways

Freeways are premium road infrastructure and much more indicative of automobile dependence than roads *per se*. Ideally, freeways should really measure lane kilometres for a better indication of capacity, but in practice it is surprisingly difficult to obtain even linear length of freeways, let only lane kilometres. A pattern begins to emerge here in the Swedish cities of relatively strong orientation to the car and this is despite comparatively moderate wealth when measured by GDP per capita in the metropolitan regions, though it does tend to correlate with the lower density nature of Swedish urbanism.

Combined with lower densities, the Swedish cities are well-endowed with freeways, averaging 0.230 m/person, significantly higher than any other group of cities in the global sample. US and Canadian cities had in 2005 some 0.156 and 0.157 m/person of freeway respectively, while the global sample averaged 0.112 m/person, or less than half that of the Swedish cities. In keeping with Stockholm's distinctive features, it also has the least freeway infrastructure (0.138 m/person), while Helsingborg, on a per capita basis, has a little higher freeway availability than Calgary in Canada, the highest city in the global sample for freeways in 2005.

Spatially, the lower density of Swedish cities is not able to eliminate high freeway availability per urban hectare (4.7 m/ha compared to 4.1 in European cities), which is also twice as high as in US cities in 2005 (2.3 m/ha). In every respect, these five large Swedish settlements have a high availability of freeways. Figure 2 depicts this significant result.

3.5. Car ownership

So far Swedish cities in density, roads and freeways, present themselves as being rather auto-oriented. However, in car ownership, interestingly this picture begins to change to a degree. Figure 3 presents the car ownership results graphically, showing that Swedish cities in 2015 average a comparatively modest 423 cars/1000 persons. This is below the averages for all other groups of cities (Australian and American cities were 647 and 640 cars/1000 persons respectively and European cities were 463 cars/1000 persons in 2005) and the global sample as a whole (512 cars/1000). Only the two large Asian urban regions have less with a paltry 78/1000. Stockholm has only 398 cars/1000, while the Malmö region has 442/1000. Swedish city car ownership is thus caught in quite a tight and comparatively modest band of car ownership between about 400 to 450 cars per 1000 persons. It would be expected that by 2015, the other cities would have increased a little more in car ownership, further emphasising the low result in Sweden. Car usage, a more important factor than car ownership per se, is considered later in the report.

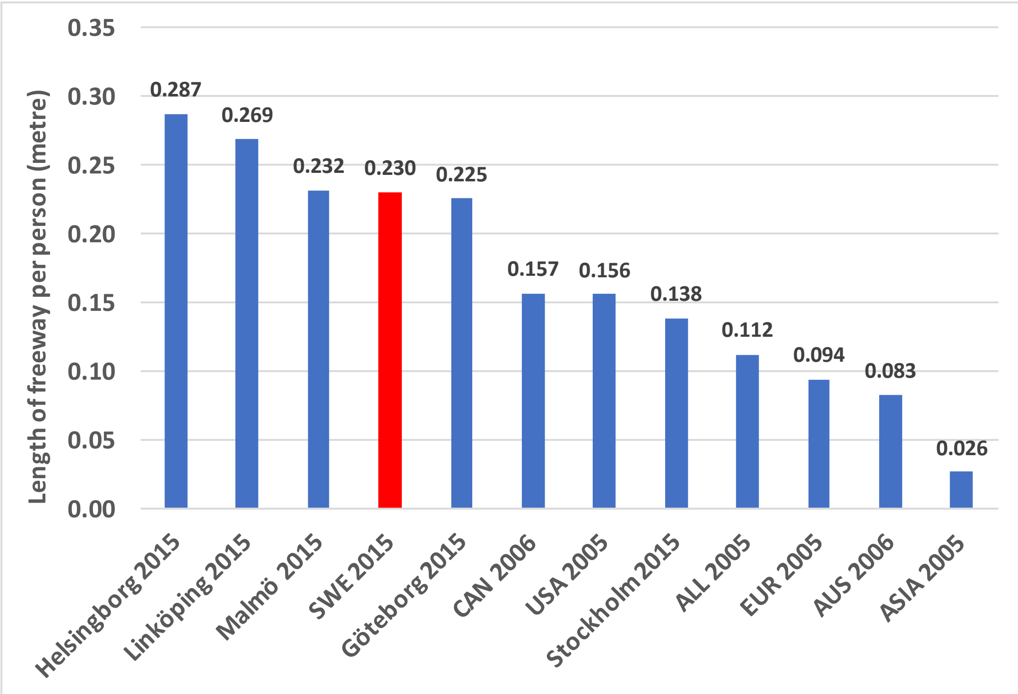

Figure 2. Freeway linear length per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.6. Motorcycle ownership

In Swedish cities, like in many other cities in the developed world, motorcycles play a relatively small role in urban transport. Motorcycles per 1000 persons in the five cities averages only 30, (one motorcycle for every 33 people), which is less than in the European cities in 2005 (41), but quite a bit higher than in the US (16), Australia (21), Canada (15) and Singapore and Hong Kong (19). Motorcycle usage is considered later in the report.

3.7. Public transport data

This research project has a strong focus on public transport systems and their characteristics. Public transport variables are spread over Tables 1 and 2 and cover the following twenty-four items:

Per capita line length

1. Per capita reserved route by mode
2. Per urban hectare reserved route by mode
3. Per capita public transport vehicle fleet by mode
4. Per capita public transport service level (vehicle kilometres)
5. Per capita public transport service level (seat kilometres)
6. Percentage of daily trips by public transport
7. Average speed of public transport by mode
8. Per capita public transport use (boardings) by mode
9. Per capita public transport (passenger kilometres) by mode
10. Public transport vehicle occupancy by mode
11. Public transport seat occupancy by mode
12. Public transport operating cost recovery
13. Average public transport farebox revenue per boarding
14. Average public transport farebox revenue per passenger kilometre
15. Average public transport farebox revenue per vehicle kilometre
16. Public transport operating cost per vehicle kilometre
17. Public transport operating cost per passenger kilometre
18. Public transport operating cost per capita
19. Percentage of metropolitan GDP spent on public transport operating costs
20. Public transport energy use per capita
21. Proportion of total motorised passenger kilometres on public transport
22. Ratio of public versus private transport speeds
23. Ratio of segregated public transport infrastructure versus expressways

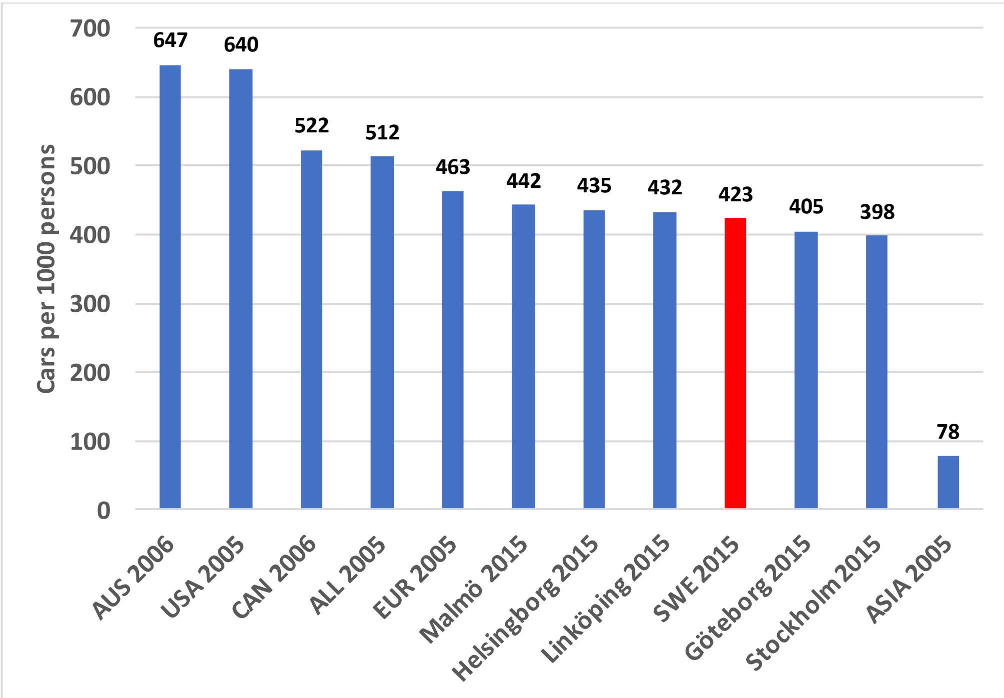

Figure 3. Car ownership in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.1. Per capita length of public transport lines

Table 1 contains the above data. It shows that these five Swedish cities have very high per capita provision of public transport lines, indeed by far the highest on average of all cities in the global sample. They have 77% higher line length per person than the European cities, the next highest in the sample. This suggests that Swedish urban regions have relatively good coverage with public transport, but this items does not give an indication of how well-serviced the lines are. A line providing an hourly service is not of great utility compared to a line with a 10-minute service. Later in the discussion public transport service provision is reviewed, which reveals that overall, Swedish cities are also relatively well-serviced with public transport, based on the two variables collected.

3.7.2. Length of reserved public transport route per person

Perhaps a more revealing and important item in public transport is the extent of reserved public transport routes. This is route that is fully protected from general traffic and therefore not subject to hold ups due to congestion. It consists mainly of rail lines (metro, regional rail), some parts of tram/LRT systems and busways. The magnitude of this variable is something of a measure of the quality of public transport services, because clearly such routes offer speedier travel and services running along them often can compete with the speed of cars, which are frequently stuck in parallel traffic jams.

Table 1 suggests that on a per capita basis, Swedish cities are well-endowed with reserved public transport route, exceeding by a small margin even that of European cities more generally. This is mainly achieved by the rail systems and much less so by bus lanes, except in Göteborg where bus lanes are more common and represent a higher proportion of reserved routes than in the other four Swedish cities.[1]

Figure 4 provides an overview of these data showing that Helsingborg and Linköping have the highest provision, while Malmö has the least. It shows the very stark contrasts between the modest density Swedish cities and the low density American, Australian and Canadian cities. Asian cities are also less well endowed with reserved route on a per capita basis, but this is partially explained by their high densities.

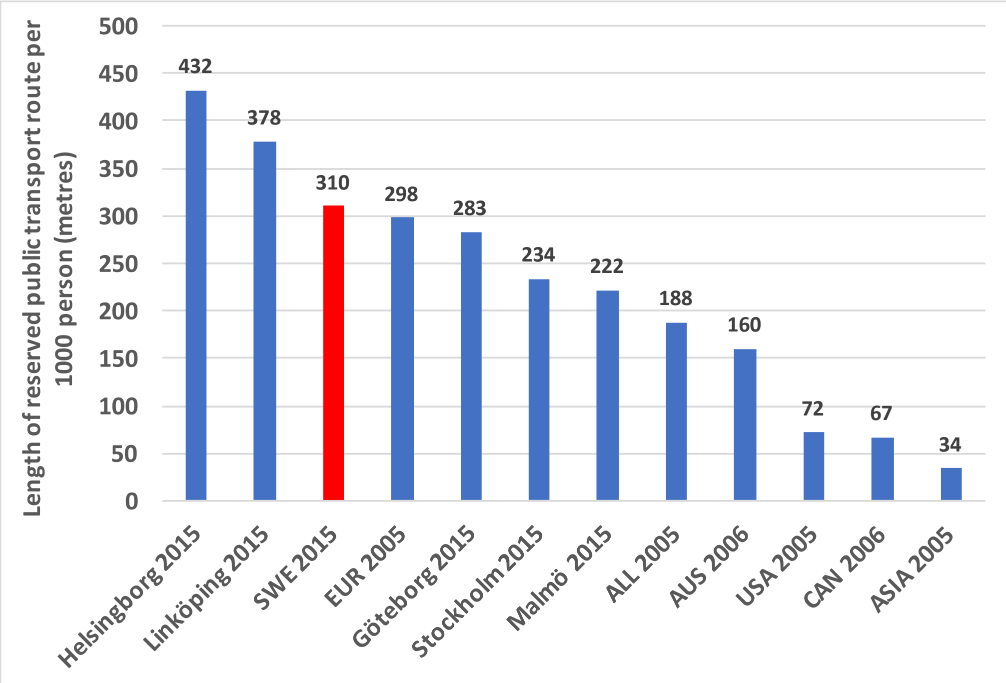

Figure 4. Reserved public transport route per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.3. Ratio of reserved public transport route to freeways

One way of measuring the relative commitment in cities to the car versus public transport is through comparing their respective highest order pieces of infrastructure. In the case of cars this is freeways and the case of public transport it is reserved public transport routes (rail lines separated tram/LRT track and bus lanes). Table 2 and Figure 5 shows the ratio of these two items.

It reveals that these five Swedish cities have 1.36 times more reserved public transport than they do urban freeways. Although this suggests a greater priority to public transport, the value is low in this global sample and in fact only better than the Canadian and American cities. Other European cities have 5.51 times more reserved public transport

[1] It should be noted that it was extremely difficult assembling data on bus lane lengths in Sweden. Each municipality controls this along with bus lanes provided nationally on larger roads. There is no single repository of this information. The data reported here represent an utterly unique compilation in Sweden as it had to be collected carefully from each municipality and for bus lanes on national roads, from the national level.

route than freeways and the whole global sample of other cities overall has 3.16 times more.

Performance on this factor is determined by the fact that although Swedish cities have comparatively good busway lengths and regional rail lines, this is eclipsed by the extensive freeway systems.

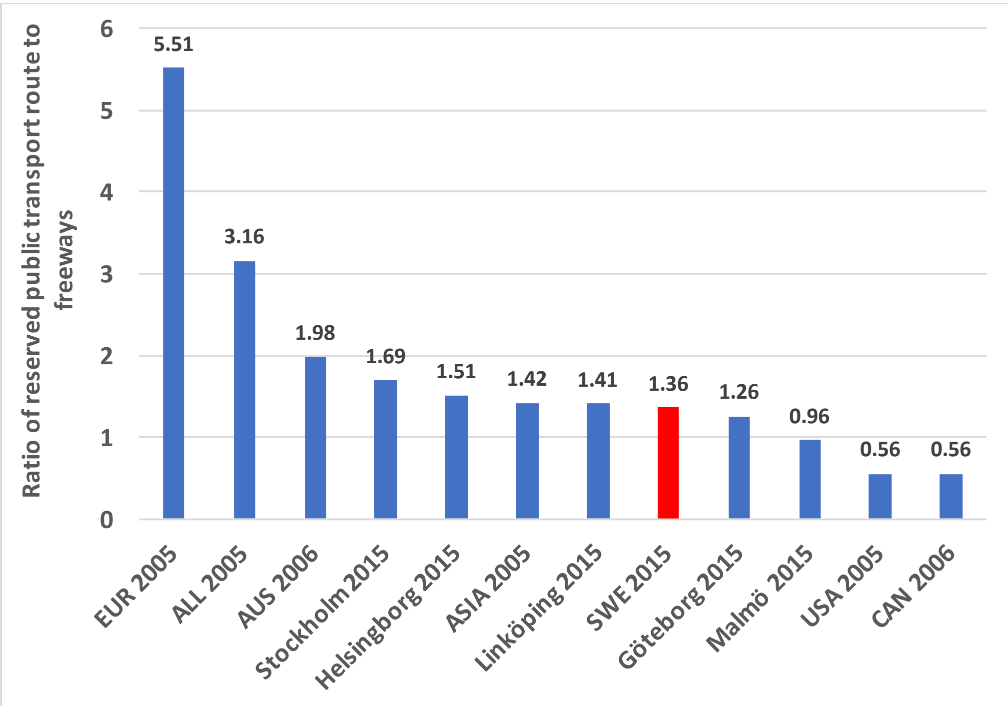

Figure 5. Ratio of reserved public transport to freeways in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.4. Length of reserved route per urban ha

Another perspective on reserved public transport route is seen by examining the spatial density of this factor. Here we see than the Swedish cities with their lower densities fall well below the spatial density of reserved public transport routes in other European cities. They are also below the high density Asian sample on this factor but not by a huge margin. However, even though their urban densities are modest, their reserved route ratio still manage to eclipse that of American, Australian and Canadian cities by a large margin. Swedish cities are on average over three times higher than the average for these three auto-oriented groups of cities (5.63 compared to 1.74 metres per ha). Figure 6 shows these data.

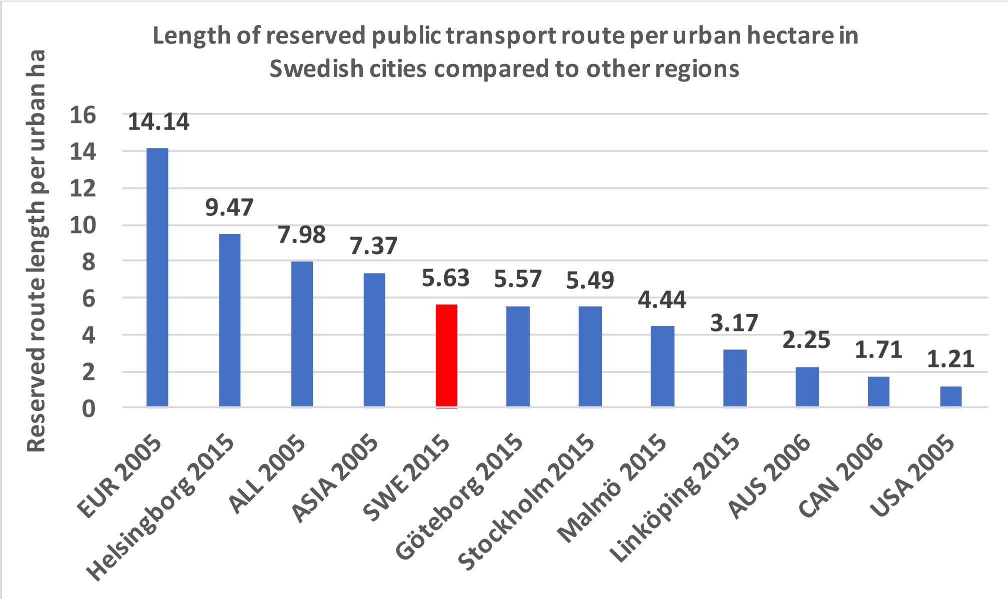

Figure 6. Reserved public transport route per urban hectare in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.5. Public transport vehicles per capita

Another indirect measure of the strength of public transport in a city shown in Table 1 is the number of public transport vehicles it has available. Here we combine all the modes on an equitable basis by using wagons for the rail modes instead of "trains" due to the widely varying train consist sizes. Swedish cities here distinguish themselves in having significantly higher public transport vehicles per person than in the American, Australian and Canadian cities (1.37 vehicles per 1000 persons, compared to 0.76, 0.93 and 0.92 respectively). They do, however, fall short of the other European cities and the Asian cities with 1.51 and 1.50 per 1000 persons respectively.

3.7.6. Annual public transport service per person (vehicle kilometres)

Public transport service levels can be measured in vehicle kilometres of service and seat kilometres of service, the latter giving a much better idea of actual capacity of supplied services due especially to the much larger vehicles involved with rail services compared to buses.

The Swedish cities have comparatively healthy levels of public transport service especially when compared to the auto-oriented cities in the USA, Australia and Canada, which also have low density land use patterns. We thus begin to see further evidence of how Swedish urban regions distinguish themselves from other low density regions by still providing relatively good quality and abundant public transport systems, that go beyond what is normally provided in lower density, auto-oriented environments and cultures.

Figure 7 shows that Swedish cities average 98 vehicle kilometres of public transport service per person (v.km for short), while US cities had only 39, Australian cities 59, Canadian cities 52 and the global sample overall was 81 v.km/person. The other European cities, even though being more than twice as dense, had in 2005 only 9% more service per capita than the Swedish cities (107 v.km/person) and the Asian cities had the most at 134 v.km/person. In this variable, Göteborg distinguishes itself with very high service (151) and Stockholm is also high at 114, or better than the average for the other European cities. Linköping has the lowest level of public transport service at 66 v.km/person, but even here with its low density of 13.8 persons/ha, its public transport service provision per capita is better than US, Australian and Canadian cities.

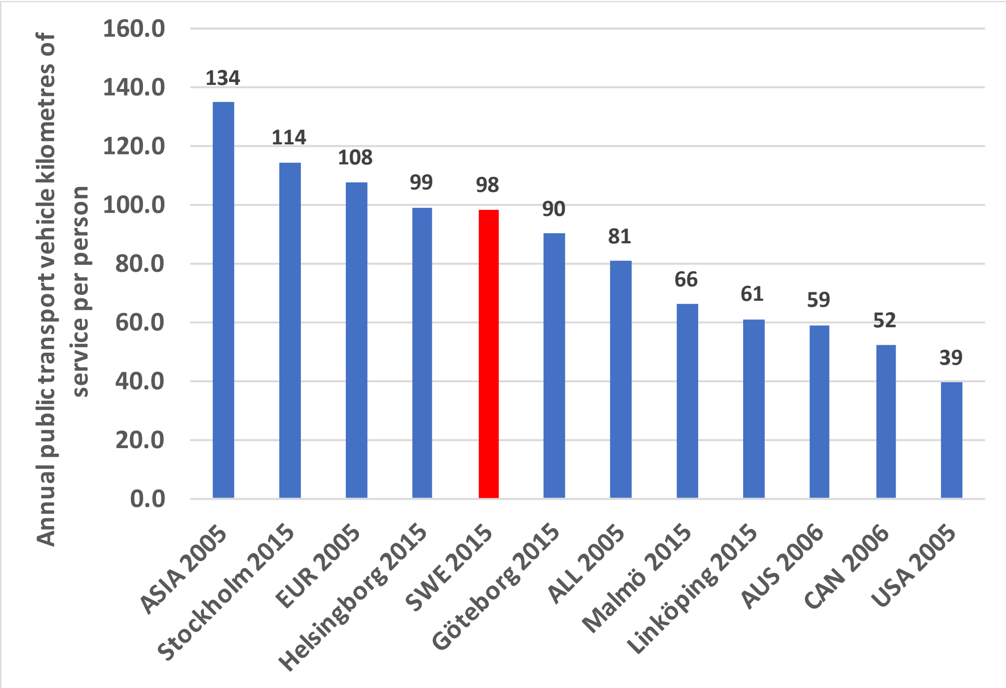

Figure 7. Annual public transport vehicle kilometres of service per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

Except in Stockholm, public transport service is dominated by buses (Stockholm is the only city with a metro). Although all five Swedish cities do have suburban/regional rail services, the other European cities have much more rail service. Tram, light rail, metro and suburban rail services combined averaged 57 v.km/person in the European cities, whereas in Swedish cities it was only 25 v.km/person and this is very likely to be a factor that leads to lower public transport use in Swedish cities (see Kenworthy, 2008 on the importance of urban rail and later discussion).

Having said this, the Swedish cities distinguish themselves in a large amount of bus service per person (73 v.km/person), which is significantly higher than all other cities except the Asian cities, which it equals. Bus service per person is also double the global cities average and 71% higher than the other European cities.

3.7.7. Annual public transport service per person (seat kilometres)

Seat kilometres of public transport service per person represents a better measure of the capacity of public transport services that are provided. In this regard, Swedish cities again distinguish themselves well. Their average level of 6,895 seat kilometres per person, exceeds even the average European level of 6,126 and is massively bigger than anything provided in Australia, the USA or Canada. Only Asian cities with their huge metro systems exceed the Swedish level. Even Linköping, the lowest of the Swedish cities (4,647) is higher in seat kilometres than the averages for Australia, the USA and Canada.

Again, this indicates that the inherent disadvantage for sustainable transport of lower density cities in Sweden, is at least partially overcome or offset by a very high commitment to providing public transport service, a quite unusual combination. Figure 8 provides the comparative data on this factor.

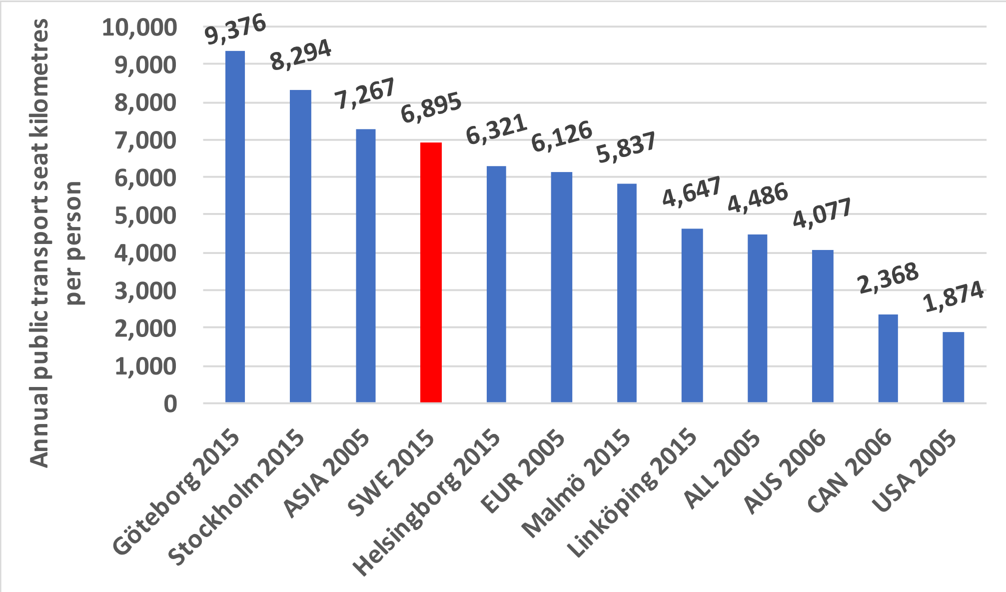

Figure 8. Annual public transport seat kilometres of service per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.8. Annual public transport boardings per person

Public transport boardings per person is one measure of the usage of public transport. Table 2 shows that on average, these five Swedish cities are only moderate in their use of public transport (195 boardings/person). This is considerably higher, however, than the average usage of public transport in American cities (67), Australian cities (96) and Canadian cities (151).

On the other hand, European cities in 2005 had 386 boardings per person (or virtually double the Swedish level) and the global sample average was 254/person. The lower density nature of these Swedish cities and their generous road and freeway networks, probably explain at least some of this lower public transport usage, along with the aforementioned lower levels of rail service.

Digging a little deeper, we find that the Swedish cities had 114 bus boardings per person while the European cities had 145. Notwithstanding this difference in bus use in favour of European cities, the big distinguishing factor was the use of urban rail modes (trams, light rail, metro and suburban rail). While European cities had 240 annual boardings on all rail modes, the Swedish cities had only 80, or one-third as much. Stockholm, where rail is much more abundant, had 214 rail boardings per person, even though overall it is a lower density region (24 persons/ha).

Stockholm has, however, developed at focussed and significantly higher densities around many rail stations on the Tunnelbana network throughout the region, where such higher densities (and mixed land uses) do support the use of rail and Stockholm's relatively new and expanding tram/light rail lines are also in areas of high density. The low per capita use of rail in both Malmö, Linköping and Helsingborg is noteworthy, being lower than even in the larger US cities. This difference in the use of urban rail in Swedish cities is shown in Figure 9.

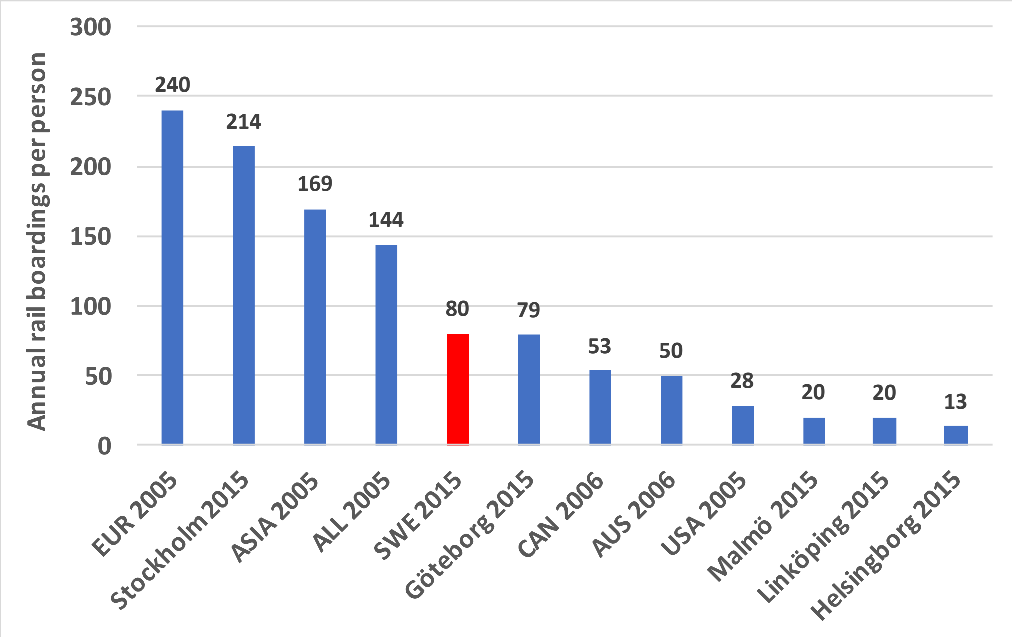

Figure 9. Annual rail boardings (tram, light rail, metro and suburban rail) per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.9. Annual public transport passenger kilometres per person

Another measure of public transport use is passenger kilometres, which takes account of the distances passengers travel on public transport (Table 2). Interestingly, here a slightly different picture emerges of public transport in Swedish cities compared to boardings. Swedish cities have healthier levels of public transport use based on passenger kilometres or distances travelled by users, possibly because of their lower densities requiring longer trips on public transport. So, whereas boardings averaged only 195 per person and were 49% lower than the European cities, passenger kilometres per person average 1,792 per person in the Swedish cities compared to 2,234 in European cities, or only 20% less.

Table 2 also shows that while boardings by rail only constituted 41% of total boardings per capita in the Swedish cities, rail accounts for 54% of the total average per capita public transport passenger kilometres in the Swedish cities. Unsurprisingly, rail is used to travel longer distances by public transport in Swedish cities. Finally, the data also show that the Swedish cities far exceed the public transport passenger kilometres per capita in the American, Australian and Canadian cities. Clearly, and despite comparatively low densities overall, Swedish cities do offer public transport systems that are used to undertake a lot more travel than in auto-oriented cities and only 20% less than in a large sample of other European cities. Figure 10 displays these results.

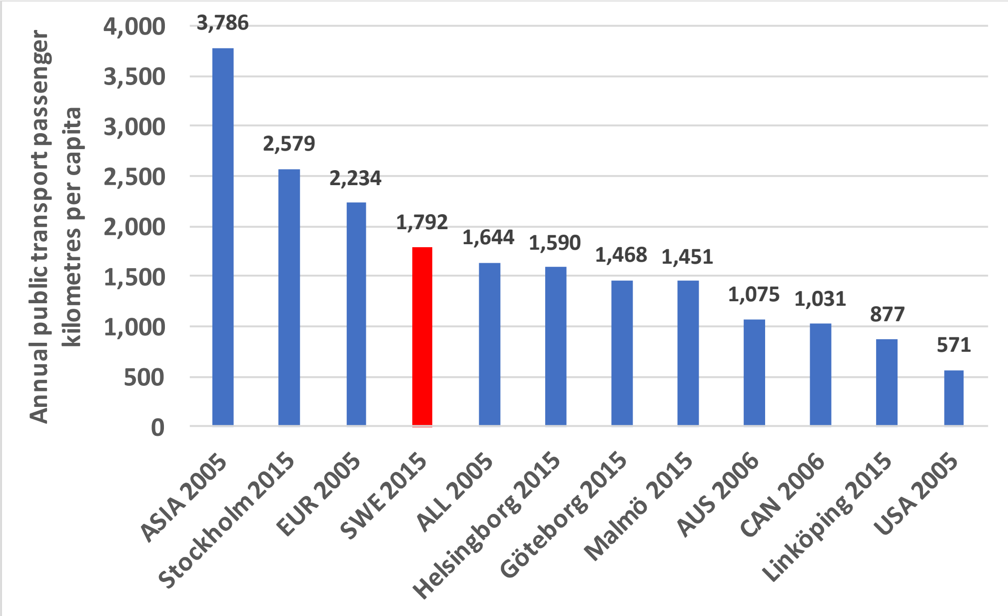

Figure 10. Annual public transport passenger kilometres per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.10. Annual public transport vehicle occupancy

This factor is a measure of the intensity of use of public transport service that is provided. It is derived by taking the annual passenger kilometres and dividing by the annual vehicle kilometres of service to provide a measure of the average number of persons per vehicle. With rail modes, each wagon is counted as a vehicle so rail vehicle kilometres means "wagon kilometres" and persons per vehicle means persons per rail wagon.

Table 2 shows that in the five Swedish cities, average vehicle occupancy ranges from a high of 23 persons/vehicle in Stockholm to a low of 14 in Linköping, with an average of 18 persons/vehicle. This does not differ greatly from average loadings in other cities globally, except in US cities where it is only 13 and in Asian cities where it is higher at 28. European cities averaged 21 persons per vehicle in 2005. Across the entire sample of cities in 2005, average vehicle occupancy was 19 so the Swedish cities are rather typical in public transport vehicle occupancy.

Bus loadings are clearly lower than for the rail modes in all cities, with Swedish cities averaging 11 persons/bus compared to 15 in European cities in 2005 and 14 for the global sample. Swedish cities, however, are consistently higher in the number of persons per suburban/regional rail vehicle (62) with the global average being 34 in 2005. There may be an influence here from the way trains are being configured over recent years with a tendency towards multiple units, which can lead to fewer individual wagons being declared in the statistics and the resulting vehicles are therefore bigger with larger loadings (in the past such "vehicles" may have constituted two wagons instead of one so loadings per wagon would have appeared less).

Overall, the occupancy data suggest that there is a lot of spare capacity in public transport systems both in Swedish cities and globally. Most of this spare capacity occurs in the off-peak with many or even most peak services being oversubscribed and crowded. How to make use of this spare capacity is an important policy matter and can relate to land use planning, especially centres and sub-centres to ensure a healthy demand for public transport services throughout the day and backloading in the peak period when many vehicles returning from city centres have much spare capacity (Cervero, 1998).

3.7.11. Annual public transport seat occupancy

This variable measures the intensity of the use of public transport in terms of what percentage of seats are, on average, occupied. It is derived by taking the annual passenger kilometres and dividing by the annual seat kilometres of service to provide a measure of the percentage occupancy of total seats. Table 2 and Figure 11 provide the results and show that these Swedish cities are overall rather low on seat occupancy (25%) while European cities average 39%. Stockholm is the highest with 31% and Linköping the lowest with 19%. Swedish cities are below all the city groups in this factor. The data suggest that there is certainly spare capacity provided in these Swedish cities which could be utilised, most likely in the off-peak if better urban planning can create more demand throughout the day and better back-loading, as well as the provision of more circumferential public transport options to move across the cities.

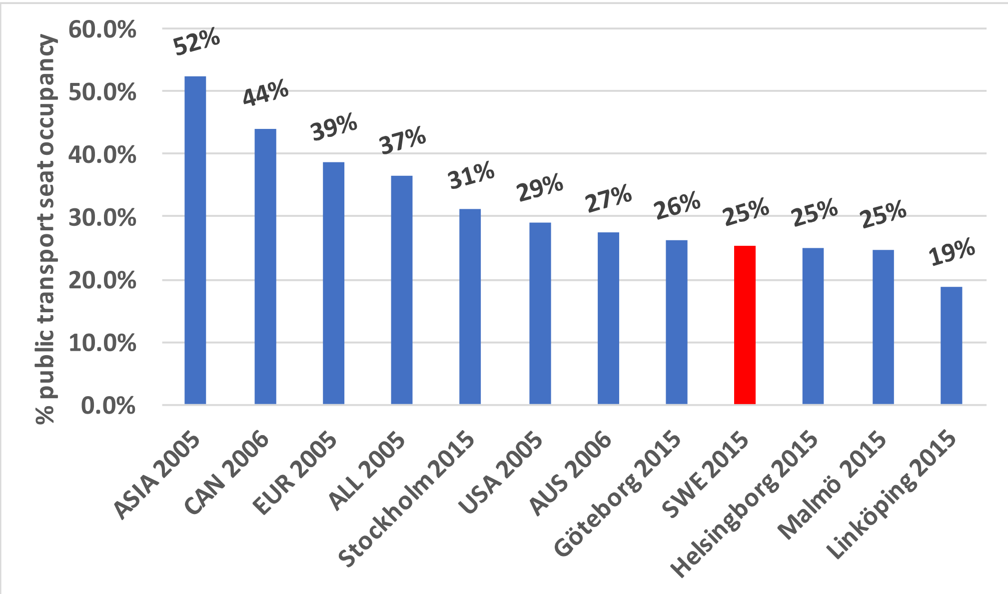

Figure 11. Public transport seat occupancy in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.12. Average speed of public transport systems

Speed-competitiveness in public transport is an important factor in helping to determine public transport use. The relative speed between private transport and public transport is particularly important (Newman and Kenworthy, 1999b). Let us first compare average speeds amongst the public transport systems themselves. Table 2 reveals that Swedish cities overall have relatively healthy average speeds for their public transport systems (the overall speed of the entire public transport system is a weighted speed based on passenger hours by each mode). At 36.3 km/h the five Swedish cities have the highest public transport operating speeds of all cities, ahead of the next highest the Australian cities which average 33.0 km/h. The global average from the sample of cities here was only 25.1 km/h and the European cities a little better at 29.8 km/h.

The Swedish cities achieve these high average speeds for public transport predominantly because of the average speed of the suburban/regional rail trains that operate at high speeds in each region over long distances (their speeds average 71.5 km/h), significantly higher than suburban rail systems in other cities (51.7 km/h for the global average), which for the most part operate over smaller distances. However, Swedish urban bus systems also have the highest speed in the global sample, averaging 27.1 km/h, which is very competitive when compared to the bus system average speeds in all other groups of cities in Table 2 (the range was 23.6 km/h in Helsingborg and 31.3 km/h in Linköping). The global average speed for urban buses was only 21.5 km/h, and the European cities only 21.9 km/h, so Swedish urban bus services clearly operate at healthy speeds compared to other cities.

3.7.13. Relative speed of public transport versus general road traffic

A more important factor regarding speed of transport systems is the relative speed between public transport and private transport (or general road traffic). Figure 12 provides a graph of this and shows, as the previous variable implied, that overall, public transport systems compete very well with cars in Swedish cities.

The overall averages for both parameters suggest a near parity situation, with a range from public transport being 27% faster in Linköping to a low of public transport being only 79% as fast in Göteborg (most likely because of slower trams/LRT system). Compared to all other groups of cities including the European, Swedish cities do better on this item. European cities' public transport system average out at 88% as fast as cars and American cities' are only 55%, such that their public transport systems overall do not compete with cars on this most basic of modal choice factors.

3.7.14. Public transport operating cost recovery

For better or for worse, the percentage of public transport operating costs recovered from the farebox is a typical financial measure quoted for public transport systems, although it fails to capture the many unquantified benefits of public transport, including congestion relief for road users. It is calculated here using the farebox revenue including reimbursements for concession fares and the operating costs of public transport exclusive of finance and depreciation charges. Table 2 shows that the five Swedish cities recovered in 2015 an average of 46% of their costs from fares, ranging from 64% in Stockholm to 33% in Helsingborg. The global average was 54%, while the European cities on average recovered 60%. The two Asian cities enjoyed a surplus of fares over costs (121%).

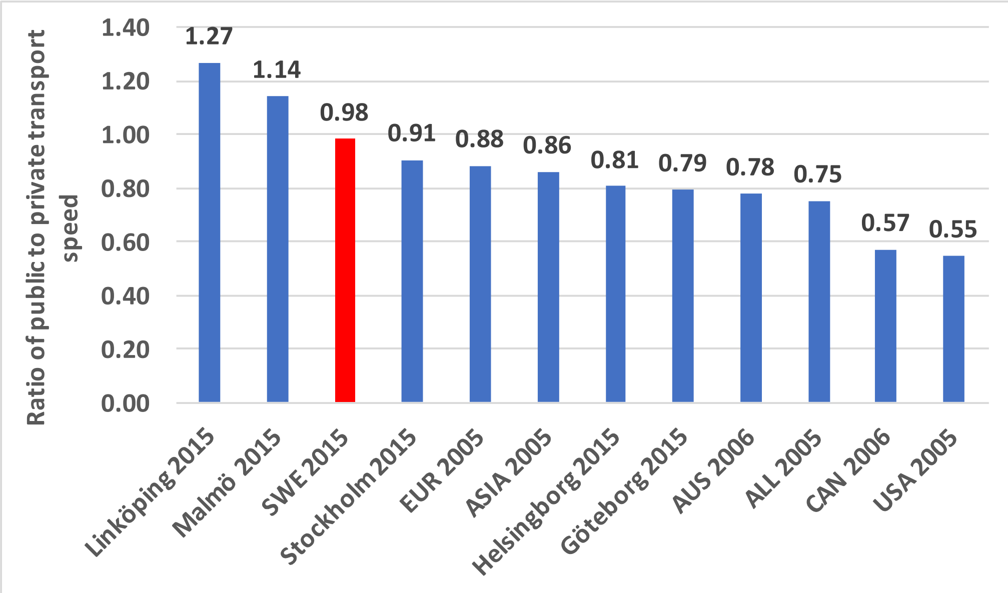

Figure 12. Relative speed of public transport versus general road traffic in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.7.15. Public transport farebox revenue per boarding, per passenger km and per vehicle km of service

Table 2 shows three variables that measure the collection rate of fares based on level of patronage and level of service. All financial data are in constant 1995 US dollars for comparative purposes. For every boarding, these five Swedish cities in 2015 collected \$0.94, ranging from \$0.77 in Helsingborg up to \$1.17 in Linköping. Globally, the Swedish cities collected more in fares than all groups of cities except in Australia which averaged in 2006 \$0.96 per boarding. European cities in 2005 collected \$0.80 per boarding.

Fare collection per passenger km travelled was \$0.09 in the Swedish cities and this is a reasonably consistent figure across the global sample (the global average was \$0.11 and European cities were \$0.13). In terms of fare collection per kilometre of service delivered, the Swedish cities collected \$1.73, which again was not far astray from the global average of \$1.99, but the European cities collected much more at \$2.52. Fare collection per kilometre of service depends on the intensity of use of public transport systems and as shown before, the boardings per capita in Swedish cities are significantly below the European level (roughly half).

3.7.16. Public transport operating costs per vehicle km, per passenger km and per capita

In terms of what it costs to operate public transport in these five Swedish cities, Table 2 shows that \$4.09 is expended per vehicle km of service provided, which again is not radically different across the global average of forty-one cities (\$4.44), though the European cities on average paid \$5.05, so 23% more than the Swedish cities. Costs per passenger km were \$0.23, which again compared closely to the global average of \$0.28. The other European cities expended \$0.27 per passenger km.

Costs expressed as per capita figures across the population reveal that each person paid in 2015 on average in the five Swedish cities $488, ranging from $410 in Helsingborg to $618 in Göteborg. The Swedish cities averaged significantly more spending on public transport operational costs than the global average of $391, but less than the European cost of $560. This figure varied quite significantly throughout the sample due to a wide range of differing factors such as wage costs, fuel prices and other matters.

3.7.17. Percentage of metropolitan GDP spent on public transport operating costs

It is also interesting to normalise the data on public transport operating costs by wealth. Table 2 shows that these Swedish cities paid in 2015 the equivalent of 1.34% of their metropolitan GDPs on operating their public transport systems, a relatively small figure, but more than the global average in 2005 of only 1.08%. There was a considerable range with Linköping spending 2.00%, while Malmö only spent 0.84%. The European cities, perhaps unsurprisingly given their extensive public transport systems, paid the most at 1.50% of their GDPs to operate public transport. Sweden here is thus close other European cities. Again, somewhat predictably, American cities, which do not generally prioritise public transport, spent the least of their wealth on this factor (only 0.44% of metropolitan GDPs in 2005). Figure 13 shows these findings.

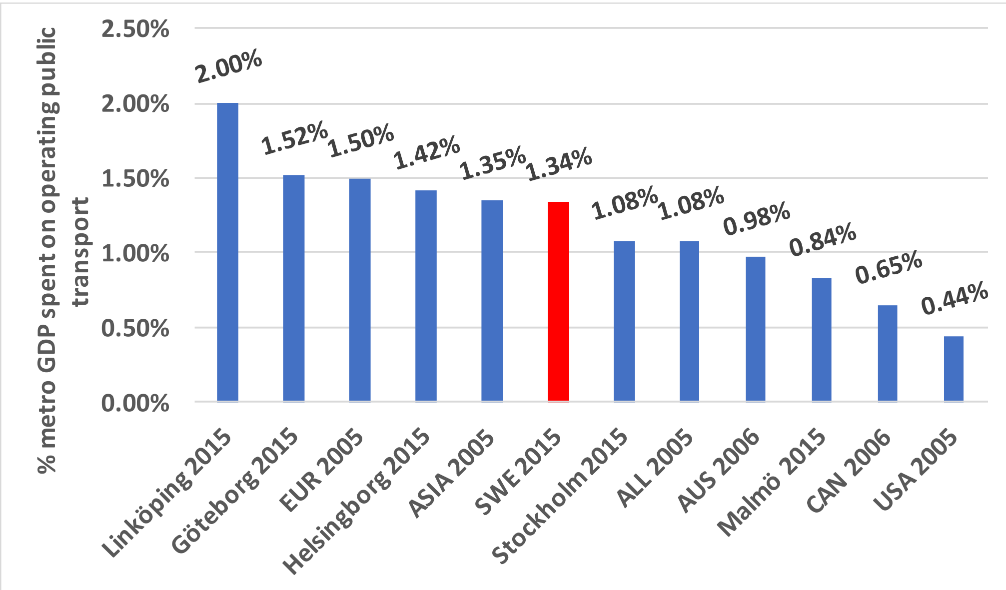

Figure 13. Percentage of metro. GDP spent on operating public transport systems in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.8. Modal split data

It is important to understand in each city the prominence of different transport modes and this is usually best expressed by modal split data from travel surveys. The latest of these surveys were gathered from each Swedish city and the percentage of daily trips by non-motorised modes (walking and cycling), public transport and private transport were collected. Taxis were classed as private transport. Table 1 contains these data.

3.8.1. Non-motorised modes modal share

Despite cold weather for much of the year, the Swedish cities acquit themselves well in walking and cycling, averaging 27.1% of all daily trips by these modes. The best performing cities are Linköping (33.0%), which probably partly benefits from its small size and shorter travel distances and Malmö with its strong orientation to bikes, at least in the City of Malmö, is second with 31.2% of trips by walking and cycling. Stockholm is lowest of the Swedish cities on this factor with 22.1%, though it is by far the best for public transport (see next). The Swedish cities do not reach the heights of other European cities for walking and cycling, which are the best globally at 34.5%, but some clearly come close. As shown in Figure 14, compared to every other group, the Swedish cities are the next best for walking and cycling.

3.8.2. Public transport modal share

Public transport share of daily trips in Swedish cities (19.4%) is much better on average than in the American, Australian and Canadian cities but falls a little short of the European figure of 22.4% and is only a fraction of the two large Asian cities where public transport strongly dominates (46%). The range on this factor within these five Swedish cities is also large with Linköping having only 9.7% of daily trips by public transport (just a bit more than in Australian cities), while Stockholm reaches 31.6%, very much higher than the European average and the only Swedish city to achieve this. Globally, the Swedish cities exceed the average of 16.8%. So again, while not being as good as other European cities, Swedish cities do comparatively well in public transport on a global scale, given their disadvantages of low density, high road and freeway provision and fewer rail systems. Figure 15 shows the data graphically.

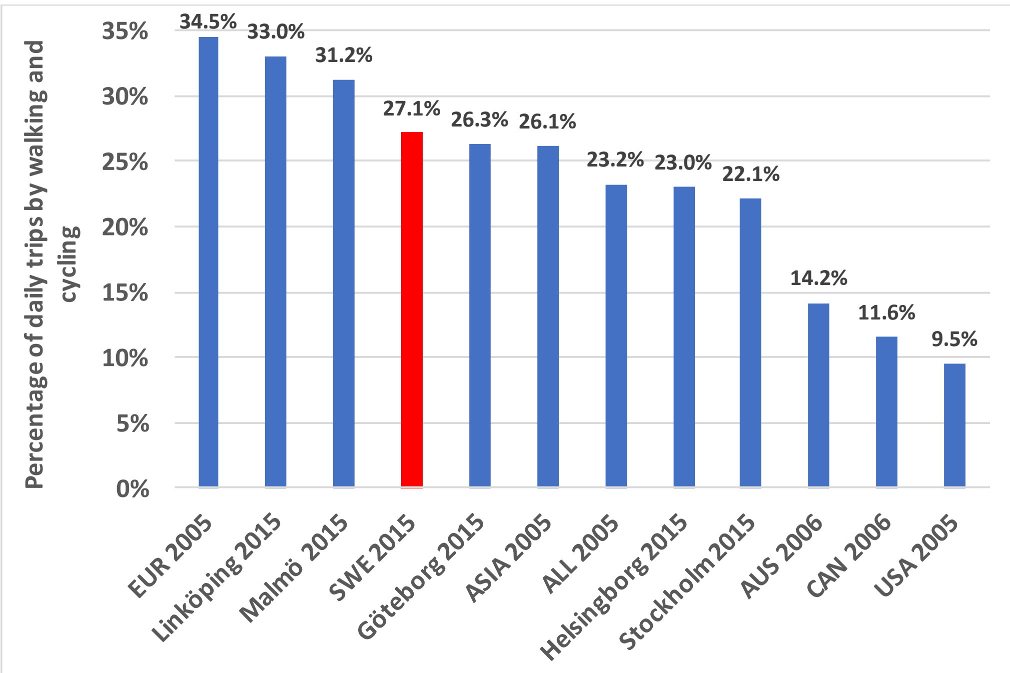

Figure 14. Percentage of daily trips by non-motorised modes in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

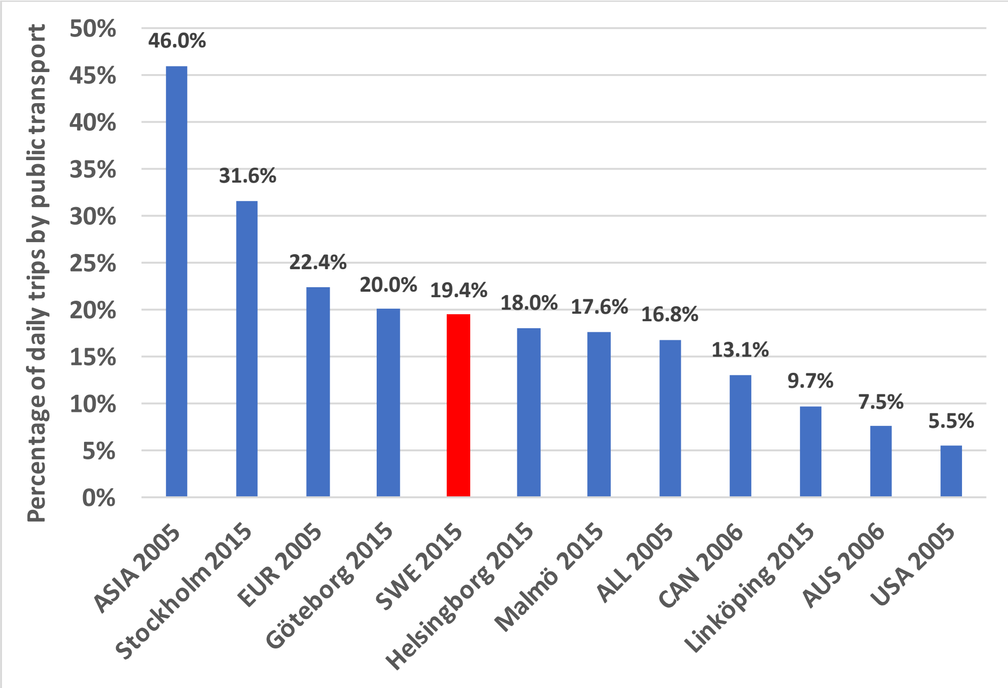

Figure 15. Percentage of daily trips by public transport in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.8.3. Modal share by private transport modes

This is the corollary of the previous two modal share variables. Swedish cities have a little over half of all daily trips (53.5%) by private motorised modes, which while it is not at the European level of only 43.1%, it is still an enviable modal split globally when it is considered that American cities have 85% of all trips by private transport, Australian cities 78%, Canadian 75% and the global average was 60% in 2005. Stockholm is clearly the lowest city in private transport with only 46.3% or much closer to the European level, while Helsingborg experiences 59.0% of daily trips by private modes. Malmö in 2015 was essentially split half and half between the more sustainable modes and private transport modes (51.1% private transport). While the trip making level and its split by private transport is important, the actual kilometres of driving by private transport is also critical to understand because it is driving that consumes energy, emits pollution, causes traffic accidents and affects public spaces in a city.

3.9. Car use (VKT)

Car use is a critical indicator of sustainability and auto-dependence in urban transport systems. High car use is associated with a host of negative, environmental, social and economic problems (Schiller and Kenworthy, 2018; Newman and Kenworthy, 2015). This factor can of course be measured by the above modal split data for trips, but a critical aspect is how much driving is done. This is measured generally by two indicators – vehicle kilometres of travel (VKT) and passenger kilometres of travel (PKT). In this study both indicators were assembled, though the latter entailed much extra research due to the absence of readily available data on average car occupancy in Swedish cities.

Table 1 shows that Swedish cities averaged 5,194 car VKT/person in 2015, which was significantly below the global sample average of 7,312 km, but a little above the European average of 4,937 km in 2005 (5% more). The data for the five Swedish cities are very tightly bounded between a low of 5,068 km in Göteborg and a high of 5,343 km in Malmö. Table 1 also shows that in annual car use, Swedish cities are very significantly below the American (13,100 km), Australian cities (8,698 km), and the Canadian cities (6,519 km), despite their relatively low densities. Urban density is the strongest correlate with car use on a global scale, so in this sense the Swedish cities represent something of an outlier in this relationship, which is worthy of further investigation (see later).

In simple terms, it appears that there are relatively strong countervailing influences at work in Swedish cities that keep car use somewhat suppressed. Based on the analysis already undertaken on available data, it appears that the relatively good Swedish public transport systems with high average operating speeds and usage levels far above those in more auto-dependent regions, plus the ability and willingness to walk and ride a bike for many trips, especially in those parts of Swedish cities that are significantly higher in density (see modal split data in previous section), help to keep a lid on car use.

In short, Swedish cities seem to be able to compensate for their overall lower densities with other positive features which strike some semblance of balance between all the modes and allow them to have car use levels that are commensurate with other European cities. More work would be needed to explore other reasons for this (e.g. economic factors related to the costs of owning and running cars in Sweden, cultural influences and others). Figure 16 contains the data on car use in Swedish cities compared to others.

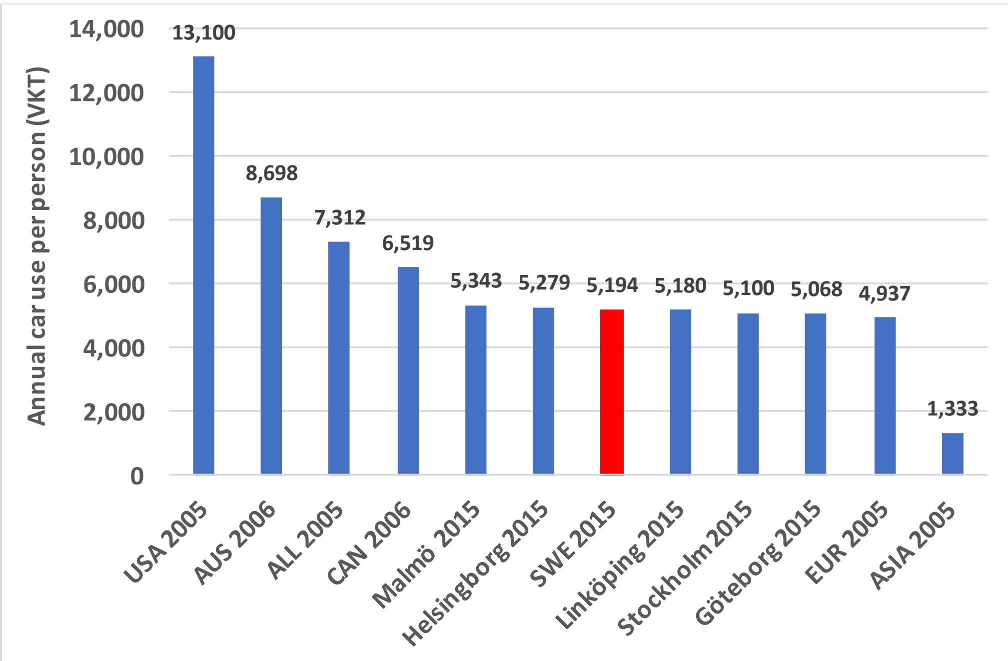

Figure 16. Annual car use per person (VKT) in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.10. Motorcycle use (VKT)

Table 1 also contains data on annual motorcycle use per person, although motorcycles are not large contributors to the mobility needs of Swedish cities or indeed most cities in the developed world. In the Swedish cities, motorcycles on average represent only 1.2% of the combined car and motorcycle use (VKT). The data show that motorcycle use varies from an annual average of 54 km/person in Stockholm, to 77 km in Göteborg, with an average of 61 km. Swedish cities are well below the global sample average of 104 km/person in 2005 and a little less than half the European average (123 km). Swedish cities only exceed the Canadian cities in motorcycle use (55 km).

It could be that the cold climate in Sweden is not necessarily a large factor in the low motorcycle use compared to other European cities, since many of these cities also have unattractive weather for motorcycle use for much of the year. Congestion is another factor that is positively related to motorcycle use as riders can often avoid traffic queues. Congestion in Swedish cities appears not as severe as in other European cities (37.3 km/h compared to 34.3 km/h – see Table 2), and this could also be a factor in favour of less motorcycle use in Sweden.

3.11. Car use (PKT)

Car use is also measured by passenger kilometres of travel, which is a factor that can then be compared to the equivalent for public transport (see later). Table 1 and Figure 17 show that Swedish cities again revolve around a tight mean for this measure of car use, but this time, due to the lower car occupancy in Sweden of 1.30, compared to 1.38 in European cities, car use per capita is essentially the same in Sweden as in other European cities. Only the two Asian cities are lower than any of the Swedish cities and the averages for the other groups of cities are all significantly higher than in any Swedish city. The next highest is the Canadian cities at 8,495 passenger kilometres per person compared to Swedish cities with only 6,751 (some 21% lower). This low result for Swedish cities is pursued further in Figure 22 in the Implications section at the end of this report.

3.12. Motorcycle use (PKT)

Again, in terms of motorcycles, Swedish cities are low in use. On average, they are by far the lowest of all groups of cities, with only Göteborg having annual motorcycle PKT that essentially equals that in the American and Australian cities.

3.13. Proportion of total motorised passenger kilometres by public transport

Now that we have the passenger kilometres data for private transport (cars and motorcycles) and public transport, it is possible to calculate another important factor –

the percentage of total motorised passenger kilometres that are accounted for by public transport. Table 2 and Figure 18 provide these data which shows that Swedish cities average a little over 20% of their total motorised mobility by public transport, compared to 24.5% in other European cities. Though it is less from a European perspective, it is much better than in either the USA (3.2%), Australia (8.0%) or Canada (11.3%). Furthermore, Stockholm and Göteborg are higher than the European average with 27.8% and 26.7% respectively. Again, Swedish cities acquit themselves relatively well in overall transport sustainability, though much can still be improved.

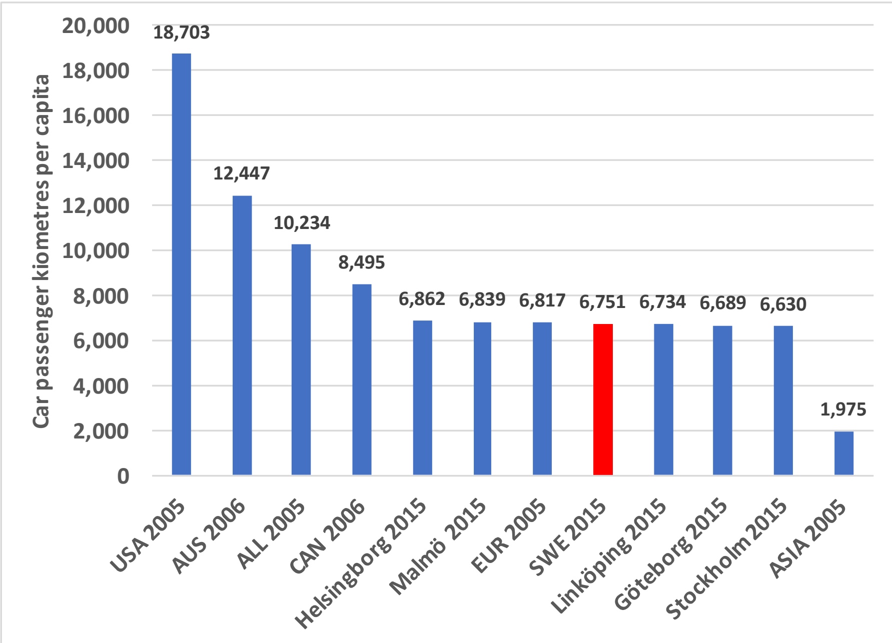

Figure 17. Annual car use per person (PKT) in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

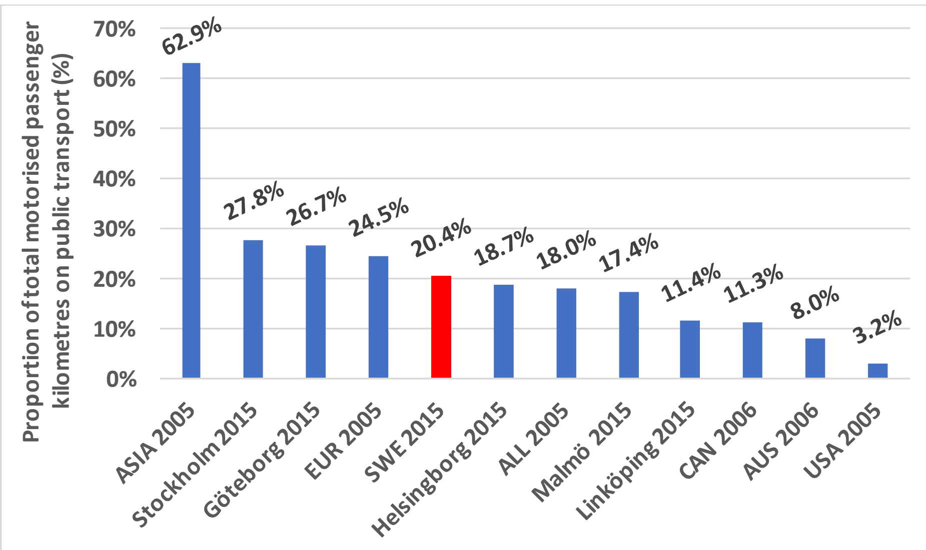

Figure 18. Proportion of total motorised passenger kilometres on public transport in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.14. Private motorised passenger transport energy use

Energy use, with its attendant costs and local environmental impacts, as well as climate change implications, is an important characteristic of urban transport systems. This variable measures the annual per capita energy use in private passenger motorised transport, which in the case of Swedish cities has been calculated backwards from the comprehensive emissions inventories that exist in Sweden for each municipality. Transport is one of the sectors in these emissions inventories, which is further broken down into its component parts and provides CO_2 equivalent emissions, as well as all other transport emissions for each municipality (see next section on transport emissions). These were converted to energy use.

The five Swedish cities in 2015 averaged 15,886 MJ/person, which is virtually the same as the average for the other European cities in 2005 (15,795 MJ). It is close to half the global sample average of 28,301 MJ and dramatically below the American, Australian and Canadian cities (Table 2). Only the Asian cities as a group have less energy use per person for private passenger transport (6,076 MJ), but they are of course radically denser than Swedish cities. Stockholm is the least energy consuming of the Swedish cities with 12,051 MJ/person and Linköping, the lowest density of the five Swedish cities, is the highest (18,124 MJ/person).

Swedish cities, like other cities, should always be aiming to use less energy in transport and there is always scope for improvement both through less driving and through technological improvements. However, as a group in 2015, they perform comparatively well against other cities in the world by consuming only moderate quantities of energy in this potentially energy hungry sector.

3.15. Public transport energy use

The use of energy in public transport systems is important to understand and to compare with its private passenger transport equivalent. Public transport energy use data are obtained from each of the public transport operators based upon known consumption from the billing for fuel. Table 2 has these data and Figure 19 graphs the data.

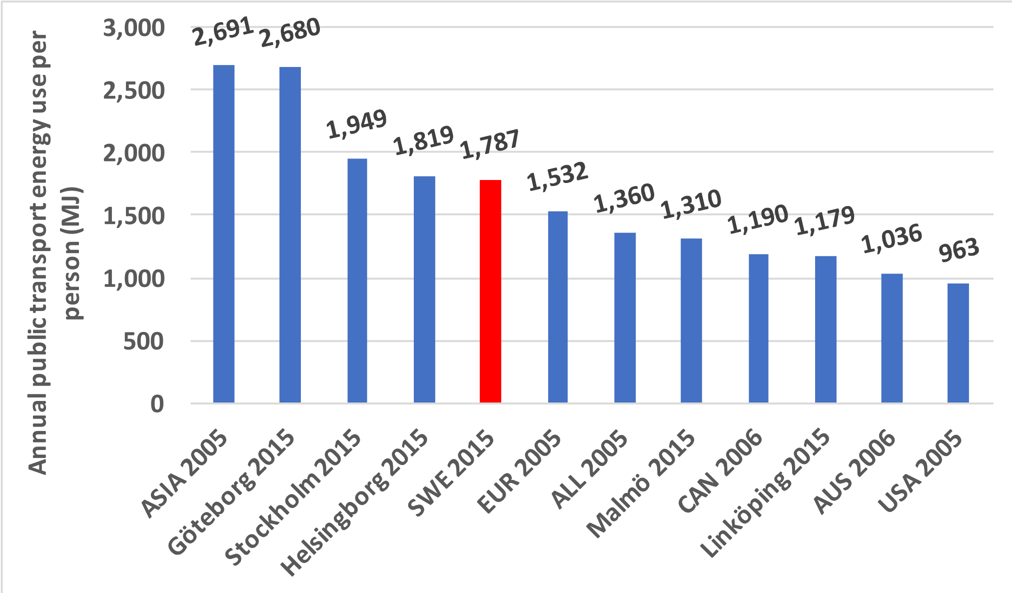

Figure 19. Annual public transport energy use per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

The data demonstrate that Swedish cities have a little higher energy use in public transport than the other European cities, and significantly more than in the three auto-oriented groups of cities with their lesser public transport systems. Stockholm, not surprisingly, consumes higher energy for public transport, but Göteborg consumes the most per person, being virtually equal to that of the two Asian giants and Linköping consumes the least, roughly equal to Canadian consumption. It is not understood why Göteborg consumes so much energy for public transport compared to the other four Swedish cities.

The data reveal, when compared to private passenger transport energy use in Table 2, how much less energy public transport consumes and how relatively energy-efficient it is on a per passenger km basis (see Kenworthy, 2018 for a full set of data on modal energy efficiencies in global cities).

3.16. Transport emissions

3.16.1. Annual transport emissions per person

Air pollution derived from transport systems is a very important source of emissions in urban areas. This research has collected the gross annual emissions of four important air pollutants CO (carbon monoxide), NOx (nitrogen oxides), SO_2 (sulphur dioxide) and VHC or VOC (volatile hydrocarbons or volatile organics) and normalised them on both a per person and spatial basis (kg of combined emissions per person and per total ha and urban ha of land).

Table 2 shows that in 2015 Swedish cities do extremely well in this factor, averaging only 18 kg/person for the four pollutants combined, compared to the global sample average of

98 kg and the European average of 35 kg/person. Of course, the Swedish cities are also vastly better than the American, Australian and Canadian cities.

It must be noted, however, that emissions from transport tend to be on a significant downwards trajectory due to tighter regulations and automotive technological advances, so it is likely that by 2015 the other cities would have reduced their emissions, so the difference between Swedish cities and the rest will likely have narrowed significantly. Within Sweden, the per capita transport emissions are tightly clustered, just like transport energy use in the previous section. Linköping was the highest emitter with 21 kg/person and Helsingborg was the lowest at 16 kg.

Figure 20 shows the dramatic differences between the Swedish cities and other cities in transport emissions per person (bearing in mind the different years of the data).

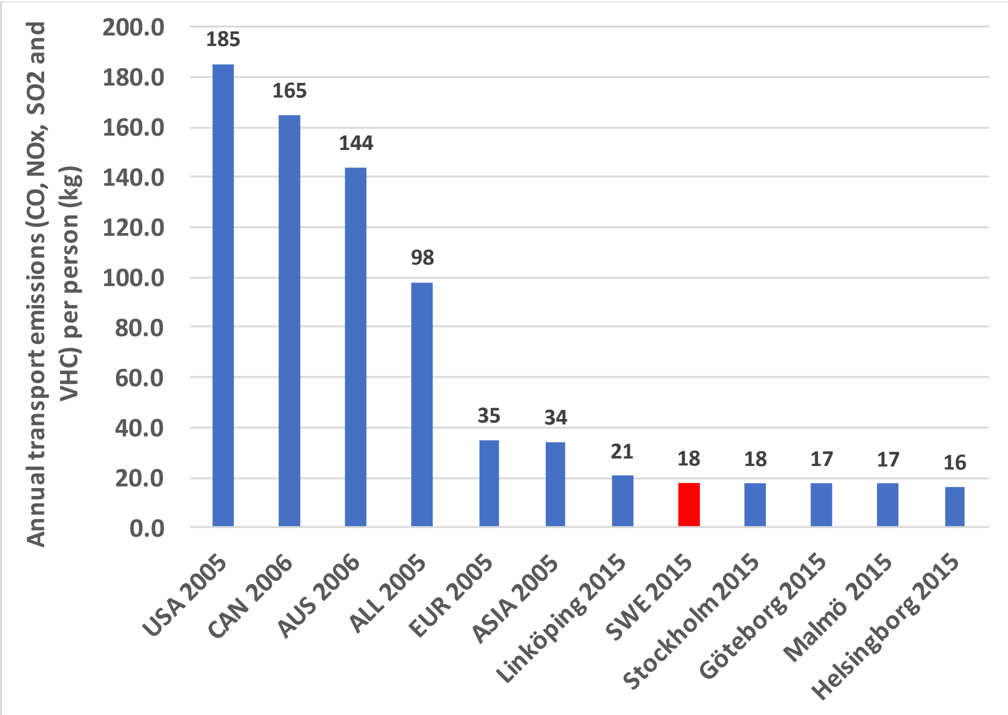

Figure 20. Annual transport emissions per person in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

3.16.2. Annual transport emissions per urban and total hectare of land

The spatial intensity of transport emissions in Swedish cities as shown in Table 2 is very low in 2015 at only 349 kg/ha compared to European cities in 2005 of 1,718 kg and the global sample of 2,446 kg. Part of the reason is of course the low density of Swedish cities and the larger areas of urban land over which emissions are spread. This overall will tend to yield lower direct exposure of populations to air emissions and therefore lower impacts. On the contrary, in the Asian cities where per capita transport emissions are low, the spatial intensity of emissions (5,401 kg/person) is very high due to their very high densities, so population exposure will tend to be much greater. Emissions per total hectare of land follow the same pattern as the urban hectare variable, with Swedish cities being radically lower than all others.

Again, in both these factors, the difference between Swedish cities and the others will have diminished as the per capita and per ha figures are very likely to have declined between 2005 and 2015 in the other cities. Emissions (as well as transport fatalities – see next section), perhaps more than any of the other factors, are likely to be very sensitive to change over the decade due to technological improvements and tougher emissions regulations.

3.17. Transport fatalities

A major cost and source of human pain and suffering in cities is the loss of life in urban transport systems. This factor measures the transport deaths in cities using the WHO's International Classification of Diseases codes (ICD10), which are much more accurate and reliable than police records. They record the cause of death in the case of transport accidents up to 30 days afterwards in hospitals as being attributable to transport reasons. Police records typically only record deaths at the scene of an accident.

Table 2 shows the transport deaths per 100,000 persons and reveals that like emissions, the Swedish cities are "star performers", recording a mere 1.6 deaths/100,000 compared to 5.5 globally, 3.4 in the European cities and an average of 7.3 in the American, Australian and Canadian cities where exposure to the automobile, through sheer usage levels, is highest. Figure 21 shows these significant differences.

Within Sweden the transport deaths do vary somewhat, with Malmö having the worst record at 2.4 deaths/100,000 and Linköping the best at only 0.7. Sweden's national policy of zero traffic deaths appears to have had an impact with these most populous of Swedish cities by 2015 enjoying the world's lowest transport deaths.

As indicated above, this factor like emissions, which generally shows a strong downward trend, at least in cities of the developed world, will have narrowed as the other cities are also likely to have reduced in transport deaths by 2015.

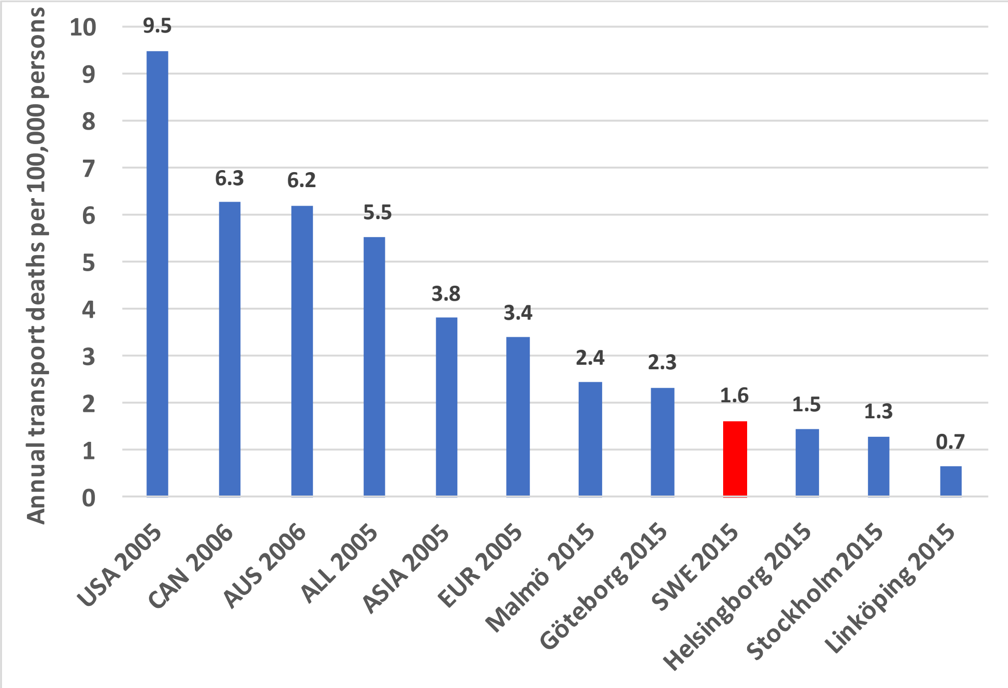

Figure 21. Annual transport deaths per 100,000 persons in five Swedish cities (2015) and their average (red column), compared to a sample of global cities (2005-6).

4. Implications and Summary

This report has presented the results of urban transport related indicators for 2015 for some of Sweden's five most populous urban regions and has compared them with each other and against a large sample of cities in the USA, Australia, Canada, Europe and two large cities in Asia (Singapore and Hong Kong).

It has revealed that as a group, Swedish cities are somewhat unique and distinguish themselves from other European cities in a number ways. Perhaps the best way to show this is to add the five Swedish cities to the rather well-known graphic of urban density versus per capita car use (or private passenger transport energy use, depending on one's purpose).

Figure 22 shows urban density of the global sample of cities compared to annual car use per capita (passenger kilometres), with the five Swedish cities shown in red. It can be clearly seen that the Swedish cities, although generally following the curve (r^2 0.75), are something of outliers. They achieve lower car use at lower densities than is typical in this global sample of 48 wealthy cities.

Fitting the power equation for the line of best fit in Figure 22 to the average Swedish urban density of 19.8 persons per ha, we get a predicted annual car passenger kilometres per capita of 11,127. However, the actual average is 6,751 PKT per capita or 39% lower than would be typical for this density.

It would appear that the performance of public transport, walking and cycling in the mobility patterns of Swedish urban residents keeps their car use to atypically low values. The transit leverage effect (Neff, 1996) where one passenger kilometre on public transport replaces multiple passenger kilometres by car is having some effect here (Newman and Kenworthy, 1999a). This substitution of car passenger kilometres appears primarily related to the trip-chaining behavior of public transport users, trip purposes that would be otherwise made in individual car journeys.

The five Swedish cities are marked in red in the graph. This interesting result begs some questions, which are at least partly addressed in the following points, though more detailed explorations are needed.

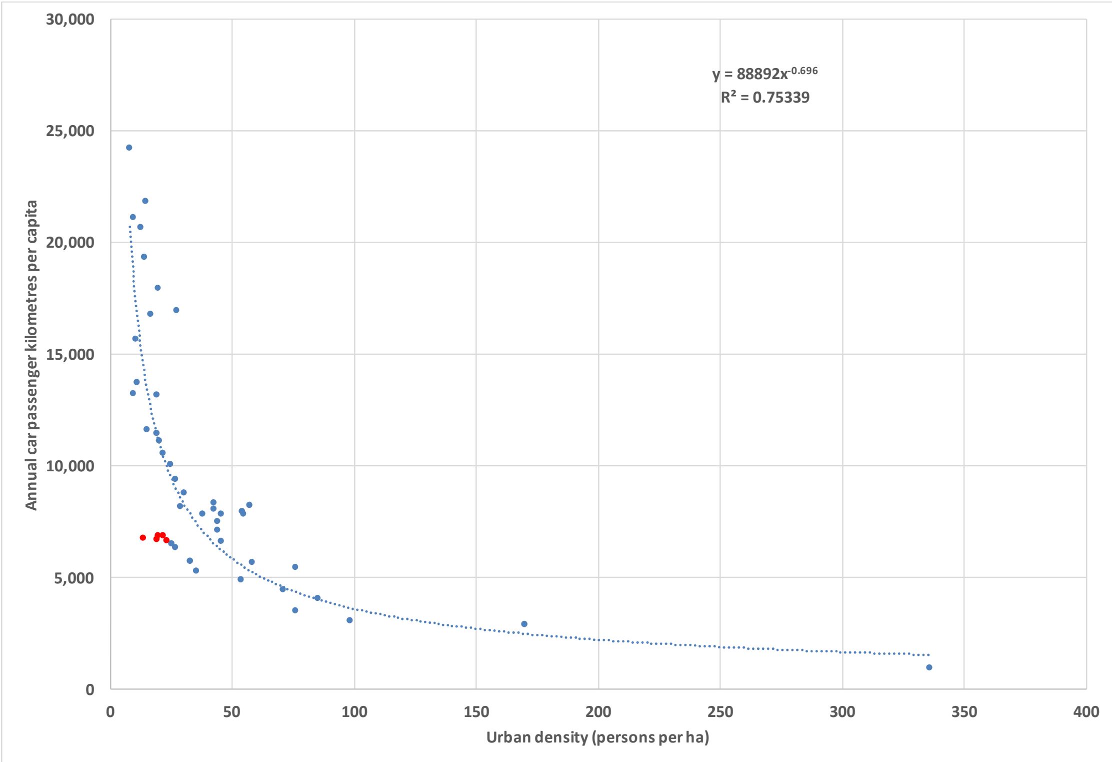

Figure 22. Annual car passenger kilometres per person versus urban density in a global sample of 48 cities (Swedish cities, 2015 in red, remainder of data, 2005-6).

Some salient findings are:

a. Swedish cities are atypically low in density, and high in roads and freeways compared to most European cities.

b. Work is rather centralised in these five Swedish cities with 16.3% of jobs in their CBDs compared to 18.3% in Europe. Swedish cities are the second highest in this factor across the city groupings. This generally works in favour of public transport, at least for work-related travel.

c. For trips to the CBD (central business district), parking is comparatively limited in Swedish cities with only an average of 246 spaces per 1000 jobs, theoretically meaning that only about 1 in 4 people working in the CBD would be able to park a car. It is about the same in other European CBDs (248 spaces per 1000 jobs). This also favours public transport, walking and cycling access to Swedish city centres

d. Despite some favourable conditions for public transport, Swedish cities on average have much lower public transport boardings than other European cities (roughly half), but at the same time much better than in the more auto-dependent regions in the USA, Australia and Canada where densities are also low. This might be expected given the significantly lower density of Swedish cities compared to other European cities, but is somewhat unusual when compared to similarly lower density cities in the USA, Australia and Canada.

e. Public transport use measured by passenger kilometres is closer to European levels due to the longer distances travelled by public transport in Swedish cities, which again probably relates to low densities and longer travel distances.
f. Modal split of daily trips is also just under 50% for public transport, walking and cycling combined, meaning that modal share in these larger Swedish urban regions is pivoted rather equitably between the more sustainable and less sustainable modes.
g. Car use per person (vehicle kilometres) is only a little higher in the Swedish cities than other European cities and is almost identical in car passenger kilometres per person compared to European cities. Use of cars in Swedish cities is very much lower than in the three auto-dependent regions of the USA, Australia and Canada (see Figure 22).
h. Using motorised passenger kilometres as a measure, Swedish cities on average have a healthy 20.4% of total motorised passenger kilometres on public transport, beaten only by their European neighbours and of course the Asian cities, which have 24.5% and 62.9% respectively.
i. Energy use in private passenger transport is commensurate with the other European cities and very much lower than in the auto-cities of North America and Australia.
j. The Swedish cities excel in their extremely low transport emissions per capita and per hectare compared to every other region in the world and even the worst Swedish cities are better than the best of the others. Of course the other data are 2005-6 so one might expect the other cities to draw closer to Swedish cities in 2015, given big advances in automotive technology and tough air pollution regulations.
k. Likewise, in transport fatalities per 100,000 persons, Swedish cities are the lowest in the world (and possibly would remain so even if the other cities were to be updated to 2015, due to Sweden's zero transport deaths policy.

Some factors that seem to contribute to the above sometimes paradoxical situations are that:

a. Swedish cities have significantly lower car ownership than might be expected, lower even than other European cities.
b. Average wealth levels as measured by metropolitan GDP are below typical European levels (though comparable to Australian and Canadian cities). This will have changed though, as the other cities are 2005-6 data and their per capita GDPs will have grown.
c. Despite low densities, Swedish cities have developed relatively well-performing and more extensive public transport systems than many comparable lower density cities. There seems perhaps to be a generalised European cultural factor at work here, that in Europe, public transport is generally more accepted and utilised across a wide range of incomes. At this point, this is only speculation.

d. They have generous amounts of public transport lines compared to other cities and the highest amount of reserved public transport route per person in the global sample. Unfortunately, this is offset by the high per capita provision of urban freeways, which leads to a relatively low ratio of reserved public transport to freeway in Swedish cities, thus perhaps offsetting the advantages of their public transport systems.
e. Swedish cities also have comparatively healthy public transport fleet levels being only eclipsed a little by the European cities and two Asian cities.
f. Service provision as measured by seat kilometres is second in the sample only the other European cities, but only by a small margin (5% lower).
g. Average operating speeds for public transport in Sweden seem to be higher than most other cities, which leads also to the best average ratio of public transport system speeds to general road traffic of all groups of cities (0.98, the next closest result being 0.88 in the other European cities).
h. Swedish cities spend relatively generous amounts of money operating their public transport systems, on average about 1.34% of their local GDPs, which significantly exceeds other regions, including in Singapore and Hong Kong and is nearly comparable to the other European cities (1.50%).
i. Cost recovery of public transport operating costs from fares is on average a bit less than 50% in Swedish cities and less on average that the other global cities. This is perhaps at least partly indicative of a recognition of the proven broader value of public transport systems in helping to create urban regions that are only moderately car dependent by global developed world standards, despite lower densities, as demonstrated in this report. The broader economic benefits of public transport systems such as reduced congestion, less air pollution, less health costs and so on are not accounted for or recognised in farebox recovery ratios.
j. Notwithstanding the above, Swedish cities have comparable farebox revenues per vehicle km, boarding and passenger km to other cities in the world and not dissimilar operating costs per vehicle km and per passenger km, though they do spend more per capita operating their systems than the global average and most other groups of cities.
k. Swedish cities have significant areas of urban fabric that are supportive of non-motorised modes and where walking and cycling is high, leading to over 27.1% of daily trips in Swedish cities by these modes, despite a very cold climate. Only the other European cities have more with 34.5%. There are numerous areas in Swedish cities where bicycling is supported with reasonable infrastructure and walking generally seems to be much safer in Sweden than many other cities.
l. Anecdotally, when staying in Malmö and Lund, I have consistently experienced cars giving way to me as a pedestrian. This seems to be a very pleasant aspect of Swedish society, although only others can say if it is generalizable.

Three key weaknesses in Swedish cities seem to be:

a. Their overall low density would benefit from targeted increases in higher density development, especially linked to expanded and improved public transport. Stockholm is by far the best of the Swedish cities in sustainable transport and although it is still overall a low-density region, it is bound together by strong and now diverse urban rail networks (light rail, metro and regional rail), around which very high density, mixed use development has occurred in strong centres throughout the region;
b. The need to restrict further development of already abundant freeway and road systems in all Swedish cities and;
c. An over reliance on bus systems and the need for more extensive urban rail networks. A major difference between Swedish and European cities generally, is that European cities have three times higher rail use and this is a critical distinguishing feature in the lower public transport use in Swedish cities compared to European cities.

Importantly, the results highlight the valuable policy perspectives that can be developed from this kind of comparative urban analysis.

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APPENDIX 1

Definitions of Swedish metropolitan areas for the purposes of this study

Stockholm

Stockholms län

Göteborg

We are using the official definition of *Metropolitan Göteborg* consisting of the following municipalities. Names and reference numbers are from the Statistics Sweden system.

(1384) Kungsbacka

(1401) Härryda

(1402) Partille

(1407) Öckerö

(1415) Stenungsund

(1419) Tjörn

(1440) Ale

(1441) Lerum

(1462) Lilla Edet

(1480) Göteborg

(1481) Mölndal

(1482) Kungälv

(1489) Alingsås

Malmö

We are using the official definition of *Metropolitan Malmö* consisting of the following municipalities. Names and reference numbers are from the Statistics Sweden system.

(1230) Staffanstorp

(1231) Burlöv

(1233) Vellinge

(1261) Kävlinge

(1262) Lomma

(1263) Svedala

(1264) Skurup

(1267) Höör

(1280) Malmö

(1281) Lund

(1285) Eslöv

(1287) Trelleborg

Helsingborg

(1283) Helsingborg

Linköping

(0580) Linköping

APPENDIX 2

Detailed description of the data to be collected for the Swedish Cities comparison (2015 data or close to that year)

1. **Total land area of the metropolitan area**
We need to define which geographic area will be the defined the metropolitan region that will act a the boundaries for data collection for most items. For short, this is referred to below as the Define Area or DA.

2. **Urbanised area of the metropolitan area**
Urbanised land area is very important and refers to the total “urbanised territory” within the DA. W have an additional table which describes what counts as urban land and what is non-urban. This i appended below. Access to actual land use data is needed for this item, NOT, planned urban zone land which may or may not be developed yet. Usually it is best to receive a land use inventory fror the agency with land use divided up into whatever categories they use. The more detail the better.

3. **Total population of the metropolitan area**
This is the official population of the DA, however that is determined.

4. **Number of jobs (at place of work) in metropolitan area**
This is the number of actual jobs physically located within the defined area. It includes full and part time jobs, and where part-time jobs can be distinguished from full-time jobs, these would generall be divided by two to estimate equivalent full-time jobs.

5. **Number of jobs (at place of work) in CBD**
This first requires a working definition of the Central Business District or CBD. This is the main centr of the DA, usually the central core of the oldest part of the city, though in some cities they hav shifted their CBD to new locations (e.g. in Taipei and Berlin had some adjustments after re unification). Again, the data are the number of jobs physically located within that generally quite sma area. My experience is that it is best to define the CBD according to some already established sma designations within the city such as city districts, administrative zones, traffic analysis or Origin Destination zones…whatever best facilitates the collection of the required data on jobs and parkin (see Items 13 and 14 below).

6. **Gross domestic product of the metropolitan area**
GDP of the metropolitan region is an item that always must be collected for the full commuter belt c the DA (in German it is called the Arbeitsmarktregion). The reason is that if you take the GDP of onl the Municipality and calculate a GDP per capita using just its population, it will be way too hig because actually many more people contribute to this GDP than those who live in the Municipality *So, we collect the GDP for the whole commuter belt and divide by it population.*

7. **Number of private cars and station wagons, RVs, company cars (not taxis)**
Should be obtainable from the vehicle registration system, whoever controls that. For this item, w generally include also “light commercial” vehicles as many of the trips made by these vehicles ar for personal transport purposes. In the USA, this includes what they classify as light duty trucks whicl are mostly SUVs (Sports Utility Vehicles). It depends the different vehicle types i Sweden/Helsingborg are classified in the registration system.

8. **Total annual vehicle kilometres of travel (VKT) in private cars**
This generally comes from the “traffic model” and includes all VKT by private passenger vehicle (excluding motorcycles, which we try to collect separately). The VKT are meant to represent drivin by residents of the defined area, so if Helsingborg only is used as the DA, then there would need t be some way of distinguishing VKT by residents of this area from the total VKT of all driving whicl occurs within the boundaries of the DA. An alternative approach could be if there is good data on th annual average number of kilometres driven per year by passenger vehicles in the DA, (odomete surveys?), then this could be multiplied with the number of such vehicles. Another method might b the total annual number of person trips in private passenger vehicles in the DA multiplied by a reliabl overall average trip length (all trip purposes) and then divided by the average occupancy of th vehicles (see Item 9).

9. **Total annual passenger kilometres (PKT) in private cars**
This PKT requires an average annual (24 hours-a-day/7 days-a-week) figure for the average numbe of people per car (including the driver of course). In wealthy cities today this figure tends often to b around the 1.40 to 1.45 mark (weekend occupancies in particular are much higher than weekends) which is much higher of course than the typical peak period figure which is often only 1.10 or so. Thi

occupancy figure multiplied with VKT gives PKT. Also, referring back to Item 8, if there exists th total annual person trips by private passenger vehicles and a reliable overall average trip length i kilometres, then these two multiplied together will also give a measure of PKT.

10. Average road network speed (7day/24hour)
This measures the overall average road system speed across all road types and trip types (24 hour/ days a week system average). One method can be the VKT from the traffic model divided by th equivalent number of vehicle hours. This item can use the total VKT and total vehicle hours drive within the DA, as it is simply measuring speed of the system experienced by everyone.

11. Total centreline length of the road network (all roads including residential)
This simply measures the total linear length of all roads, often referred to as centreline length (a road types from freeways down to residential streets). Generally, in developed cities, the roads ar sealed and so would exclude, for example, unsealed roads only used for forestry purposes).

12. Total length of express road network (ALL expressways, freeways, tollways)
This refers to all roads that fulfill three conditions:

(1) no traffic lights,

(2) no intersections and

(3) no direct property access from the road…

i.e. fully controlled access roads.

13. Number of parking places in the CBD (off-street)
Once the CBD has been defined we need the total number of off-street spaces (surface parking lot and parking buildings open to the public and also all tenant parking in buildings dedicated to th employees who work in those buildings). All parking spaces that are dedicated 100% to resident only parking are EXCLUDED.

14. Number of parking places in the CBD (on-street)
This is the number of parking places on the streets within the defined CBD area. They can be metere or un-metered spaces, short or long term. These also exclude all on-street spaces that are dedicate purely for resident parking, requiring a permit to prove that one is a resident of the street.

15. Length of reserved public transport routes by each mode
This data item is the total length of routes for public transport vehicles that are legally and/or physically separated from general traffic. It includes all traditional rail modes that operate on their own dedicated right-of-way as well as those sections of tram route and bus-only lanes that are protected from general traffic. Reserved route is only counted once, regardless of how many actua public transport routes/lines share the reserved route length (see also Item 28 for clarification).

16. Average operating speed of each public transport mode
This is the essentially the commercial average operating speed of each public transport mode in the defined area. It can and is generally derived by operators by obtaining the annual revenue vehicle kilometres of services divided by the annual revenue vehicle hours of service needed to deliver those kilometres. It specifically excludes dead-heading kilometres and time.

17. Annual revenue vehicle kilometres of service by each public transport mode
For each mode, this item is the total annual number of kilometres of service operated by the public transport provider. It is a widely reported operating statistic and excludes dead-heading.

18. Annual revenue seat kilometres of service by each public transport mode
Some operators report this but most usually they report place-kilometres. Once we have vehicle kilometres of service, the best way to obtain this item is to get a table showing the number and typ of each vehicle operated by all the public transport providers (see Item 27 on public transport fleets) and the number of seats that each of these different types of vehicles contain. In this way a weighted average number of seats can be used to calculate the annual seat kilometres for each operator and mode.

19. Annual boardings by each public transport mode
Boardings are the number of entries into public transport vehicles in one year (as opposed to a whole public transport trip from A to B, which may involve several boardings due to changing modes or routes).

20. Annual passenger kilometres by each public transport mode
Annual passenger kilometres by public transport modes is an item that is often reported by public transport operators. If it is not then we need the average distance that each boarding travels within

the system. Most operators know this today from electronic ticketing systems and other electronic surveillance means, or they conduct manual boarding and alighting surveys on the vehicles themselves.

21. **Private passenger transport energy use (litres of petrol, diesel, LPG, CNG, kWh of electricity)**
This can be a tricky item to obtain, but is often known or estimated by the local, regional, state c national environment agency due to the need to conduct inventories of CO_2 emissions. The fuel us should match the VKT reported in Item 8. It is the fuel use only of private passenger motor vehicles Another potential way is to have a good estimate of the average litres per 100 km of fuel by in-us vehicles operating on the road system within the DA. Today, one usually needs to collect the relevar quantities of petrol, diesel, LPG, CNG, and now, even electricity (kWh) used by private passenge vehicles.

22. **Public transport energy use (for each public transport mode, all fuel types)**
Public transport operators always know exactly how much fuel they have consumed in each of thei vehicle types (because they pay for it…liquid, gaseous and electric fuel!). So this item is generall quite precise and again covers all the varied fuel types that are today found in the public transpoı systems of cities (e.g. bio-diesel, RME etc in addition to the others mentioned above).

23. **Total transport-related deaths**
Transport deaths cover all transport modes within the DA. These are NOT the deaths reported b the police, which typically only record deaths at the scene of an accident. The source is th International Classification of Diseases (ICD 10) and the item numbers within this database are V0 to V99. Usually it is the local or national health authority that has these data. These data apply a 3 day rule of death in hospital after a transport accident.

24. **Number of two-wheeled motor vehicles (motorcycles)**
The total number of motorcycles is defined as all motorised vehicles with two wheels which ar admitted to general traffic. This definition includes all classes of motorcycles as well as motor assisted bicycles (mopeds) and motorcycles with attached side cars. A Pedelec (e-bike) would b classed as a bike and excluded here.

25. **Vehicle kilometres of travel on two-wheeled motor vehicles (motorcycles)**
This is the same as for Item 8, but only for motorcycles as defined in Item 24. Hard to get. An averag annual number of kilometres per year of a typical motorcycle multiplied by the number of registere motorcycles is probably a good method, given the general lack of attention to motorcycles in transpoı planning

26. **Passenger kilometres on two-wheeled vehicles (motorcycles)**
This is the same as for Item 9 but only for motorcycles as defined in Item 24. Generally, the averag 24/7 occupancy of a motorcycle in wealthy cities is close to 1.00, most often between 1.02 and 1.0 rarely more.

27. **Public transport vehicle fleet by mode**
This was already mentioned in Item 18 when discussing seat kilometres. Essentially what is require is an inventory of the public transport vehicle fleet by mode (number of buses, minibuses, trar wagons, rail wagons, ferries etc). It is important to note that for all rail modes it is the number c *wagons* that are of interest. We are not reporting the number of trains consisting of variable number of wagons.

28. **Length of public transport lines by mode**
This item measures the actual length of all lines by mode. Where multiple routes share the sam section of track or roadway they are counted multiple times. For example, five bus lines all operatin over the same five kilometres of road would constitute 25 km in public transport (bus) line lengtr The same for rail modes. This is unlike reserved route where, in the case it is dedicated right of wa it is only counted once, regardless of the number of lines operating along it.

29. **Annual total public transport farebox revenue**
Here we collect all farebox revenue for all modes together (we do not split modal data but we d need the farebox revenue for ALL modes and operators in one figure). We also need the figure WIT and WITHOUT government reimbursements for concession fares (pensioners, students, people wit disabilities etc).

30. **Annual operating expenses of public transport**
Here we need all genuine operating costs, again we don't need this split by mode, but it needs t cover ALL modes and operators. Public transport operating costs should include: • purchase c energy and of supplies of goods and services (including subcontractor's services); • personnel costs

salaries, charges, retirement pensions, etc; • overheads (rent, etc.); • *financial charges (interes payments);* • *depreciation;* • maintenance of rolling stock and infrastructure; • taxes and fees. Pleas note we need to be able to see the *finance and depreciation charges separately*.

31. **Air pollutant inventory from transport sources in the city (CO, NO_x, SO_2 and VHC-volatile hydrocarbons)**
    These data generally come from an inventory of emissions prepared by the national or loca environmental agency. They include all transport sources of emissions.

32. **Number of daily walking trips**
    These are the walk-only trips from origin to destination

33. **Number of daily mechanized, non-motorized trips**
    These are the basically the bike-only trips (or any other “feral transport” like skateboards, in-lin skates etc)

34. **Number of daily motorised trips on public modes**
    These are trips on all the public transport modes (bus, rail, ferry, whatever public transport exists They are linked trips, not trip segments or unlinked trips.

35. **Number of daily motorised trips on private modes**
    These are the trips by all private motorized modes such as cars, vans, motorcycles and taxis (agair linked trips, not trip segments).

Urban land definition (Item 2)

Land use category	Type	Comment
Agricultural	n/u	
Meadows, pastures	n/u	
Gardens, local parks	u	These areas are not generally built up, but in their size they are generally too small and in their human recreational use are too intense to qualify as genuine non-urban land.
Regional scale parks	n/u	These are large, contiguous areas set aside within metropolitan areas for non-intensive or restricted recreational uses, water catchment functions, green belts etc.
Forest, urban forest	n/u	Urban forests are larger than parks and are often significant wildlife and forestry areas.
Wasteland (natural)	n/u	This includes flood plains, rocky areas and the like.
Wasteland (urban)	u	This includes derelict land, culverts etc.
Transportation	u	Road area, railway land, airports etc.
Recreational	u, n/u	Depending on the intensity of use, this group can belong partly in either category. Golf courses are urban, as their use is intense, while skiing areas for example are less intense in use and generally large and therefore non-urban. Mostly, however, recreational land is considered urban.
Residential	u	
Industrial	u	
Offices	u	
Commercial	u	
Public Utilities	u	
Hospitals	u	
Schools, Cultural uses	u	
Sports grounds	u	
Water surfaces	n/u	

Statistics Sweden provided detailed land use inventories for every municipality and county in Sweden. The land uses used for urban land area in this report for Sweden are called “Built-up land and associated land” which consists of:

- Land with one- or two-dwelling buildings
- Land with multi-dwelling buildings
- Land used for manufacturing industry
- Land used for commercial activities and services
- Land used for public services and public facilities and leisure
- Land used for transport infrastructure
- Land used for technical infrastructure
- Land with agricultural buildings and other buildings

It should be noted that the urbanised land area data for 2015 from Statistics Sweden has been carefully checked for accuracy and compatibility with urban land area for other cities. There are two categories of land use above that are used in Sweden which could have raised doubts about their low densities relative to other cities but when checked, they did not. Included are land for “golf courses and ski pists” (also in other cities) and “land with agricultural buildings and other buildings”. By taking these two land uses completely out for Stockholm and Linköping, the highest and lowest density of the Swedish cities, Stockholm would have an urban density of 25.3/ha (instead of 23.5/ha) and Linköping 15.5/ha (instead of 13.8/ha). Although a little higher, the urban densities do not fundamentally change, so these land uses have remained in the calculations.

K2 is Sweden's national centre for research and education on public transport. This is where academia, the public sector and industry meet to discuss and develop the role of public transport in Sweden.

We investigate how public transport can contribute to attractive and sustainable metropolitan areas of the future. We educate members of the public transport sector and inform decision-makers to facilitate an educated debate on public transport.

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