

Transport Modeling And Policy Evaluation

AH 2307 Urban Modeling and Decision Support

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1 Introduction

Nowadays transportation is a big challenge for a city development, especially the commuting transportation, which causes highest traffic flow on weekdays. Due to the uneven workplaces and residence places distribution as well as the lacking of capacity in Stockholm, some congestion appear in the network, along with some pollution problems. What's more, there will be a continuous population growth, which might aggravate the problems in the future. In this project, we will simulate a transportation system in Stockholm using Matlab. By changing the land use, network and other model parameters, we can evaluate some solution for those problems.

1.1 Background

1.1.1 Assumptions

In order to simplify the current situation, we made some assumptions:

·All the people go to work at different areas from their home
·All the commuters leave home to work at the same time
·We only consider the commuting traffic during weekdays
·All the people are rational to choose the shortest way
·The parking fee and fuel price are considered the same among all the areas

1.1.2 Network

In this project, Stockholm is simplified into 14 areas (Figure 1). As demonstrating in the figure, all the areas are representing using centroid points, and the links between each point are defined as different class of capacities, accessibility and toll.

Between each link there are three kinds of capacity: motorway with 5000veh/h, road with 800veh/h and street with 300veh/h. Basically, inner city is equipped with roads and streets while suburban areas with motorway.



Figure 1 Map of Stockholm Network

1.1.3 Land use

Given in the instruction, there are numbers of workplace, population and income in each zone in the year of 2013 and 2020 (table 1). Generally, at current situation, there are 15000 commuters going to work everyday. It's clear that north part provides more workplaces, which means the commuting from south counts a lot in this system.

In terms of mode share, car ownership is an important parameter for car driving. In this project we considered the car ownership depends on income and the utility of having a car. The incomes of inner city people are higher, which makes them easier to get access to a car; on the other hand, the inner city is well equipped by public transport. So we established the utility function for having a car and used binary logit model to insert the car ownership to the whole model during all the evaluation.

Table 1 Data of Land use

		2013			2020		
Zone	Name	Employment	Population	Income	Employment	Population	Income
1	Gamla Stan	10000	2000	400	13333	2667	450
2	Norrmalm	22000	10000	400	29333	13333	450
3	Södermalm	16000	8000	400	21333	10667	450
4	Kungsholmen	15000	10000	400	20000	13333	450
5	South west	10000	16000	300	13333	21333	400
6	West	10000	20000	300	13333	26667	400
7	South	8000	20000	300	10667	26667	400
8	North east	8000	15000	300	10667	20000	400
9	North west	13000	18000	300	17333	24000	400
10	Nacka	4000	10000	300	5333	13333	400
11	Danvikstull	8000	3000	300	10667	4000	400
12	Årsta	4000	5000	300	5333	6667	400
13	Västberga	7000	3000	300	9333	4000	400
14	Norrtull	15000	10000	300	20000	13333	400
Total		150000	150000		200000	200000	

However, the future scenario above is a simplified forecast. In order to make a real forecast, some real statistics are found as table 2. Here, the workplace and population increase are based on the public transport plan of SL (*SL, 2012*), and the income is based on the Sweden wages trend (*Tradingeconomics, 2013*).

Table 2 Land use of 2020 forecast

2020 forcast				
Zone	Name	Employment	Population	Income
1	Gamla Stan	10879	2263	450
2	Norrmalm	24809	12099	450
3	Södermalm	17407	9053	450
4	Kungsholmen	16915	12099	450
5	South west	12321	17282	338
6	West	11964	21950	338
7	South	10667	21860	338
8	North east	9600	16500	338
9	North west	16824	20500	338
10	Nacka	5600	11515	338
11	Danvikstull	9600	3148	338
12	Årsta	4800	5247	338
13	Västberga	8400	3148	338
14	Norrtull	15000	10000	338

1.2 Objectives

·From the model, we can know the current traffic situation in Stockholm: the mode share, travel time, the existence of congestion, total cost of emission and so on. Based on the current situation, evaluate some policy to improve the situation. These policies refer to four aspects: congestion charge, improving network, improving public transport and increasing driving cost.

·Considering about the future, there would be a growth of population and income. We can simulate the impact of changing of land use using current network, we can also apply the policies to forecast the situation in the future.

1.3 Methodology

Generally, this project followed the four step planning method: trip generation, trip distribution, mode share and assignment. For the first and the second step, the trip generation and distribution is influenced by the population, employment and car ownership. The mode share is also modeled in the demand, using a nested logit model. For the supply, the network and tolls will affect the assignment of the trip. During assignment, we apply Dijkstra algorithm for gaining the shortest path in terms of general cost (time, toll). What's more, in order to obtain the optimal assignment, an interaction was created to find the situation of equilibrium. The methodology can be described as figure 2.

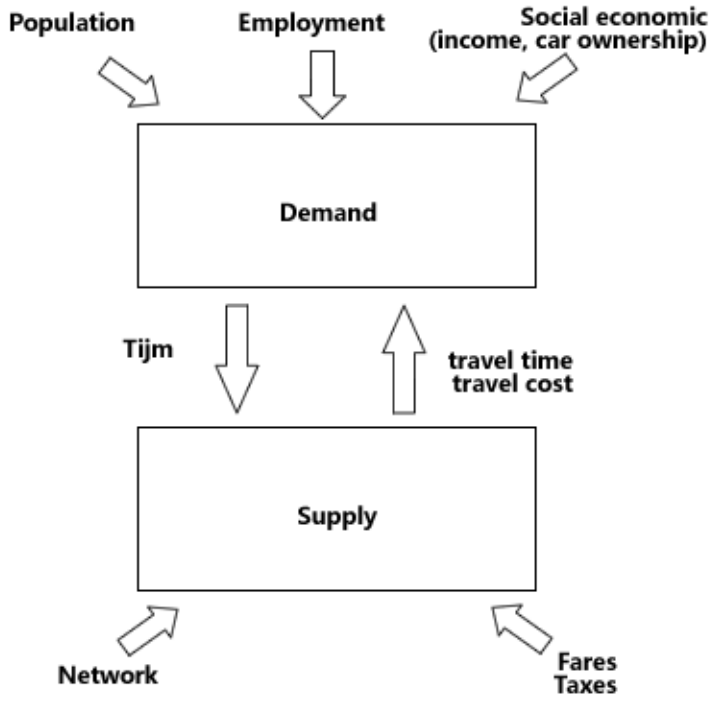

Figure 2 Methodology

1.3.1 Car ownership model

The car ownership was assumed to be influenced by income and the utility of having a car. Normally, people in the inner city tend to gain more income to buy cars; at the same time, they have better access to public transport. So here we can use a binary logit model, where the alternatives are to have either zero or one car. The utility of owning a car is influenced by income and inner city location. After creating the utility function V, the probabilities of owning a car could be $P = \frac{e^V}{1+e^V}$.

1.3.2 Travel demand

The travel demand model combined the trip generation /distribution/ mode share together. The mode and destination choice is represented by a nested logit model. For the destination zone, the choice set is D= {1, 2, …, 14}. For the mode choice, there are three kinds of mode: car, transit which is metro and bus, and slow which contains bicycle and walking. We divided individuals into two categories: people who have access to a car and those who do not, they have different mode choice set. The nest logit model is illustrated in figure 3.

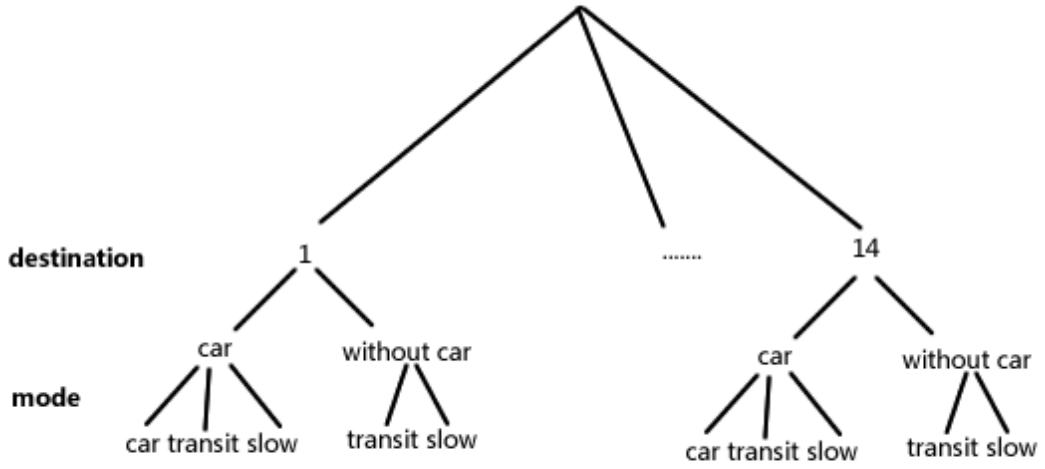

Figure 3 Nest logit model

So, the probability for an individual choosing a destination j and mode m is

$$P^i(j,m) = P^i(j)P^i(m|j) = \frac{e^{V_j+\mu L_j^i}}{\sum_{j'\in D} e^{V_{j'}+\mu L_j^i}} \frac{e^{V_{jm}^i/\mu}}{\sum_{m'\in M} e^{V_{jm'}^i/\mu}}$$

Where L_j^i are propagated to the destination choice through the expected maximum utility of all modes: $L_j^i = ln\sum_{m'\in M} e^{V_{jm}^i}{}'/u$

And the destination part is a function of the work places$V_j = \theta \ln(employed)$.

1.3.3 Demand – supply interaction

According to user equilibrium, we hope that the travel time in each link is equal. However, the assignment procedure happened to determine some congestion which leads to longer travel time. We created a loop of updating the travel time and the travel cost as average to get the user equilibrium. Here we applied the Stopping criterion as the difference of travel time is lower than 0.1min.

1.3.4 Externalities Effect

Along with the trip generation, there appear some externalities such as CO2 emission, traffic safety and noise. Given in the instruction, the marginal costs of all the externalities were used to evaluate the effects. Here we introduced vehicle kilometers traveled (VKT) to get the cost.

1.3.5 Policy

After creating the current model, we can try different possible ways to improve the situation. Here we considered introducing new congestion charge to new links, introducing new links, improving the public transportation and increasing the driving cost. Changing the toll area in the network can make difference to the new congestion charge while changing the waiting time or cost of public transport can make improvements to public transport. Similarly, increasing parking fee, toll and cost of fuel can increase the driving cost. What's more, according to vision 2030 (*Stockholmstad, 2012*) in Stockholm, there will be a new network which contains a bypass from south to north in order to reduce the traffic congestion in inner city. We can try to simulate these new changes in the network file.

2 Results

2.1 Current situation

·Without congestion charge

As we know, the congestion charge system has been used since 2006 in Stockholm. Imagining if this system were not used in Stockholm, what would the situation be like? By canceling the congestion charge in the network, here are the results we gain:

About the mode share (figure 4), the shares of car and transit are almost equal at about 43%, 13% of people choose slow mode. The total car traveling distance is 514779.459km, which brings 137832.2kg CO2 emissions. The cost of externalities such as emission, accident and maintenance are 384347.214SEK.

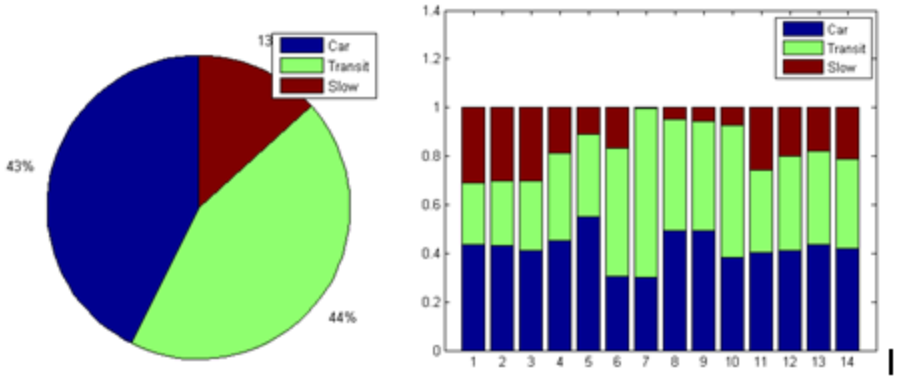

Figure 4 Mode share of current situation (without congestion charge)

Looking at the volume/capacity ratio (table3), all the links towards inner city are experiencing serious congestion.

Table 3 V/C ratio of current situation (without congestion charge)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	2.7247	1.349	0	0	0	0	0	0	0	0	0	0	0
2	5.239	0	3.567	1.291	0	0	0	0	0	0	0	0	0	1.366
3	5.677	4.7124	0	1.652	0	0	0	0	0	0	1.6464	0.835	0	0
4	0	3.4848	3.058	0	0	2.31	0	0	0	0	0	0	0.6344	0.828
5	0	0	0	0	0	0	0	0	0	0	0	0	1.3023	0
6	0	0	0	5.159	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0.585	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	1.082
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0.951
10	0	0	0	0	0	0	0	0	0	0	0.4485	0.25	0	0
11	0	0	2.994	0	0	0	0	0	0	0.04	0	0.28	0	0
12	0	0	3.903	0	0	0	0.03	0	0	0.1	1.6306	0	0.6348	0
13	0	0	0	1.125	0.372	0	0	0	0	0	0	0.608	0	0
14	0	4.5309	0	1.204	0	0	0	0.175	0.2034	0	0	0	0	0

·With congestion charge

By running the transport model in current situation, we can gain the mode share as figure 5. 40% of Car sharing, 46% of transit mode share and 14% of slow mode. The total distance of car traveling is 481530km.

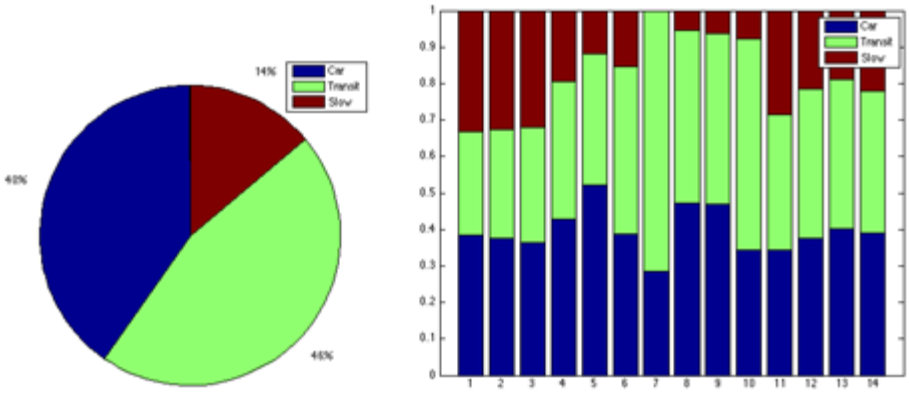

Figure 5 Mode share in current situation

Obviously, the congestion charge has some impact on decreasing car travelling. However, by checking the ratio of the flow and the capacity (Table 4), there still exists some congestion in inner city. This is due to the low capacity of the inner city streets. As a result, some other policy should be introduced to solve this problem. Although the congestion charge is already used in this system, we can still consider about the improvement of this system itself.

Table 4 Volume/capacity rate in current situation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	2.4838	1.083	0	0	0	0	0	0	0	0	0	0	0
2	4.557	0	3.189	0.938	0	0	0	0	0	0	0	0	0	0.885
3	4.924	4.1877	0	0.721	0	0	0	0	0	0	0.5946	0.532	0	0
4	0	2.5134	1.824	0	0	2.27	0	0	0	0	0	0	0.7241	0.834
5	0	0	0	0	0	0	0	0	0	0	0	0	1.2379	0
6	0	0	0	5.019	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0.519	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	1.02
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0.888
10	0	0	0	0	0	0	0	0	0	0	0.3424	0.262	0	0
11	0	0	1.776	0	0	0	0	0	0	0.03	0	0.541	0	0
12	0	0	2.781	0	0	0	0.03	0	0	0.11	2.1344	0	0.6714	0
13	0	0	0	1.147	0.369	0	0	0	0	0	0	0.635	0	0
14	0	3.424	0	1.172	0	0	0	0.169	0.1963	0	0	0	0	0

In terms of the revenue of the congestion charge and the public transport, this system can make 63956.137SEK from congestion charge and the ticket revenue is 581466.518SEK.

Speaking about the externalities, the CO2 emission generated by this system is 128929.232kg. The costs of the externalities are listed in the table below.

Table 5 Cost of externalities in current situation

Cost of Externalities (SEK)				
accident cost	**emission cost**	**maintenance cost**	**Total cost**	**Mean cost**
120380	193390	4815.3	359521.151	5.942

2.2 Future situation

As is metioned above, there will be a growth in population in the future. In that situation, the total car traveling distance will be up to 647230km, which is twice of the current situation. Because it's still the same network, the mode share will not change as much, with 2% increase of car using and 1% decrease of transit using (figure 6). The revenue gained from congestion charge will be 82327.369SEK and the ticket revenue would be 760106.692SEK.

About the externalities, respectively, they increased along with the increasing of VKT. But the mean cost will decrease.

Table 6 Cost of externalities in future

Cost of Externalities (SEK)				
accident cost	**emission cost**	**maintenance cost**	**Total cost**	**Mean cost**
161810	259940	6472.3	483234.872	5.811

However, when checking the ratio of flow and the capacity of the road, the congestion will be much more serious. The link between area 1,2,3 will be experiencing high level of congestion. At the same time, the suburban links are not fully used. There will still be lots of potential of capacities in suburban area.

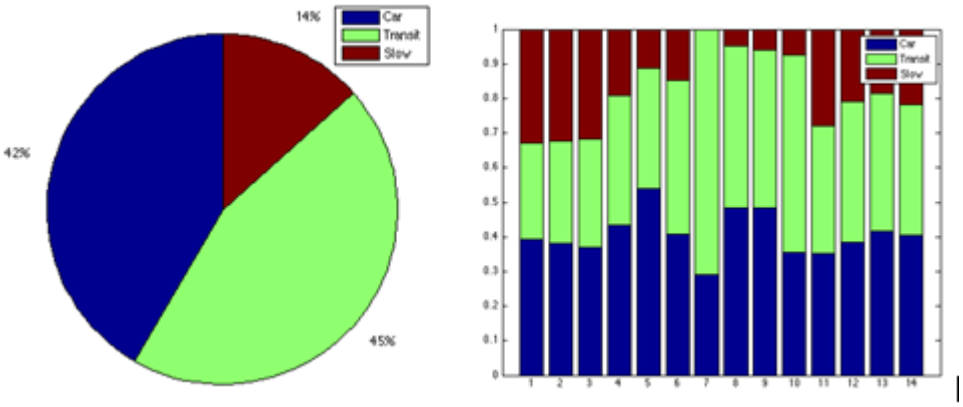

Figure 6 Mode share in future situation

Table 7 V/C ratio in future situation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	3.6064	2.858	0	0	0	0	0	0	0	0	0	0	0
2	6.386	0	3.793	1.274	0	0	0	0	0	0	0	0	0	1.346
3	6.745	4.7953	0	0.9	0	0	0	0	0	0	0.8294	0.747	0	0
4	0	3.2447	2.205	0	0	2.73	0	0	0	0	0	0	0.987	1.137
5	0	0	0	0	0	0	0	0	0	0	0	0	1.6644	0
6	0	0	0	6.919	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0.667	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	1.347
9	0	0	0	0	0	0	0	0	0	0	0	0	0	1.164
10	0	0	0	0	0	0	0	0	0	0	0.4642	0.365	0	0
11	0	0	2.319	0	0	0	0	0	0	0.05	0	0.754	0	0
12	0	0	3.379	0	0	0	0.04	0	0	0.15	2.7904	0	0.9196	0
13	0	0	0	1.544	0.516	0	0	0	0	0	0	0.833	0	0
14	0	4.3391	0	1.525	0	0	0	0.239	0.2787	0	0	0	0	0

2.3 Policy Evaluation

According to the future situation, some improvements should be done to solve the problems. Here we considered three ways to improve: improving the congestion charge system, improving network and improving the public transport.

2.3.1 Improving congestion charge system

After comparing the situation without and with congestion charge, we noticed the importance of this policy. On the other hand, without considering improving the capacity of the inner city, the pricing policy is also necessary. In order to improve congestion charge system, we added some place into the charging area based on their congested situation. The new charging links are 1 -2, 1-3, 2 -3, 4 -6, 5 -13, 8 -14. The following evaluations are all based on the new charging locations.

Along with adding the new charging links, we tried two ways to improve the system: increase all the tolls at the same level or just increase tolls of the most congested locations.

·Increase all the tolls at the same level

Here we tried to increase tolls from 5 to both 7 and 10. Here some results of toll 7 are listed. According to the mode share charts (figure7), the tolls have significant effect on the mode share. The percentage of people choosing public transportation has raised 5 percent. As a result, the congestion situation has improved, according to the volume/capacity ratio (table8, 9). But there are still unbalanced congestion existing in the network especially in inner city area 1,2,3,4. The total distance of car traveling decreased to 382329.994km in present and 511144.416km in the future while Co2 emission decreased to 102368.856kg in present and 381633.2kg in the future. Accordingly, the revenues from tolls raised to 160493.607SEK in the current situation and 201724.615SEK in the future; the public transport revenues raised sharply to 639134.37SEK now and 843198.861SEK in the future.

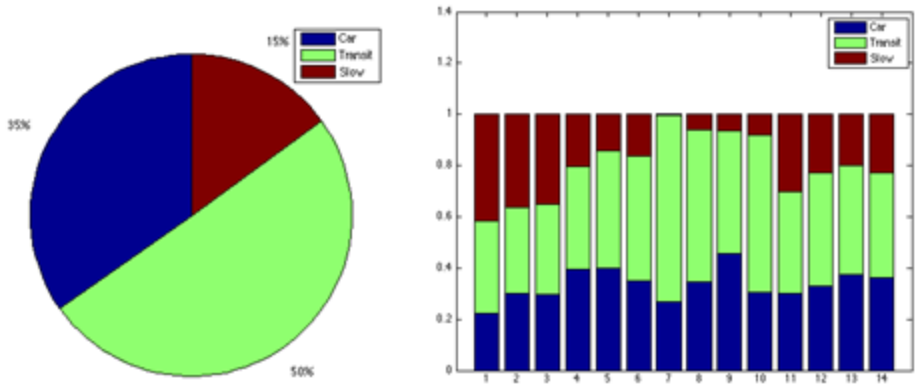

Figure 7 Mode share after increasing the tolls in all locations

Table 8 V/C ratio after increasing the tolls in all locations at present

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	0.642	0.419	0	0	0	0	0	0	0	0	0	0	0
2	2.034	0	1.496	0.705	0	0	0	0	0	0	0	0	0	0.625
3	1.72	2.1123	0	0.626	0	0	0	0	0	0	0.3905	0.282	0	0
4	0	1.8699	1.412	0	0	1.18	0	0	0	0	0	0	0.57	0.713
5	0	0	0	0	0	0	0	0	0	0	0	0	0.7389	0
6	0	0	0	3.843	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0.448	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.564
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0.826
10	0	0	0	0	0	0	0	0	0	0	0.277	0.244	0	0
11	0	0	1.179	0	0	0	0	0	0	0.03	0	0.511	0	0
12	0	0	1.468	0	0	0	0.02	0	0	0.1	1.9442	0	0.6211	0
13	0	0	0	0.886	0.167	0	0	0	0	0	0	0.468	0	0
14	0	2.2848	0	0.935	0	0	0	0.072	0.1672	0	0	0	0	0

Table 9 V/C ratio after increasing the tolls in all locations in the future

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	0.9224	0.61	0	0	0	0	0	0	0	0	0	0	0
2	2.373	0	2.016	0.984	0	0	0	0	0	0	0	0	0	0.893
3	2.092	2.6634	0	0.877	0	0	0	0	0	0	0.5596	0.411	0	0
4	0	2.0936	1.635	0	0	1.52	0	0	0	0	0	0	0.7257	0.91
5	0	0	0	0	0	0	0	0	0	0	0	0	1.0268	0
6	0	0	0	3.301	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0.595	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.778
9	0	0	0	0	0	0	0	0	0	0	0	0	0	1.094
10	0	0	0	0	0	0	0	0	0	0	0.3858	0.342	0	0
11	0	0	1.604	0	0	0	0	0	0	0.04	0	0.717	0	0
12	0	0	1.929	0	0	0	0.03	0	0	0.13	2.5104	0	0.8565	0
13	0	0	0	1.211	0.237	0	0	0	0	0	0	0.613	0	0
14	0	2.799	0	1.271	0	0	0	0.104	0.2301	0	0	0	0	0

·Increase tolls of the most congested place

The congestion charge is efficient in controlling traffic. Increasing tolls can make a large impact on the mode choice towards public transport; hence, the congestion can be reduced. We have tried to increase all the tolls at the same time, but the congestion place might remain the same since all the location charging the same cause no difference for people choosing the link. As a result, there would still be an unbalanced distribution of the flows. Here, we consider about double the tolls of the most congestion place (2-1, 3-1, 3-2, 4-2, 4-3, 6-4, 14-2).

According to the result, the mode share is almost the same, but the travel distance of car is more than the method above, car drivers can still choose cheaper links in this situation. By checking the ratio between volume and capacity, we found that though the situation now is almost the same, in the future, this method will cause less congestion in most congested links comparing to the method evaluated above.

2.3.2 Improving network

Improving the infrastructure is also a good way for the future development. According to the Vision 2030 Stockholm, there will be a bypass connecting south and north without passing the inner city. This might reduce the congestion of inner city significantly. Here we add this link as 7-5-6-9 in the future and the capacity is defined as motorway.

According to the result, this bypass will increase the using of car, though the mode share (figure 8) is almost the same as using the current network, the travel distance of car increased to 681701.043km. By comparing the volume/capacity ratio (table) we found the congestion of inner city has decreased dramatically. The bypass is proved to be good for the development.

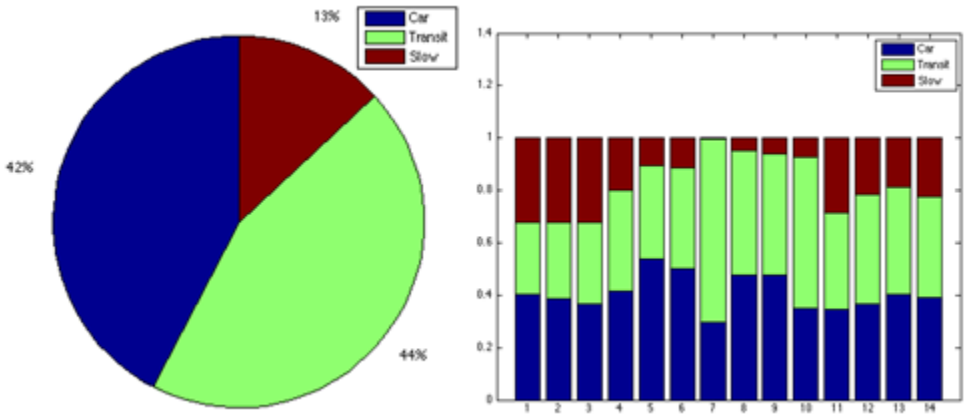

Figure 8 Mode share after building the new bypass

Table 10 V/C ratio after building new bypass in the future

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	3.414	2.235	0	0	0	0	0	0	0	0	0	0	0
2	4.652	0	3.879	1.384	0	0	0	0	0	0	0	0	0	1.419
3	4.329	3.515	0	1.148	0	0	0	0	0	0	0.914	0.838	0	0
4	0	2.037	1.736	0	0	2.472	0	0	0	0	0	0	0.814	1.123
5	0	0	0	0	0	0.383	0.04	0	0	0	0	0	1.682	0
6	0	0	0	4.794	0.739	0	0	0	0.389	0	0	0	0	0
7	0	0	0	0	0.213	0	0	0	0	0	0	0.544	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	1.32
9	0	0	0	0	0	0	0	0	0	0	0	0	0	1.103
10	0	0	0	0	0	0	0	0	0	0	0.431	0.379	0	0
11	0	0	2.03	0	0	0	0	0	0	0.052	0	0.788	0	0
12	0	0	3.168	0	0	0	0.0332	0	0	0.159	2.709	0	0.895	0
13	0	0	0	1.352	0.442	0	0	0	0	0	0	0.878	0	0
14	0	3.173	0	1.575	0	0	0	0.258	0.248	0	0	0	0	0

2.3.3 Improving public transport

Improving public transport will lead people choosing the high-capacity but low-emission transport mode, accordingly, the environment will the cost of externalities can be reduced. More importantly, the congestion caused by private car can be lightened. We advised that government should give subsidies to public transport using the congestion charge fee and taxes, in order to lower the cost of public transport and higher the quality of service such as decrease the waiting time. Here we consider about the following two ways:

·Decreasing the cost of public transport

The average cost of public transport in inner city is 5kr and in suburban area is 10kr, we reduced them into 4kr and 8kr, here are the results:

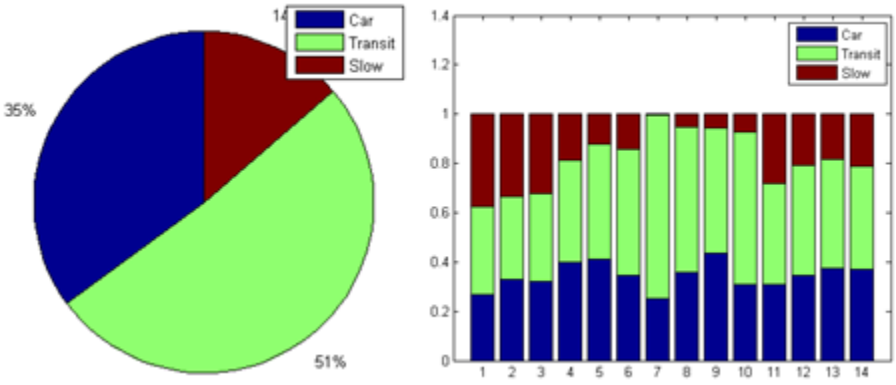

Figure 9 Mode share after decreasing the cost of public transport

Obviously, in this situation, over half of the commuters will choose public transport. The travel distance of car decreased to 387096.684km in present and 519563.657km in the future. Speaking about the externalities, positively, the CO2 emission reduced to

103645.137kg at present and 139113.169kg in the future. The cost of externalities would decrease respectively (table 11).

Table 11 The cost of externalities after decreasing the cost of public transport

Cost of Externalities (SEK)					
	accident cost	emission cost	maintenance cost	Total cost	Mean cost
now	97509	156650	3900	289016.062	5.579
future	130800	210130	5232	387919.216	5.447

In terms of flow and capacity, the congestion could be reduced (table 12).

Table 12 V/C ratio in the future after decreasing the cost of public transport

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	1.174	0.776	0	0	0	0	0	0	0	0	0	0	0
2	3.227	0	2.572	1.144	0	0	0	0	0	0	0	0	0	1.061
3	2.793	3.844	0	1.023	0	0	0	0	0	0	0.698	0.594	0	0
4	0	2.595	2.05	0	0	1.777	0	0	0	0	0	0	0.74	0.927
5	0	0	0	0	0	0	0	0	0	0	0	0	1.153	0
6	0	0	0	4.145	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0.573	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.876
9	0	0	0	0	0	0	0	0	0	0	0	0	0	1.069
10	0	0	0	0	0	0	0	0	0	0	0.411	0.326	0	0
11	0	0	1.934	0	0	0	0	0	0	0.043	0	0.693	0	0
12	0	0	2.632	0	0	0	0.033	0	0	0.126	2.425	0	0.808	0
13	0	0	0	1.226	0.281	0	0	0	0	0	0	0.648	0	0
14	0	3.334	0	1.289	0	0	0	0.125	0.229	0	0	0	0	0

·Decreasing the waiting time of public transport

Another way to improve public transport is to increase the frequency of the transit in order to decrease the waiting time. The average waiting time of public transport in inner city is 5min and in suburban area is 10min, we reduced them into 4min and 8min. According to the result, the percentage of people choosing transit increased more than the method above. This is because in the utility function of transit, the waiting time weights more. Therefore, the distance of car traveling increased more to 387096.684km at present and 519563.657km in the future, along with the higher decreasing of CO2 emission.

Table 13 The cost of externalities after decreasing the waiting time of public transport

Cost of Externalities (SEK)					
	accident cost	emission cost	maintenance cost	Total cost	Mean cost
now	96864	155610	3874.5	289283.178	5.549
future	129480	208000	5179	386677.776	5.43

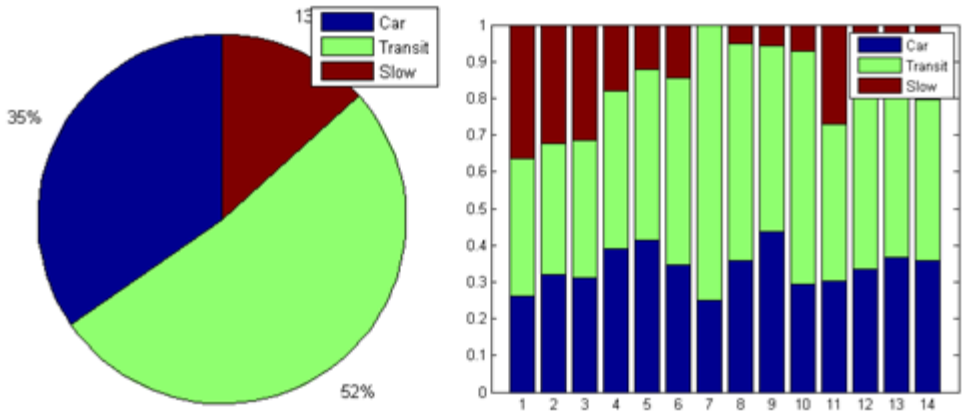

Figure 10 Mode share after decreasing the waiting time of public transport

2.4 Future scenarios

As it's mentioned above, we have improved the land use closer to the real future. For the future policy, we believe that the bypass will be implemented, the congestion charge will still be using with the improvement of double the price of most congested place (2-1, 3-1, 3-2, 4-2, 4-3, 6-4, and 14-2) and the waiting time of public transport will be reduced. Based on our assumption, we evaluated the future forecast.

Here, we gained both the results of the forecast future with the old network and with new policy.

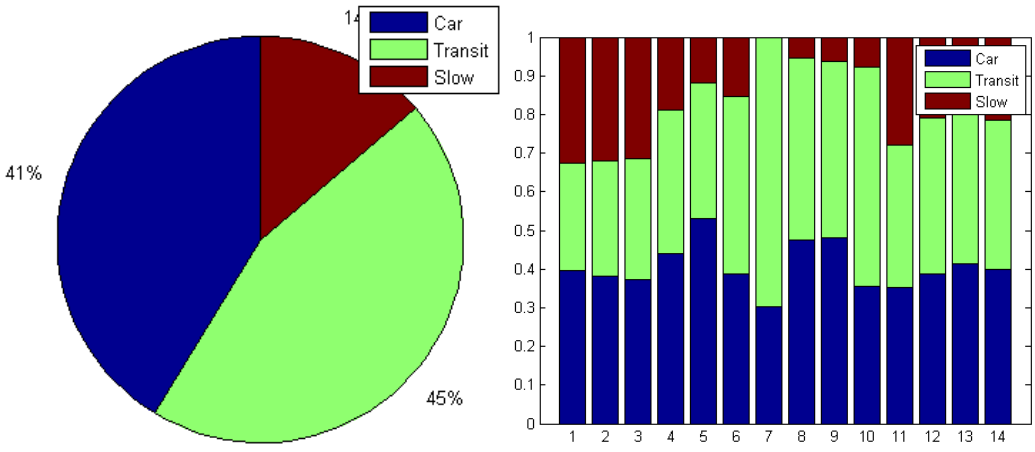

Figure 11 Mode share of future scenario using the old network and policy

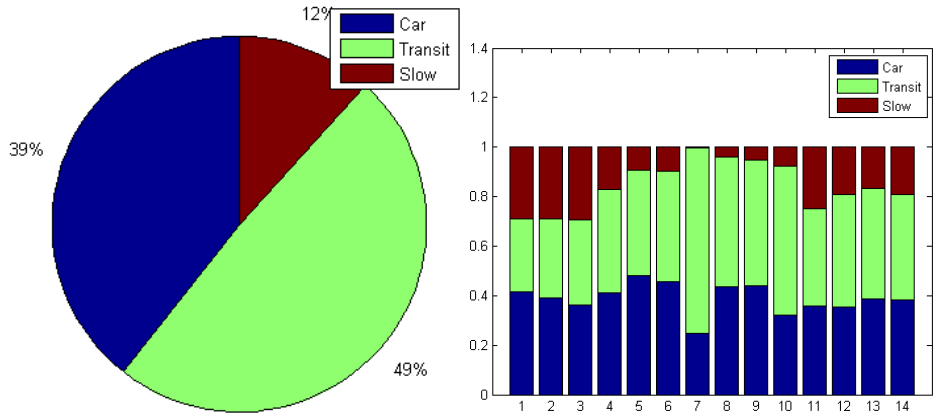

Figure 12 Mode share of future scenario using the new network and policy

From the mode share (figure11, 12) we can see a satisfying future with half of people choosing public transport. The car traveling distance is reduced from 537636.767km to 512118.343km, along with the lessening of CO2 emission and less costs of externalities. Accordingly, the congestion has been effectively alleviated.

Table 14 The cost of externalities in future scenario (with old network/ with new network and policy)

	Cost of Externalities (SEK)				
	accident cost	**emission cost**	**maintenance cost**	**Total cost**	**Meancost**
old	134057.9441	215364.0872	5362.317765	401413.051	5.835
new	128038.9761	205694.615	5121.559042	382360.358	5.832

3 Conclusions

3.1 Main results

There are some main features of the transportation system:

·The problem of inner city congestion is very serious, we have tried lots of ways to improve, but the results are always unsatisfying. This is due to the low capacity of the network in inner city. However, it will be facing lots of difficulties to improve the inner city network since it's full developed. In order to solve this problem, we should do various aspects of improvement, to maintain the congestion and improve the network in suburban area at the same time.

· The percentage of car and transit mode share is easily influenced by the price of all modes.

·Congestion charge in this system is efficient and necessary. It's useful to maintain this policy at present and in the future along with some improvement at the same time.

·By developing the public transport, the cost of externalities can be lower, it obeys the trend of environmental friendliness and sustainable development.

·Proper new link can be added to increase the capacity of the whole network, like the bypass connecting north and south without going through inner city. It would be useful for the future. But whether it's beneficial in financial aspect remains to be evaluated.

3.2 Weakness

There are some weaknesses in the model. According to our assumption, first, all the population was considered going to work at the different places from home, which is not true as in the reality. This might cause an overestimation of the trip generation. Next, the commuters were considered leaving home at the same time; this could explain the congestion since the real traffic flow doesn't start at the same time. What's more, in the model, the bus lines weren't taken into account. Bus is a kind of public transport but in terms of network, they occupy some capacity of the road, which is the same as the private cars. So it might be much more complicated to take bus into account. Last but not the least, in the model all the commuters are regard as rational, in which case, people in real life might be lacking information of choosing the best way or they tend to follow their habit.

All the critiques above have tendency to cause the inaccurate results of the model.

3.3 Recommendation

Here are some recommendations for the city according to our evaluation:

·Remain the congestion charge policy, keep making improvements according to the changing situation.

·Improve the infrastructure by building the bypass. According to Trafikverket, by 2030, the population of the Stockholm region is expected to have increased from 2 million today to roughly 2.5 million. It's very important to minimize vulnerability, relieve Essingeleden and to improve communications (*Trafikverket, 2013*).

·Improve public transport. Public transport is considered as high capacity with low emission, but the comfortableness and convenience are not as good as private cars. So raising the standard of service, decreasing the waiting time, lowering the cost as well as developing the network would have a good impact for the city.

·At the level of individuals, traffic department should give more publicity to new policies and the way to reduce congestion such as give information to lead people choose uncongested ways or stagger the commuting time by avoiding peak hours.

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