Integrated space-transport modelling for a strategic analysis of congestion in a strongly developing region

I. Anindia
Delft University of Technology
P.O. Box 5048, 2600GA Delft, The Netherlands
ismiraanindia@yahoo.com
R.J. Verhaeghe
Delft University of Technology
P.O. Box 5048, 2600GA Delft, The Netherlands
R.J.Verhaeghe@TUDelft.nl
B. Zondag
Delft University of Technology/Significance
Schipholweg 13, 2316 XB, Leiden,The Netherlands
zondag@significance.nl

Abstract

The current population of about 20 mln in the Jabotabek region is projected to reach 50 mln over 25 years. Congestion has strongly increased over the last decade and is expected to further drastically increase in the future due to demographic and socio-economic conditions. Infrastructure development has not kept pace with the demand on transport. Congestion is strongly influenced by the mono-centric structure of the urbanizing area. A modelling instrument to analyse congestion in the regional development context has been developed by establishing a dynamic coupling between a land-use and transportation model.

The spatial modelling is triggered by scenarios on socio-economics conditions and policies in spatial and transport development: demographic/socio-economic condition, economic growth, employment policy, conservation policy, and accessibility. The modelling has been used to project congestion levels for different scenario's and combinations of potential land-use and transport policies. The present modelling does reproduce major processes in the settlement and mobility system of the region; it allows to trace congestion behaviour in the region in the future and for combinations of different space and transport interventions. It is shown that currently planned major infrastructure will not be sufficient to curb the strongly increasing congestion.

1. Introduction

The Special Capital Region of Jakarta (in Indonesian known as Daerah Khusus Ibukota (DKI) Jakarta) is Indonesia's largest and most important city. It has a status equal to a province. The city has been established for over 460 years, and in the past 40 years has grown at an explosive rate. This has resulted in a significant shortfall of infrastructure in terms of public services and has highlight the urgent need to consider means of coordinating the management of the city's development and growth with the surrounding regions, namely, the kabupatens of Bogor, Tangerang, and Bekasi (acronym for total region: Jabotabek).

The current traffic congestion has been aggravated by a poorly developed hierarchical road structure and insufficient capacity on the secondary roads serving the main arterial network. For many roads, particularly in the secondary and local network, traffic capacity is reduced by inefficient use of kerb space, poor parking controls, unregulated bus stopping, mixed vehicle types, and undisciplined driver behaviour. Figure 1 shows the present congestion condition in Jabotabek.

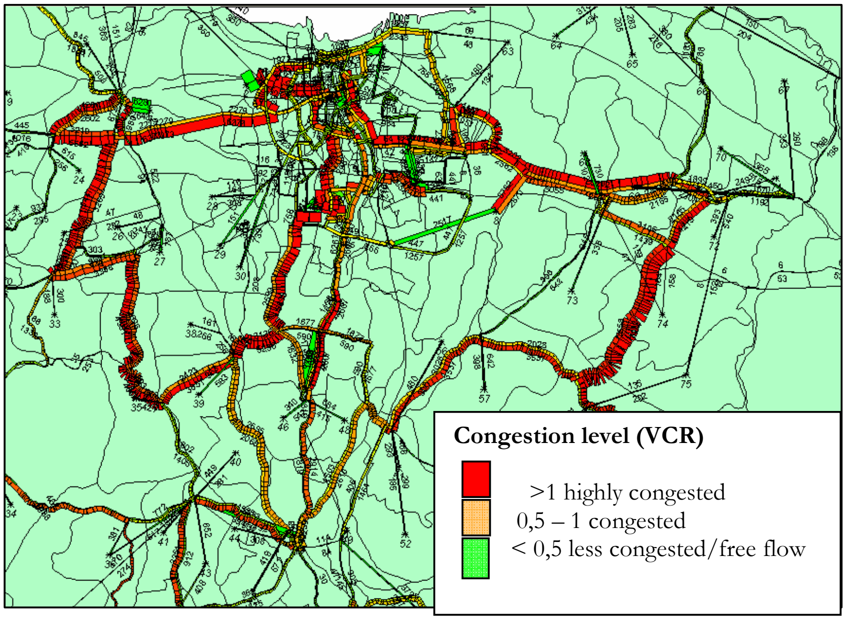


Figure 1: Indication of congestion in the Jabotabek region (Volume to Capacity Ratio)

At present, infrastructure development for the region has not kept pace with the strongly expanding settlement and economic activity in the last 20 years, resulting in considerable congestion and environmental adverse conditions. A further strongly increasing settlement and – congestion are expected. This development can not be considered sustainable in the long run. The dynamic situation in settlement and large impacts emphasize the importance of making the right (strategic) decisions in the period ahead, to correct adverse conditions and arrive at a desired situation.

Planning of infra development for the Jabotabek region, in relation to settlement and mobility development, require to make a projection of settlement and transport performance into the future for a selected planning horizon. Modelling for such projection should take into account the sequence and timing of various space– and transport measures which influence the development. Such modelling framework, including the time dimension, is elaborated below.

Modelling of both land use and transportation require much data to estimate relationships and validate the modelling. A particular challenge for the Jabotabek region is to establish an adequate modelling, based on relatively limited data base. The objective of the present study has been to identify, develop and test/apply a modelling instrument to support strategic planning addressing the above mentioned challenges.

2. Land Use and Transport Interaction

Theories on the two-way interaction between urban land use and transport address the location and mobility responses of private actors (households and firms, traveller) to changes in the urban land use and transport system at the urban-regional level. The close linkage between urban land use and transport is common wisdom among planners and the public. The spatial separation of human activities, creating the need for travel and goods transport is the underlying principle of transport analysis and forecasting. It follows then that the suburbanisation of cities is connected with increasing spatial division of labour, and hence with an ever increasing demand for mobility.

The reverse impact from transport to land use is less well known (quantified). There is a broad understanding that the evolution from the dense urban fabric of medieval cities, where almost all daily mobility was on foot, to the vast expansion of modern metropolitan areas with their massive volumes of intra-regional traffic, would not have been possible without the development of first the railway and later the private automobile, which has made every corner of the metropolitan area almost equally suitable as a place to live or work. However, how the development of the transport system influences the location decisions of landlords, investors, firms and households is complex and no exact theoretical framework is available to explain the inter-relationships. The explanation of land-use and transport interactions relies on many different disciplines such as economic theories (utility theory, markets, macro economy), demography and social sciences, urban design, and transport planning.

Over the last decades, since Lowry's developed his Metropolis model in the early sixties (Lowry, 1964), several integrated land-use and transport models have been developed. These models have mainly been developed for the Western countries reflecting available funding and data sources in these countries. For in-depth reviews of state-of-the-art LUTI-models and their characteristics reference is made to Miller et al., 1998, EPA 2000 (all land-use models), Wegener and Fürst, 1999, RAND Europe 2001, and Wegener 2004. This focus on developed nations does not reflect the policy relevance of these models; the expected impacts of transport on land-use and economy are much higher in regions without a mature infrastructure (Zondag, 2007). An example of this phenomenon is the strong influence of highways in the greater Jakarta region on land-use developments (see Sanders et al., 1997). As the impacts of transport on land-use and economy are large one would expect a strong interest in this issue in developing countries, however a lack of strategic planning and poor data sources prevent such a focus in rapid developing regions.

This paper presents an integrated land-use and transport model that has been developed for the Jabotabek region; the complexity of the model is tailored to the available data sources. Furthermore this paper illustrates the use of such a model for strategic planning by presenting the land-use and transport effects of different land-use and transport strategies.

3. Integrated modelling framework

3.1. Framework

A modelling framework was set up in the present study to do an integrated analysis of the spatial development and transport system of the Jabotabek area.

A dynamic coupling between a land-use and transportation model was established as presented in figure 2. Both models have been set up for the case region using schematizations and a variety of data. An existing spatial model (BWRMP, 2003) operational for the case region has been modified for the purpose, and the Omnitrans transport software package has been used to set up the transport model. The spatial model uses yearly time steps; the transportation model is run at 5-yearly time steps and uses the employment and settlement pattern at that time.

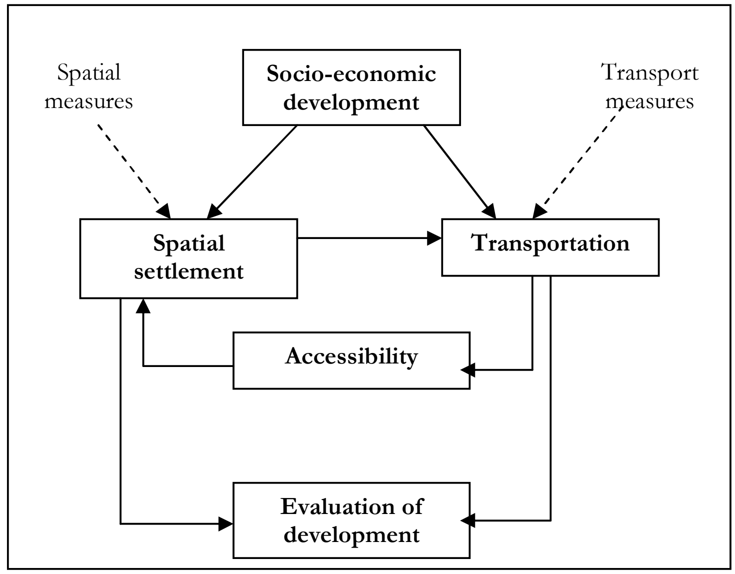


Figure 2: Framework for integrated analysis of space and transport

The spatial model is turn uses the new accessibility which is computed on the basis of the transport performance computed with the transport model.

The spatial and transport model are each influenced by scenarios and measures influencing spatial settlement and transport performance

The two models need to be adjusted to each other. The existing spatial model was extended to include employment, which is necessary for the transportation modelling and at the same is also considered a strong determinant in settlement and policy making of the government; congestion is strongly associated with home-work trips; as can be observed in practice, people are willing to travel long distances in order to assure employment/income.

3.2. Spatial Model

A functional diagram of the spatial model is presented in Figure 3. The primary concept of the spatial model is an allocation of space on the basis of a multi attribute assessment of the attractiveness of the spatial cells. This attractivity is based on the specific characteristics of the site and the position (spatial relations) of each individual part with respect to the other parts. The attractivity is (re-) computed for each time interval in the simulation and used to allocate the increment in total space required for the region. The scores on a set of individual parameters are combined into a single attractivity ranking by means of a Multi-Criteria Analysis (MCA). The weights on the different parameters reflect the importance of those aspects in determining the attractiveness for settlement. The total increment in space requirement for a particular simulation interval is allocated proportional to this ranking.

The extended model further combine the gravity potential concept similar to the Hansen model and the basic economic theory as included in the Lowry model; a balance is kept of available area for settlement. The model steps through time (yearly time steps) allocating a projected total need for space for different functions. The spatial model interacts with the transport model (see 3.3) using "accessibility to work", computed by the transport model.

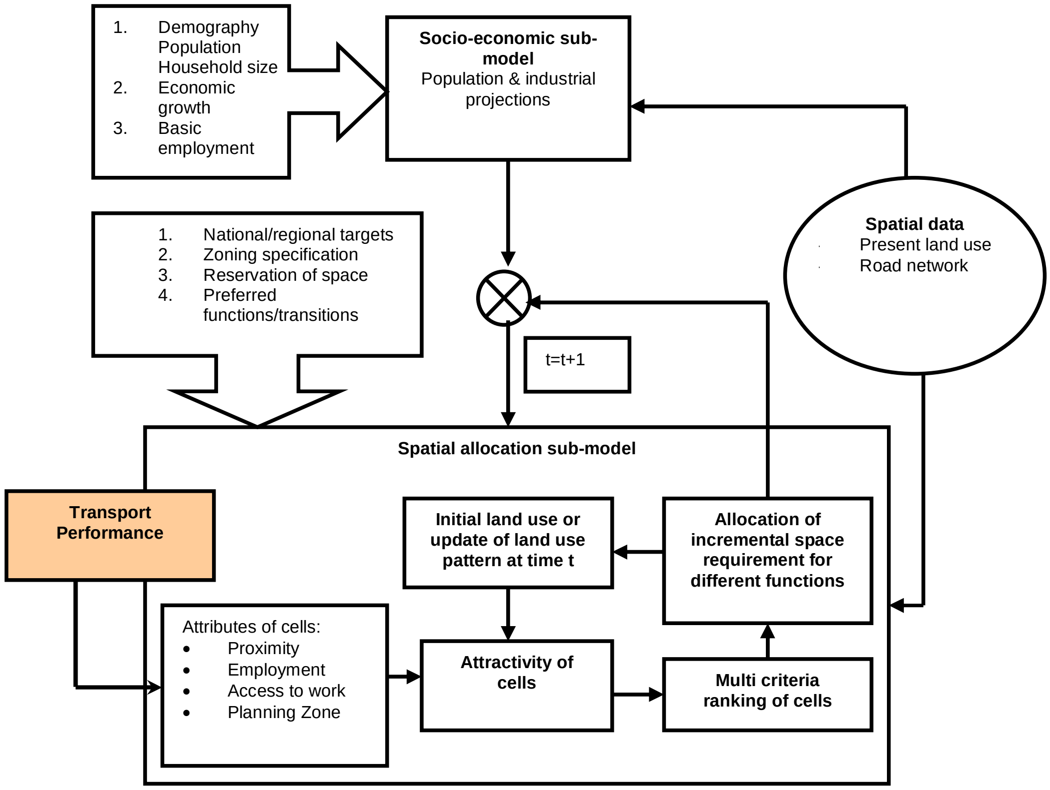


Figure 3: The spatial model schematization

Modelling of the total projection has followed a fairly standard approach, containing three sectors, population, housing and business, linked to each other through various (feedback) relationships.

3.3. Transportation Model

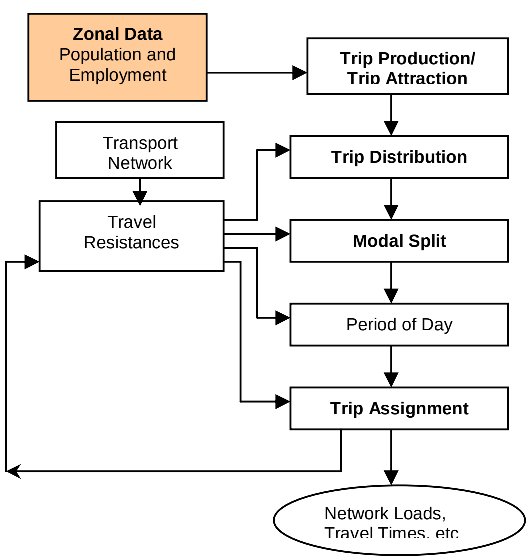


Figure 4: Steps in transportation modelling and analysis

The transport modelling for the Jabotabek region uses the classical 4-steps of transportation modelling with as final result the load and travel times on the transport network of the study area. The schematization of the region is presented in Figure 5. Seventy five transport zones have been considered which are linked with an inter-zonal transport network (highway and arterial roads).

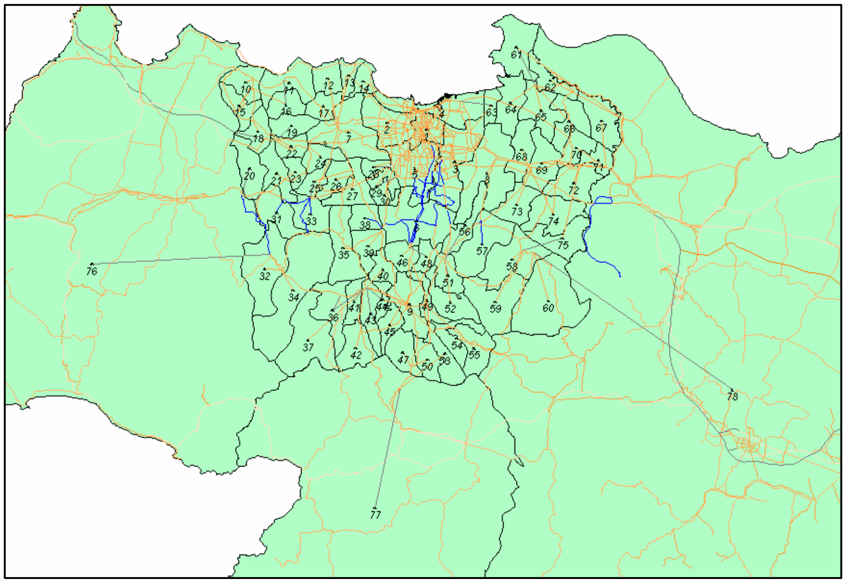


Figure 5: Jabotabek traffic zones

3.4. Accessibility

Accessibility measures how well a given location is connected with respect to activities is of a given type (e.g. work opportunities and shopping destinations). As such it is a spatial attribute of this location. A much used and general formulation of spatial interaction that can serve as a basis for accessibility studies is given by:

$$T_{ijk} = a_k X_i X_j f_k(c_{ij})$$

In which:

> T_{ijk} denotes travel demand from i to j for trip purpose k; a_k is a constant, reflecting intensity of travel for trip purpose k. X_i and X_j denote the size of activity in origin i and destination j. The deterrence function $f_k(c_{ij})$ represents the spatial dependence of the number of trips for purpose k on (generalized) transport costs c_{ij} .

Using this formulation as a starting point for measuring accessibility of i means that a summation take place across all destinations j. The accessibility is subsequently based on T_{ijk}/X_i to make it independent on the mass of the origin.
The accessibility of a node in a network is (proportional to) the spatial interaction between the node and all other nodes with the assumption that the spatial interaction between nodes may be directly measured or computed by means of a spatial interaction model. In this case, a frequently used definition is: the accessibility of a city is measured as the weighted sum of the population in all cities where weights are equal to the 'travel time decay' (cf. Keeble et al.' 1982):

$$Acc_i = \sum_j pop_j / (\text{travel time}_{ij})^{\alpha}$$

According to this measure, the location of a site at one hour's travelling distance contributes more to the accessibility than a similar site located four hours away.

3.5. Joint space-transport simulation

Figure 6 illustrates concept for an integrated simulation using the space- and transport models. The two models are used in subsequent cycles to update the socio-economic situation for the transport model, determine transport performance for this new condition and subsequently feedback the new accessibility to the new spatial allocation modelling of the next time step. The simulation of space- and transport was carried out for 25 years (2000-2025) with a step of 1 year for the spatial model and 5 years for transport model

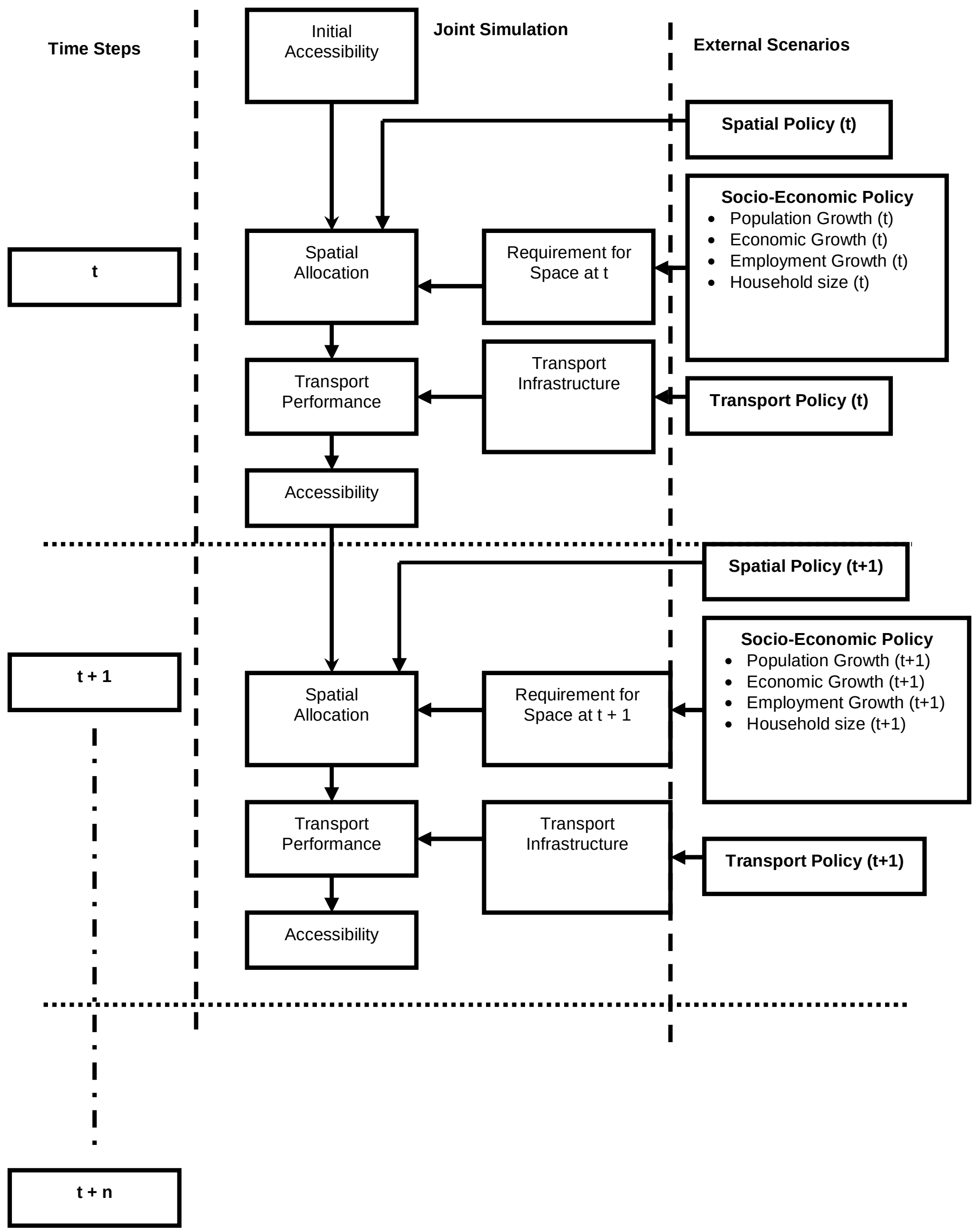


Figure 6: Flow diagram for joint simulation of space- and transport

4. Calibration and Validation

Each of the two models in the joint modelling represent complex processes of socio-economic processes and user behaviour, which have a spatial dimension as well as a dynamic time dimension (especially the spatial system). Large amounts of data are required to establish both models as representative for the actual system. The transportation modelling is, in addition to its specific aspects and parameters, strongly dependant on the projections of spatial settlement at a particular moment in time.

Validation refers to the checking if the model adequately represents the actual system based on an adequate structure of the model and fitting of this structure to the actual system behaviour. In a strict sense (usually referred to) validation refers to an ideal situation of a final checking of the prediction of the model with an extra independent data set. Calibration is usually seen as the more detailed process of fitting the proposed functionality or structure of the model to the actual system behaviour.

The present research focused on establishing a modelling approach which can capture the essential features of the space-transport systems and their interaction. In view of the limited data availability validation in the present study will be largely limited to the first step in the validation of the integrated model: identify a suitable structure on the basis of concept formulation and sensitivity testing. The limited data availability for this study does not allow detailed calibration. In the present study considerable use is made of typical data available from literature and further an informal approach is used to validate the modelling.

General data availability to establish the models for this study is poor. However a most important input for the spatial modelling is a sufficient inventory of land-use. A fairly detailed land-use data base at the Desa level (the whole of Java covered by about 25,000 desas) was available which is based on the PODES-2000 survey. This gives the present modelling of space a realistic starting base.

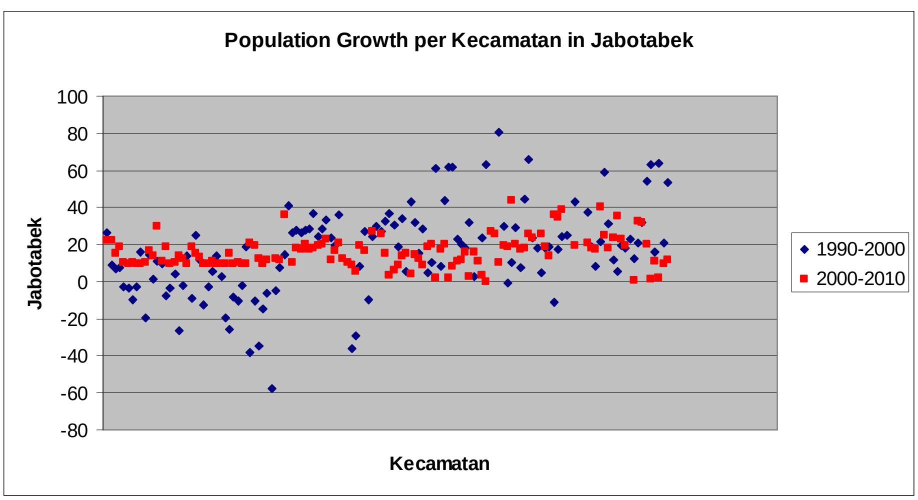


Figure 7: Population growth per spatial unit in Jabotabek

Figure 7 presents the observed (1990-2000) - and projected (2000-2010) growth trend for each of the considered zones. The graph shows a strong variation between observed and projected. It is suspected that the rest of the negative outlayer values of population growth were mainly caused by the monetary crisis in 1997 and the rest of the positive population growth were mainly caused by new housing area and suburbanisation.

Information on the consistency of the projection versus the observed change can be derived by analysing the changes in the 1990-2000 and 2000-2010 periods. It can be observed (Figure 7) that the mean growth in the two periods is practically equal (16.3 versus 16.0 %; for similar changes in the external scenarios over the period 1990-2000 and 2000-10). The range in the changes differs however considerably (-40 to 45% versus 0 to 45%). In particular the negative changes in the observation period stand out from the simulated period. The present model allocates increments in demand for space and thus cannot cause negative changes. Even if a percentage of the previous settlement is allowed to be re-allocated then for the present situation in Jabotabek, with a pressure on land, negative growth would probably not occur.

Considering the above, the projections with the current model should probably only be used to analyse larger measures and effects ("average" trends) for the region (not local measures and – effects). The adequate land-use inventory and the relative lack of (remaining) opportunities for settlement, and the monocentric build up of the urban area, further contribute to a projection which can be considered sufficiently reliable to establish trends in congestion and to differentiate the effects of various measures to relieve congestion.

5. Scenarios and Policies

Efficiency and effectiveness in urban/regional management are of critical importance for regions with rapid socio-economic change such as Jabotabek. The integrated modelling as proposed in this study can provide an important contribution to such efficiency by providing the means to make consistent projections which form the basis for planning and- impact assessment for alternative policies. Regional growth depends on many factors. For the analysis of options for spatial-and transport development the total set of factors can be sub-divided into external conditions or scenarios which are out of the range of influence of the decision maker, and policies which can be influenced by the authority responsible for space-and transport development. Simulations with combinations of scenarios and policies allow to study the impacts of options and to address uncertainties in regional development (Zondag, 1997).

5.1. Scenarios

<u>Population</u>
Population growth forms a main driver for settlement as well as demand for transport No alternative population scenarios have been used in the present analysis. The population is expected to be increasing to 110 % compare to the existing condition of 2000.

<u>Economy</u>
Economic growth is strongly linked with employment and therefore has a direct influence on settlement as well as transport demand. To test the sensitivity of space and transport development for this factor a low and high growth rate can be used. Realistic choices for a maximum can be the growth rate of about 8 % before the financial crisis in 1997 and a minimum equal to the present growth rate of about 4 %.

Car Ownership
Ownership varies strongly between different regions of Java.. For the Jabotabek region on average it is about 7 %. This is still very low compared to international levels and is expected to increase in the future. Ownership has a strong influence on transport demand. Only limited information was available on trip generation and relationships with socio-economic factors. Ownership has been kept constant for the present analyses. Projected future congestion levels should be considered as minimum projections.

Employment
Basic employment forms an external scenario input to the simulations. As a basis present base employment has been used as an initial condition and the same growth rates have been considered as for economic growth. This might be an overestimation of future employment as increases in productivity by employee are assumed to be non-existing.

Household size
Household size has decreased from 4,5 persons in 1980 to 3,5 in 2000 and is expected to decrease further to 3 in 2025. Household size has a strong influence and required settlement space. It has only influence on transport through the spatial settlement pattern.

5.2. Policies

Conservation area
The strong growth of the Jabotabek region in the past and the further expected growth will have a strong impact on the environment of the region. Water resources are strongly influenced: water quality is strongly deteriorating, pollutants cumulate in the downstream part of the region; increasing settlement in the upstream areas have reduced retention area and increased the fraction with impermeable land surface, causing strongly increased peak flows contributing to downstream flooding; water use has strongly increased in the region resulting a.o. in an over-use of groundwater, causing serious problems with land subsidence and drainage in the downstream urban area.; remaining water sources, in particular in the upstream areas should be preserved.

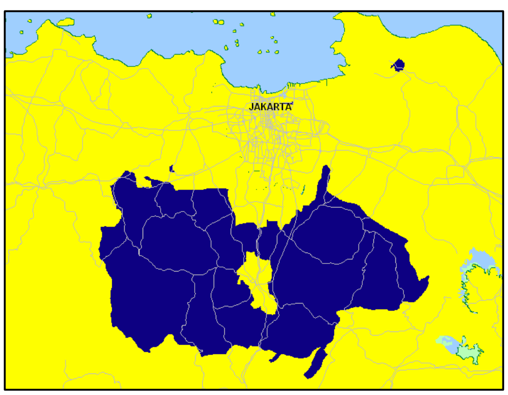


Figure 8: Conservation area for Jabotabek

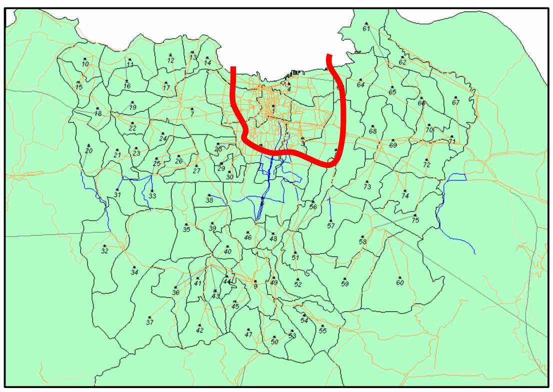
In view of the above problems further settlement in upstream regions should be limited as much as possible. To reflect this environmental interest in the planning for the Jabotabek region a conservation policy is formulated which restricts further settlement in the next 25 years; the effect of such policy on spatial development and congestion behaviour will be simulated with the model.

Employment distribution
Employment together with household settlement form major inputs to the demand for transport and are major factors in explaining congestion. Basic- and secondary employment have historically strongly concentrated in DKI Jakarta. The monocentric urban development in the region has strongly contributed to the present congestion.

A basic spatial policy which can influence congestion is then a re-distribution of basic employment outside DKI. Such spatial policy is considered here to test its influence on congestion and settlement pattern. Employment growth will be assumed as the same growth as economy. This based on theory that a low average productivity of the work force can be due to the deficiency of capital relative to labour and the use of backward technology.
In this policy is assumed that the growth of employment in DKI will only be 6 % and outside 12 % (average employment growth 8%, equal to economic growth)

Transport Policies

There are two transport policies that were tested in the integrated model: the Jakarta outer ring road and the busway public transport system. According to the JICA master plan study for Jabotabek, it is foreseen that the Jakarta Outer Ring Road (JORR) that will be completed by the year 2025. A second transport policy is the development of a bus transport system (busway) in DKI Jakarta. According to the technical review of the bus-way system carried out by ITDP in 2003, the system will be developed in 8 phases involving different corridors



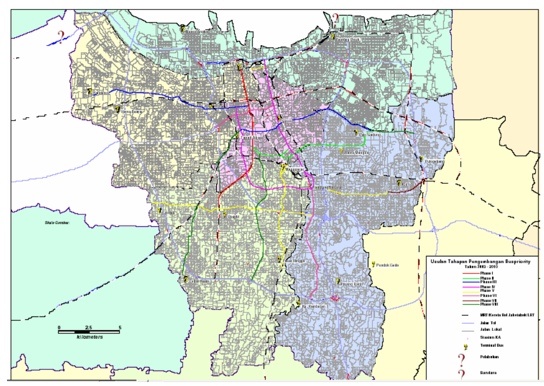


Figure 9 and 10: Transportation policies in Jabotabek: Jakarta Outer Ring Road and Busway Corridor Plan

Strong Intervention

The strong changes in the Jabotabek region which are expected to continue will cause increasing congestion levels. It is then important for planning to study the impact of potential measures on congestion in the region. Of particular interest is then the option in which the government makes a maximum effort to relieve future congestion; what is then the remaining congestion; are further measures necessary. Such option will be called "**strong government intervention"**

6. Simulation Results

Expected further strong growth of settlement and economic activities in the Jabotabek region will lead to a strongly increasing demand for mobility; if no counter-acting measures are taken this will result in a strong increase of congestion in the region.

Simulations using the earlier scenarios and policies were carried out to scope the future problems in the region and to analyse space-transport development interaction by looking at the impacts of each policy. The results are expected to be useful to support the authorities in the process of strategic policy and decision making.

Impacts from road development

Transport has a major impact on the spatial and economic development of cities and regions. The attractiveness of particular locations depends in part on the relative accessibility, and this is in turns depends on the quality and quantity of public transport (Banister and Lichfield, 1995)

Implementation of the Jakarta Outer Ring Road (JORR) is considered as the major improvement of the road system in the region is expected to contribute substantially to solve the congestion problem in Jabotabek. This ring road is expected to be completed and fully operated in the year 2025. The predicted impacts of this road improvement on the traffic condition is presented in Figures 11 and 12 for the without and with situation.

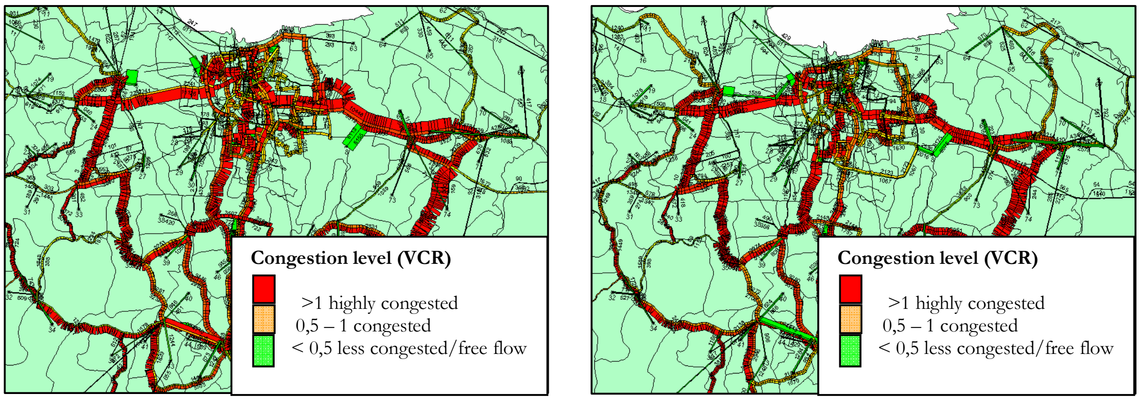


Figure 11and 12: Jabotabek congestion pattern 2025 without and with road developmentn (Outer Ring Road)

Impacts from an upstream conservation area

With the conservation area in the south of Jabotabek (Kabupaten Bogor), further settlement is limited to the east and west direction. The urban area in the DKI Jakarta area becomes slightly denser with the conservation area policy.

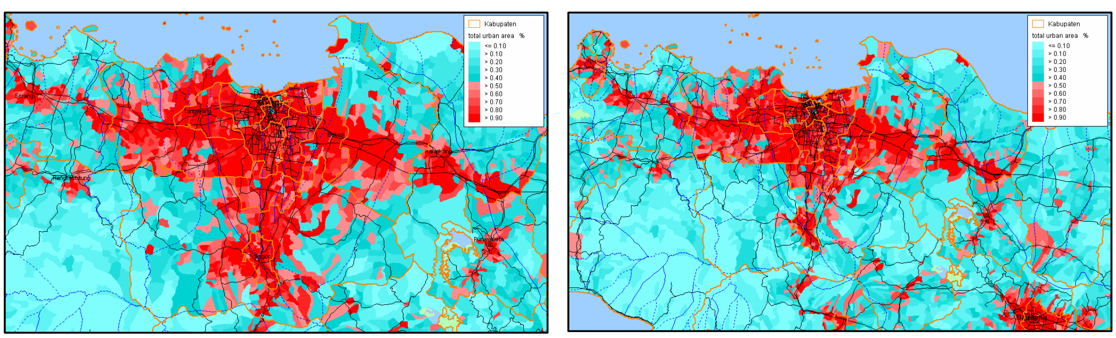
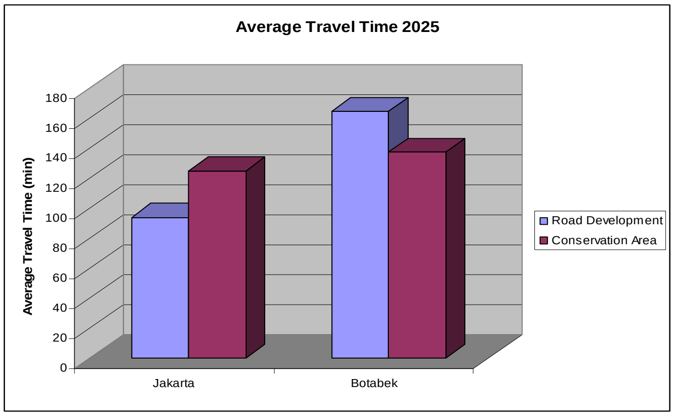


Figure 13 and 14: Jabotabek total urban area 2025 without and with conservation area

The spatial policy does not only affect the spatial allocation pattern but will also affect the traffic condition. The concentrated expansion into eat-west direction will intensify travel and increase congestion in those parts. Figure 15 presents the effects on average travel time: travel time increases substantially in the core urban Jakarta area and on average reduces in the outer areas



It can be concluded that the spatial policy of conservation area in the south of Jabotabek obviously has a significant impact on spatial allocation pattern and traffic condition in the area. It will improve ecological conditions but puts pressures on space and congestion it makes Jabotabek less attractive compared to the rest of Java.

Figure 15: Average travel time of Jabotabek in 2025 compared between road development policy and conservation area

Impacts from employment distribution

Re-distribution of employment outside the core area of Jakarta can make a significant contribution to a reduction of congestion by locating employment closer to settlement possibilities. A simulation has been carried out with a distribution of employment growth: DKI Jakarta region receives less employment growth than the other areas beside Jabotabek. Figure 16 and 17 present the projected settlement pattern in 2025 with and without such employment decentralization strategy.

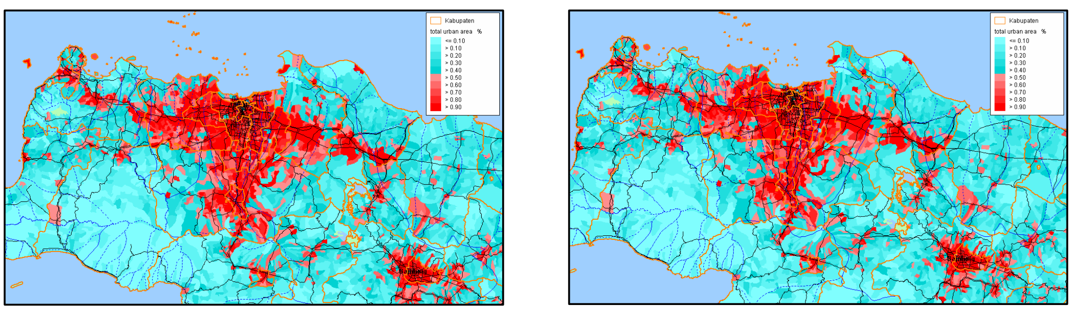
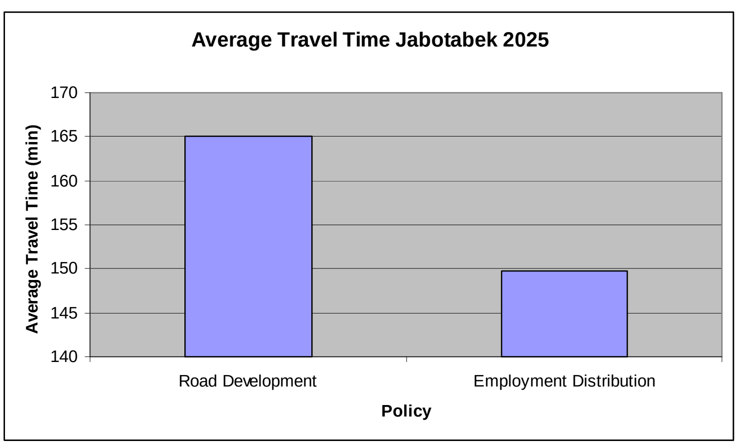


Figure 16 and 17: Jabotabek total urban area 2025 with and without employment distribution

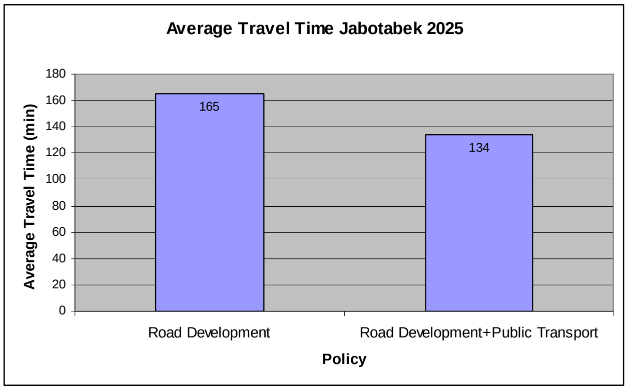


The spreading of employment has the desired effect on decreasing congestion as can be observed in Figure 18

Figure 18: Average travel time of Jabotabek in 2025 in the employment distribution policy

Impacts from public transport on spatial allocation and traffic condition

The simulation of this case indicates a spatial pattern which is practically not different from the without case. The transportation results Figure 19 shows an average travel time Jabotabek..



The average travel time for Jabotabek is decreasing with the implementation of the new busway system in DKI Jakarta.

Figure 19: Average travel time of Jabotabek in 2025 in the transportation policy

As in the road improvement policy, the congestion in DKI Jakarta (inner city area) is slightly decreasing in the year 2025 with the policy of public transport. But there is still much congestions outside DKI Jakarta. The implementation of road improvement and public transport policy only partially solves the traffic problem in DKI Jakarta.

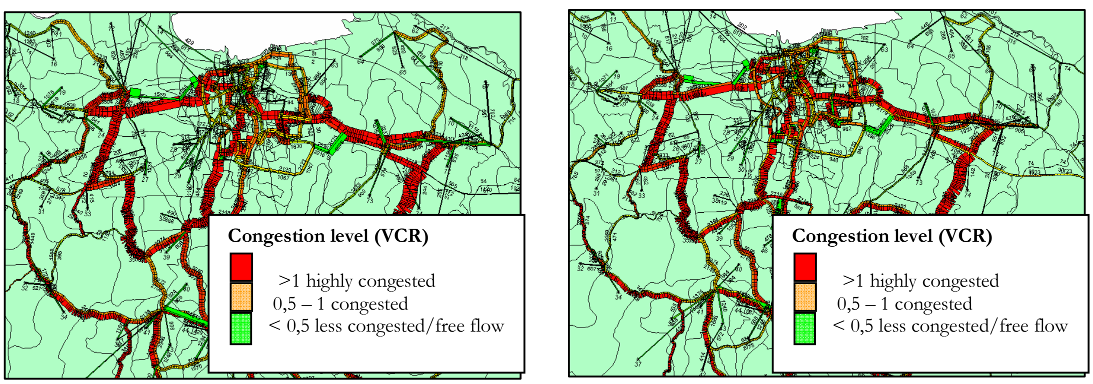
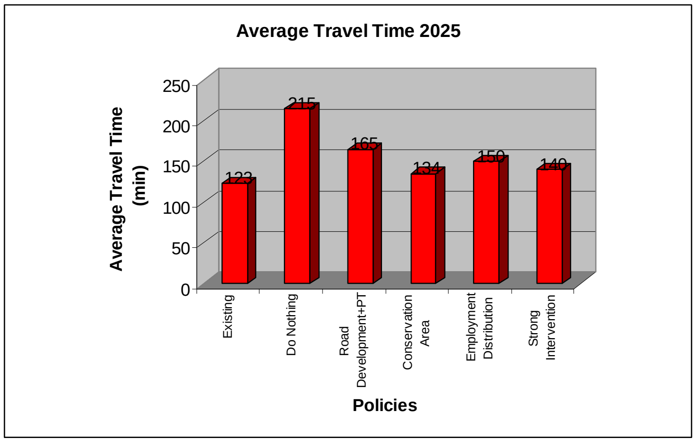


Figure 20 and 21: Jabotabek congestion pattern 2025 without and with public transport

Impacts from strong government intervention

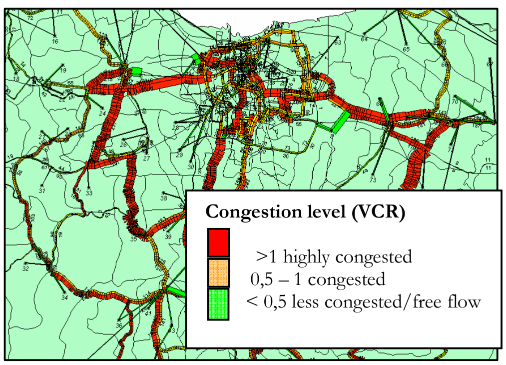
The different individual policies have mixed influence on the projected (2025) settlement pattern, the attractiveness of Jabotabek for settlement, and congestion level. The strong intervention case cumulates to some extend the influences of the individual policies.

The case is characterized by a significant reduction in population by about 1 mln, caused primarily by implementation of the conservation area and the resulting pressure on space.
The strong intervention policy cumulates the effects on average travel time. The total effect on travel is relatively small.



The average travel time in Jabotabek with the strong intervention policy is only 7 minutes better than for the employment distribution policy and 8 minutes better than in transportation policy. The more detailed congestion patterns is presented in figure 23. Further confirm the image of a strongly congested region even after the policies are implemented.

Figure 212: Average travel time of Jabotabek in 2025 in the strong intervention policy



It can be concluded that neither of the policies, including the strong intervention, provides a significant improvement in the congestion of the region. More drastic measures to relieve a growing congestion will be needed.

Figure 23. Jabotabek congestion pattern 2025 in strong intervention policy

7. Strategic Planning for Jabotabek

Simulation results in the previous sections indicate that provision of a second ring road, spreading of employment, and provision of public transport for the central DKI Jakarta area, have a significant impact on congestion but not sufficient to reach an acceptable level in the longer term future. It is observed that a conservation strategy may be highly desirable from an environmental point of view, but it puts further pressure on land and congestion. It is further observed that the monocentric settlement pattern strongly limits the effects of those policies.

Based on the projected regional patterns and indications from the different policies a policy to be further pursued can be a combination of a spatial policy which aims at a mare rigorous spreading of employment by transforming Jabotabek into a multi-centric urban area. Such spatial strategy will make transportation measures more effective. A public transport system, for example light rail, could then be further considered to link the different centers.

To some extend initiatives have been taken by the authorities to move employment outside the dense DKI Jakarta area. Provision of a regional light rail system, at an early stage, may strongly stimulate the formation of different centres.

Figure 24 provides a sketch of a possible configuration for such light rail system. It would consist of a ring which provides service in the two directions. Such system with an appropriate pricing would have a strong effect on transport flows as well as on settlement. The joint space-transport modelling would form an appropriate instrument to study such space-transport policy.

A more detailed schematization for transport analysis would be needed, as well as more information on travel preferences (mode choice), price elasticity, etc.

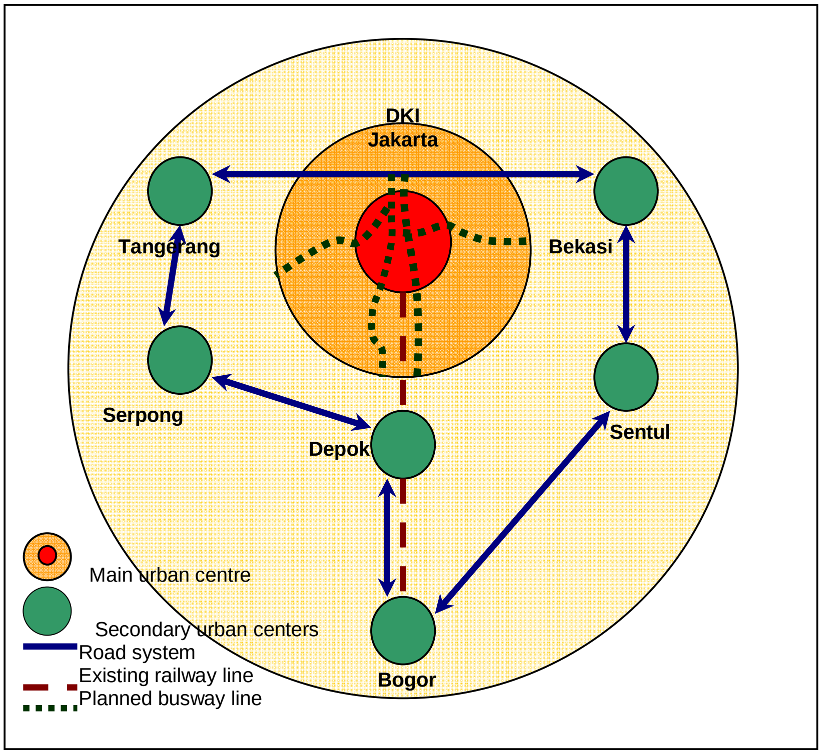


Figure 24: Sketched strategic planning of Jabotabek

8. Conclusions

In view of the expected dramatic changes in the Jabotabek region and the large infrastructure investments which will be required in the mid term and long term future, there is a strong need to make strategic choices in settlement - and infrastructure development as part of regional planning. The challenges for such planning can be characterized as follows:

- strong changes: for the future strong socio-economic changes (population growth, household size, car ownership) are projected which will have a drastic effect on settlement and demand for mobility
- data limitation: only limited data are available to prepare the urgently needed information for strategic decision making
- present status of infrastructure development: as mentioned in the literature and indicated by the strong present congestion, there is a shortage in infrastructure development in the case region; this further emphasizes the importance of strategic decisions

A modelling instrument has been developed by establishing a dynamic coupling between a land-use and transportation model. The modelling instrument has been applied to a set of policies (combination of spatial planning and specific transport relation policies) for the Jabotabek region, leading to useful insights into the future development of mobility in the region and the effectiveness of particular policies.
Conclusions with respect to modelling and policy making can be formulated as follows:

Development of the modelling instrument:

The present modelling does reproduce major processes in the settlement and mobility system of the region; it allows to trace congestion behaviour in the region in the future and for combinations of different space and transport interventions.
The advantages of the integration of the two models, which can also be operated independently, are the following

- the dynamic coupling allows to incorporate the (accessibility) effect of transportation performance into the spatial allocation process and the feedback of effects in earlier transportation performance into later transportation performance
- tuning of the two models, which cover both essential aspects of mobility, proves to be very effective to analyse those options and their impacts; the analysis of the different policy options illustrated the close relationships between spatial and transport policies for the Jabotabek region

Specific points of attention for further improvement of the model are :

- calibration of the spatial model: set-up of the land-use data base for 1990 (for Java) in order to be able to simulate the 1990-2000 period
- improved estimation of the MCA weight set; in particular the influence of accessibility on settlement; varying sets of weights can be tried out in the simulation model to represent the 1990-2000 period as best as possible; a formal estimation of the weights may be tried out using the improved 1990-2000 data base at the desa level, and using a more advanced (non-linear) estimation method
- including the housing market in the modelling would allow to address the suburbanization process in the region; this would however require a major expansion of the data base to differentiate socio-economic classes for households, different types of housing, more details on land characteristics, and preferences by households
- a more detailed level transportation network including local roads, matching a desa level spatial schematization, may be implemented; this will allow an improved estimation of the role of accessibility as well as an improved representation of congestion

Insights into the future mobility problems of Jabotabek:

Application of the modelling to the different policies has generated the following insights on the mobility problems:

- congestion in the region will strongly increase in the next 25 years
- current transportation policies (second ring road, public transport: bus-way system for DKI Jakarta) will have only limited effect on future congestion; the Jakarta bus-way system is only relieving congestion in Jakarta and does not address the growing congestion in the rest of the region

- conservation of the upstream area for environmental reasons using restriction on settlement will substantially increase pressure on space and increase congestion
- spreading of employment, now concentrated in the DKI Jakarta centre of Jabotabek, has significant impact on congestion;
- the simulation results for the various measures and including their combination in a strong government intervention policy, indicate that they will have a significant impact on congestion, but not sufficient to reach an acceptable level in the long term fuuture
- it is argued that a more drastic intervention in the spatial planning for the region, transforming the mono-centric urban system into a multi-centric situation, and an associated public transport system inter-linking those centres, could be an effective solution to counteract future congestion (at a substantial investment cost)

9. References

Annual report of the Asian Development Bank (ADB) of South East Asia. 2005

Azis, Iwan J. *Global Imbalance: Implications on Indonesia, Regional Growth and Poverty.* Paper presented at the Indonesian Regional Science Association (IRSA) Conference, Malang, August 18-19, 2006

BPS, *Jabotabek population.* 1990 and 2000

Environmental Protection Agency (EPA, 2000), *Projecting Land-Use Change: A Summary of Models for Assessing the Effects of Communnity Growth and Change on Land-Use Patterns,* Office of Research and Development, Washington, USA.

Government of Republic of Indonesia and Government of the Kingdom of The Netherlands. *General Assessment of Development Potentials, Problems and Constraints of the Province of West Java.* Volume C Sectoral Analysis. 1988.

Geurs, K.T and van Eck, Ritsema. *Accessibility Measure: review and applications.* National Institute of Public Health and The Environment. The Netherlands. 2001.

The World Bank. *Indonesia : Economic and Social Update.* March 2006.

Study by ILO, working paper 11, December 2004. *Informal economy in Indonesia.*

Ministry of Public Works Republic of Indonesia. *Jabotabek Metropolitan Development Plan Review.* Third Planning Report. 1993.

International Labour Office, Jakarta, Indonesia. *Labour Market Dynamics in Indonesia. Analysis of 18 Key Indicators of the Labour Market (KILM) 1986-1999.* 2000

Lowry I.S. (1963), *A Model of Metropolis,* RM-4035-RC, Santa Monica, CA: RAND Corporation

Miller, E.J., Kriger, D.S., Hunt, J.D., (1998), *Integrated Urban Models for Simulation of Transit and Land-Use Policies,* Final report TCRP Web Document 9, University of Toronto

RAND Europe, *Literature Review of the Land Use Models.* Report prepared for the Transport Research Centre, Leiden 2001

Sanders F.M, B. Zondag and R.J. Verhaeghe (1997), Projection of the urbanization pattern for the Jabotabek region, *Asian Urbanization conference*, London

Badan Pusat Statistik. Indonesia *Sensus penduduk 2000 Potensi Desa/Kelurahan.*

Demis BV. *Spatial Planning in BWRMP : Projecting Land-Use Change*. Indonesia Water Resources and Irrigation Reform Implementation Project (IWIRIP). 2003

Japan International Cooperation Agency (JICA) and Indonesian National Planning Development Agency (Bappenas).*The Study on Integrated Transportation Master Plan for Jabotabek (Phase I).* Final report. 2001

Wegener , M., (2004), Overview of land use transport models, in D. Hensher, J. Button, K. Haynes and P. Stopher (editors), *Handbook of Transport Geography and Spatial Systems,* Elsevier publication

Wegener, M, Furst, Frank. *Land Use Transport Interaction. State of the Art.* Institut für Raumplanung, Fakultät Raumplanung, Universität Dortmund. 1999

Zondag, B. *Jabotabek Spatial Development Study*. Final thesis. Delft University of Technology. 1997

Zondag B. *Joint modelling of land-use, transport and economy*. PhD dissertation. Delft University of Technology. expected publishing april 2007.