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Modeling for integrated planning of space, mobility and water.

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Abstract:

Infrastructure development for a high growth, dynamic region such as Jabotabek, Indonesia, requires huge investments in basic infrastructure. Two major sectors for infrastructure development are water (drainage, sanitation, water supply) and mobility (transport).
The effectiveness of investment in infrastructure is highly sensitive for alternative settlement, which influence large scale effects in infrastructure development; the settlement pattern needs to be considered as an explicit design variable in the design of future infrastructure
A modeling framework is being worked out to support such integrated planning. The total analytical framework comprising modeling modules, data bases, and user interfaces, will provide a platform to analyze, at a strategic level, packages of policies/measures in infrastructure development. A fairly detailed spatial specification in terms of networks and physical conditions is needed to evaluate impacts for the water and mobility sectors.
Generation of alternative spatial configurations, as input to impact assessments for water and mobility forms a most important component in the modeling framework. Modeling of spatial development should take into account as much as possible the demand for settlement. Preferably the labor and housing markets should be incorporated in the modeling of this demand.

Keywords: integrated planning, spatial modeling, infrastructure development, impact assessment

1. Introduction – development of the Jabotabek region

Integrated planning
Spatial planning has intensively been studied in relation to transport and mobility, the role of water in spatial planning has received only more recent an increasing attention. For example spatial planning is now often considered in relation to flood risk as well as the control of emissions. Regions with a high growth and dynamic development require huge investments in infrastructure development in order to provide for basic utilities (water, mobility, drainage) and to control environmental stress (congestion, emissions). Attention should further be paid to sustainable development; concentration of settlement and economic activities generally lead to an increasing environmental stress and require extra mitigating measures.

Spatial configuration in association with physical characteristics of the region have a strong effect on the efficiency of providing the necessary infrastructure; scale effects associated with providing infrastructure for different spatial configurations are very large.
The spatial outlay of settlement and activities should therefore become part of the design choices to plan an efficient infrastructure. Modeling to represent/configure alternative spatial patterns and quantify distributed impacts is essential for such integrated planning.

The present paper reports on the set up of a modeling framework for such efficient design of infrastructure and some preliminary results. The modeling is being set-up and applied to the Jabotabek region in Indonesia. The problems and development characteristics of this region are elaborated below.

Jabotabek development
Figure 1 presents the Jabotabek region as part of West Java. The region can be considered the

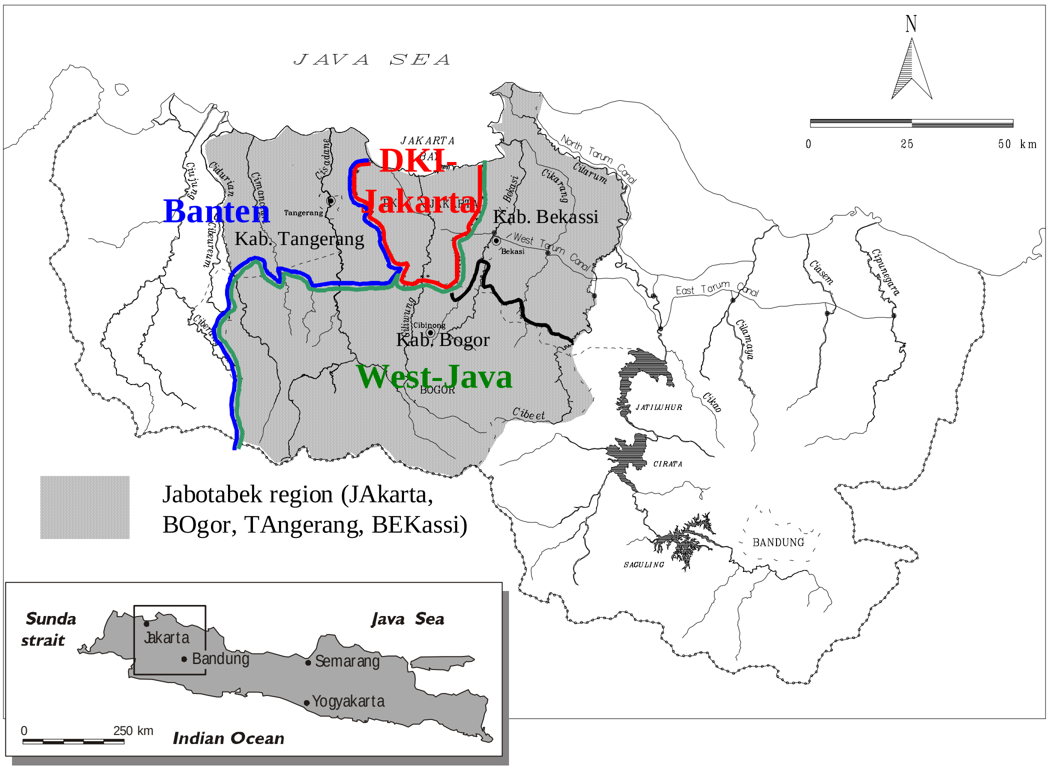

Figure 1: Location of Jabotabek region

economic heart of Indonesia/Java (70 % of capital) and is characterized by a strong concentration of economic activities and urban settlement.
Because of rapid industrialization and development of the service sector, the current population of about 20 million in the Jabotabek region is projected to increase to over 50 million by the year 2025 (MPW, 1995). A further strong urban development is foreseen for the next two decades based on a strong growth of industries- and services sector and associated household settlement. In particular the improved accessibility through some major highway (toll road) development has shaped and will continue to shape the urban expansion pattern.

The strong expansion of settlement over the last 20 years development has had drastic effects on practically all aspects of water resources in the region.
The effectiveness of investment in water resources development and the performance of water resource systems is highly sensitive to the spatial arrangement of economic activities with respect to the WR features of a region. E.g. land use changes over the last 20 years (and the lack of compensating/ controlling measures) in the Jabotabek region have completely changed water systems : twenty years ago flooding in Jakarta and surroundings was largely limited to occasional flooding close to the rivers associated with high river flow. Land-use changes have now led to a strong increase in flooding for even quite regular hydrologic events. The dominant cause of flooding has changed from spillage from rivers to local internal drainage problems. In February 2002 a modest 1 in 5 years rainfall storm caused a massive flooding of 2/3 of the city; resulting in an estimated damage of 1 billion US$; the contribution to flooding from rivers was negligible. A satisfactory/affordable solution will require interventions in spatial development and associated regulation.
Similarly because of uncontrolled urban expansion and lack of sufficient sanitation measures, emissions cumulate and cause an increasing degradation of environmental quality. Different spatial developments, e.g. less expansion (or only under certain conditions) in upstream direction will have a huge impact on environmental quality.
Availability of groundwater varies strongly for different parts of the region, generally it is over-used causing an increasing dependence on expensive surface water supply. Investment costs for water supply to the region will depend strongly on the positioning of the settlements with respect to the main supply lines. Such supply lines are in turn dependent on the evolution of environmental quality in the region.

At present infrastructure development for the region has not kept pace with the strongly expanding settlement in the last 20 years, resulting in considerable congestion and environmental adverse conditions. The current trends in impacts indicate a development which is not sustainable in the long run. An intensified program for infrastructure development is being considered by the government. 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

In the following sections of this paper the modeling framework to address integrated planning of infrastructure is elaborated; this involves an overview of the planning approach and analytical framework in Section 2; an elaboration of the spatial modeling to generate alternative spatial patterns, a primary component in the modeling framework, in Section 3; and modeling of the interactions between spatial pattern and the main impact (infrastructure) categories considered in the present project (flood risk, emissions, water supply, congestion). This is followed by observations and conclusions in Section 5.

2. Planning approach – analytical framework

The aim of an integrated planning will be to incorporate different spatial arrangements explicitly into the design of the water and mobility systems, together with the specific water and transport measures. This requires the ability to compose/generate reliable/consistent spatial patterns (taking into account the relevant processes and spatial policies) and an elaboration of the interactions between water and transport with spatial planning. The use of such modeling framework in the design of infrastructure is presented in Figure 2: the framework consists of several computational modules and associated data bases representing

sectors involved in infrastructure planning; each module uses sector specific input on policy and measures; alternative spatial configurations, including expected or desired situations, serve as input to the different impact modules; interpretation of impacts leads to the generation of adjusted/new spatial patterns. The total analytical framework comprising modeling modules, data bases, and user interfaces is intended to provide a platform to analyze, at a strategic level, packages of policies/measures in infrastructure development (including settlement and main categories of infra development).
The main purpose of the analytical framework is to be able to simulate time patterns of regional development based on some autonomic projections and a set of policies/measures from the different sectors.

The challenge in setting up this analytical framework is

- to sufficiently represent basic processes and strategic interests in the different sectors,
- to tune the different components to each other (requiring for example appropriate level of spatial and temporal detail), and
- explicitly recognize and quantify interactions.

Typical interactions are for example

1) requirements on space: by water resources functions (e.g. flood zoning)
2) demands on water resources from the spatial arrangement of economic activities (e.g. drinking water-, industrial water - and irrigation water demand)
3) water resources characteristics contribute to the attractiveness for settlement (e.g. availability of groundwater); settlement is determined by a combination of free market forces and government steering; attractiveness is a main parameter in the free market process (see section 3.3)
4) impact of alternative spatial alternatives on the effectiveness of water systems (such as costs for water supply, -sanitation, and drainage; effect on environmental quality)
5) accessibility, strongly determining settlement preferences, is defined jointly by the spatial configuration and transport possibilities.

There is considerable modeling experience on the individual sectors, however the link with the spatial pattern is usually not elaborated. Also the spatial modeling should be tuned to interact with the impact categories. An example of such tuning between the modeling of space and mobility is provided by the recent development of Tigris.xl (see section 3.1), in which spatial – and transportation modeling have been tuned to each other in such a way that the joint effect of a set of spatial and transport policies/measures can be simulated. The aim in the present modeling project is to establish such set up for all the mentioned sectors. For the water sector use can be made of extensive experience with modeling of river basins (Verhaeghe et al, 1998).

The spatial modeling is further discussed in Section 3; modeling of the different impact categories is discussed in Section 4.

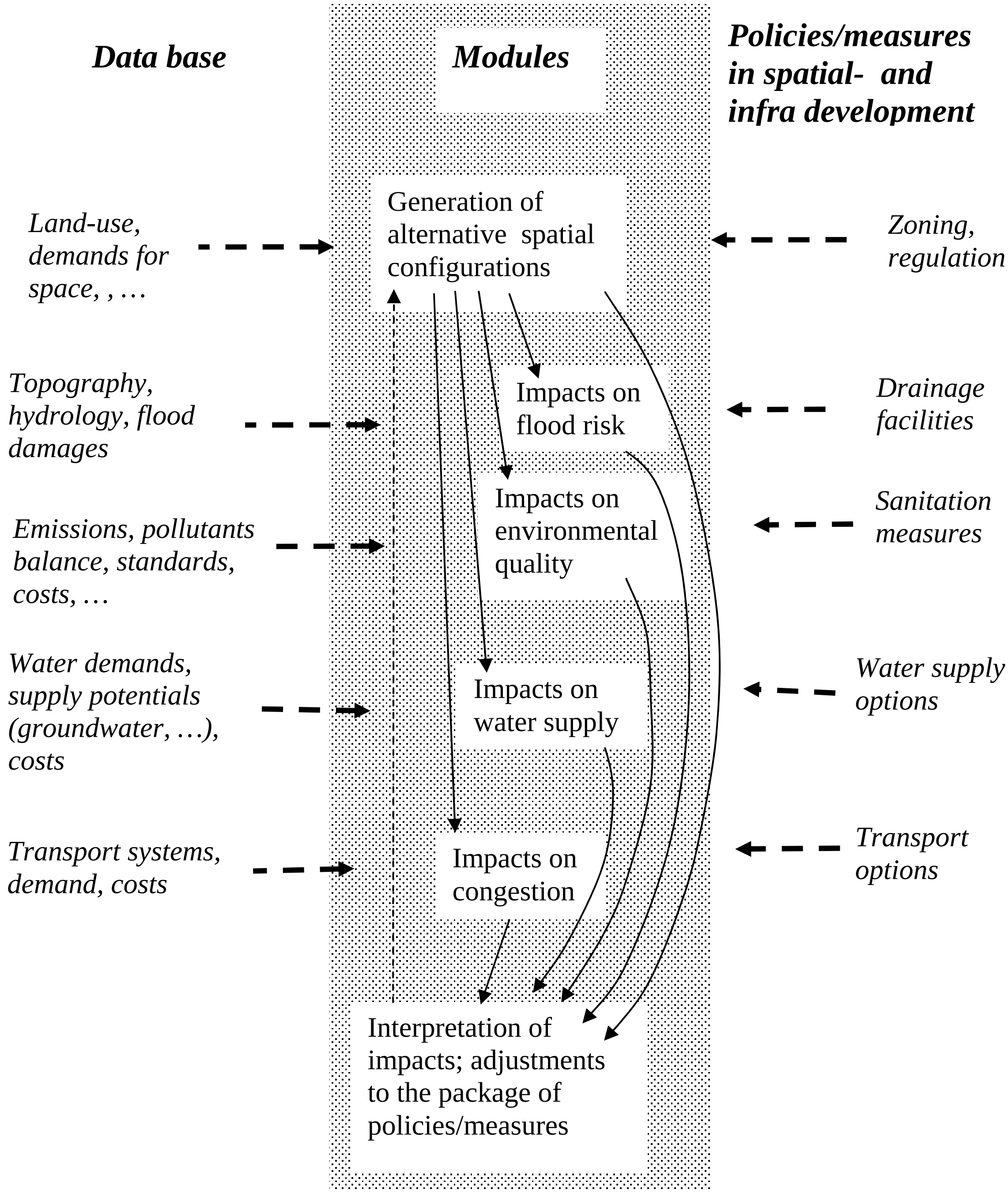

Figure 2: Analytical framework for proposed integrated planning

3. Spatial modeling

3.1 Land use modeling

A large number of land-use models are presently operational. The models can be roughly classified by different geographical scale levels. The regional economic models (e.g. the RAEM, REMI or Mobilec model in the Netherlands) operate at a regional level. The strength of these models lies in their economic foundation, but these models are clearly less qualified to address land-use changes. Regional economic studies are the core area of application of these models. At the bottom-end (most detailed micro level) GIS based approaches are used to address spatial developments in terms of shifts and redistribution of functions for a set of parcels of land. These models have their strength in the level of spatial detail and integration with standard GIS data (e.g. the “Spatial Environment scanner” in the Netherlands with cells of 500 by 500 m). These GIS based approaches are often used to analyze the environmental or land-use effects at a local level. The short calculation times and high geographic detail make these models a useful tool for sketch planning. The lack of representation of the behavior of the main “spatial markets” and the involved actors makes these GIS based approaches less qualified to evaluate planning or policy options.

Spatial markets, such as the housing and labor market, typically operate at a regional level and a detailed zoning is needed to represent the spatial dimension of these markets. The labor and housing market influence each other, firms and residents compete for scarce land and floor space and the transport market facilitates activities like commuting or shopping. The land-use and transport interaction models usually operate at this regional level and their focus is on the interaction between the different spatial markets.

Over the last decade several international literature reviews on LUTI-models have been published. For an in depth review of existing Land-use models and their characteristics, reference can be made to Miller, 1998, Simmonds, 1999, Wegener and Fürst, 1999, and Zondag, 2001. These reviews highlight the differences between the land-use models, e.g. in model structure, dynamics, scale level, interaction with transport model and way of validation and calibration; there are however also a large number of common elements in most of the state-of-the-art LUTI models. For the LUTI models the following characteristic elements can be mentioned:

- A successful modeling of land-use relies on information/insights from many different disciplines such as economic theories (utility theory, markets, macro economy), demography, social sciences, urban design, transport planning and computation science. Developing a model instrument in such a complicated environment needs the input from different fields.
- State-of-the-art land-use models address the key markets influencing land-use changes. The following markets are regularly addressed within land-use models:
  - Land market
  - Real estate market
  - Housing market
  - Labor market
  - Transport Market

  A typical characteristic of the system approach within LUTI models is that all of these markets influence each other.
- The markets mentioned here above operate for different components of the system. The three components, or layers, of the land-use[1] system are:
  - Land
  - Objects
  - Activities

[1] Please note that in land-use and transport interaction models the term land-use refers also to interactions between activities.

Each component of the system has its own time dynamics. Changes in the settlement pattern of the activities will have an almost direct impact on the transport system. The impact of changes in the transport system will have a long-term impact on the settlement pattern of the activities. Such a long time period complicates the analysis of the relationship. This split in three components or layers, is implemented in most LUTI models and these models administrate the number and changes in land-use, objects and activities for each location.

- The land-use models address the characteristics of both supply and demand side of the main markets. The market allocation mechanism depends on the local circumstances and can vary between a free market allocation (price mechanism) or a fully regulated allocation (allocation rules). The concepts and methods applied are market specific and depend on the available data sources.
  - The variety in basic theories for explaining demand behavior of residents in integrated land-use & transport modeling has diminished throughout the years and nowadays almost all 'state of the art' models rely on discrete choice theory to explain and forecast residential settlement behavior.
  - The modeling of firm behavior within land-use models is still in an early stage of development and in practice changes are modeled at the level of jobs as a best proxy for firm behavior.

LUTI-models are traditionally used for policy analysis in the field of transport and spatial planning. Recently in the Netherlands a consortium of RAND Europe, BureauLouter and Spiekermann & Wegener has developed a new land-use and transport interaction model (TIGRIS XL) for the Transport Research Center (RAND 2004). This model is capable of simulating the influence of actors like residents and firms on the spatial development under various assumptions regarding the type of land market. The model can simulate land markets varying from completely regulated, all land and houses developed according to government plans, towards a completely free market, land development depends on preferences of residents and firms. Figure 3 illustrates the functional design of TIGRIS.XL.

In Figure 3, two spatial scale levels are differentiated, namely the regional level (COROP, 40 representative regions in the Netherlands) and local transport zones of the National Model System (NMS sub-zones, 1308 sub-zones covering the Netherlands).

Core modules in TIGRIS XL are the housing market and labor market module, these modules include the effect of transport changes on residential or firm settlement behavior and link changes in the transport system with changes in land-use. A land and real estate module simulates supply constraints following available land, land-use policies and construction. The module defines different levels of government influence, ranging from completely regulated towards free market, and various feedback mechanisms between demand and supply are represented. A demographic module is included to simulate demographic developments at the local level. At the regional or national level the model output is consistent with existing social-economic forecasts.

National employment figures by sector are an exogenous input and the model (labor market module) distributes these national projections. An extension (or linkage) of the model with an inter-regional economic module at a later stage should enable an endogenous modeling of the Gross Regional Product, Employment and Income. At the moment such a link or extension is still in a research phase.

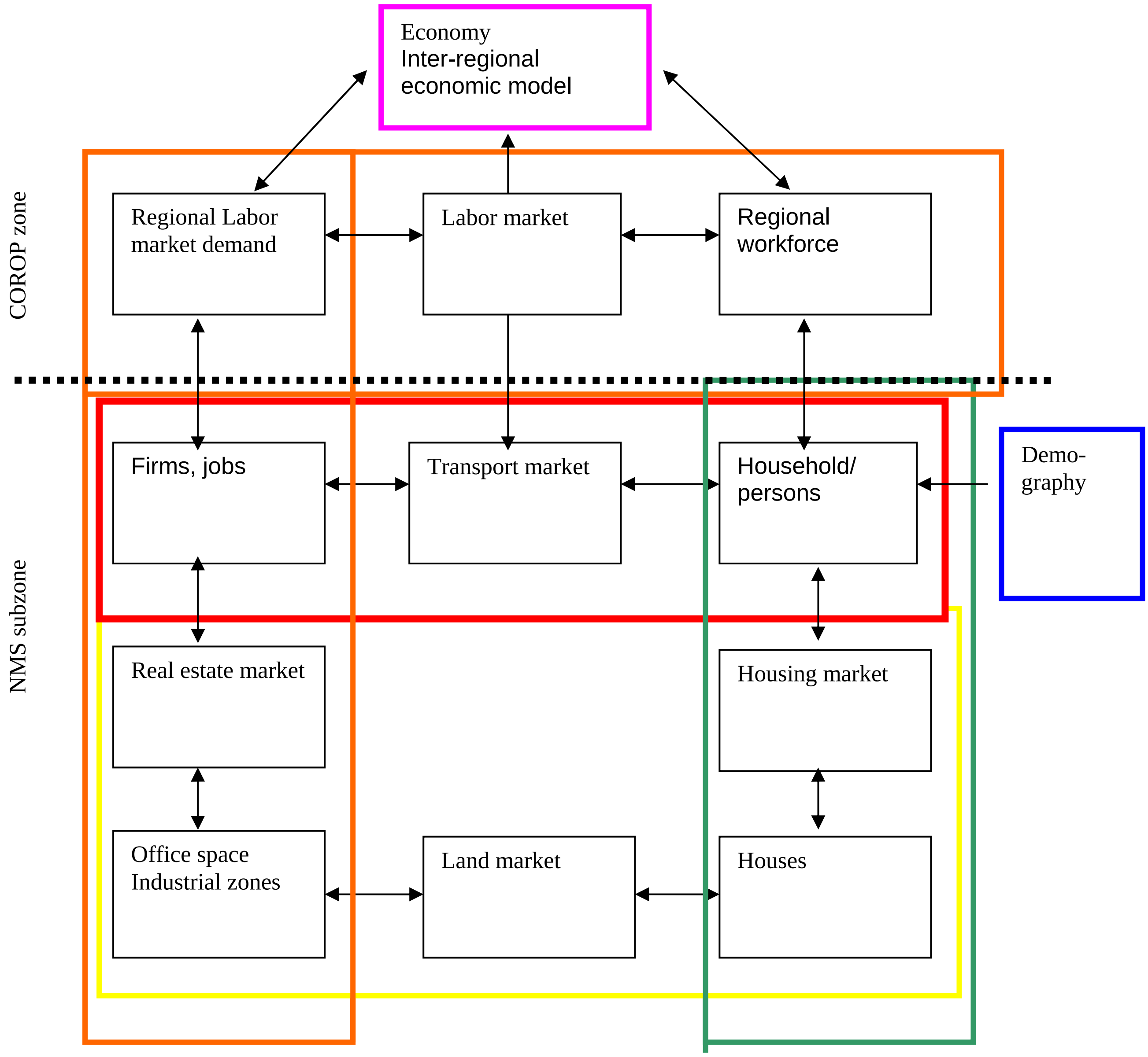

Figure 3: Components in the functional design of TIGRIS.XL

The representation of the main spatial markets in LUTI-models does offer potential for application in other sectors with a spatial dimension. For example, the water sector could use these type of models to analyze the impacts of their land claims on other markets. Insights in the consequences of land demands would strenghten a pro-active position of the water sector towards spatial planning. Vice-versa reliable land-use projections are needed for an adequate management and protection of the water resources.

The spatial level of detail in LUTI-models is normally too aggregated to use these models to deliver land-use changes at the level of grid cells as required by the water sector. This obstacle has been solved successfully in several studies with the integration of LUTI-models and GIS based raster modules, examples of such an integration can be found in the PROPOLIS study and SCARAMENTO model (Propolis, 2004). In these cases land-use is administrated at the detailed level of grid cells and the spatial markets are modeled at the more aggregated level of zones (in the order of several hundreds or thousand for a study region).

3.2 Analytical framework for spatial modeling

Different approaches to spatial planning are being practiced and different requirements are put on a spatial plan by different actors/interest parties. Physical planners tend to work with a top-down aggregate vision for a particular region (build-up/green ratio's, corridors, …). In sectoral analyses such as water and transport there is a major interest in reliable disaggregated projections of the demand for infrastructure. In reality spatial development takes place through an interplay of several market systems.
A way should be found to merge those different interests and reflect those contributions in the final plan; an analytical approach which addresses interests at different scale levels and includes supply-demand interactions is required. Such framework is elaborated below: in a first step transportation in interaction with spatial modeling is described, subsequently water related aspects are added.

Table 1 presents, for the transport-space sectors, a classification of policies by the level of spatial scale in the analysis, the involved markets/processes and potential instruments and effects. The classification in the table serves in particular to illustrate the need to identify the levels of spatial scale in the analysis. It furthermore demonstrates that each analytical instrument produces only a fraction of the output needed to evaluate policies and a policy evaluation uses therefore normally information from various analytical instruments.

An analytical framework to assess these effects thus comprises many different models operating at different scale levels. The integration of these models is normally quite poor and at best only much aggregated information is exchanged. Each of the models simulates only a part of the system and addresses all other parts as exogenous developments. Another simplification is that the analytical instruments often do not identify individual objects or parcels of land but geographical zone or road links. An example of such simplified representation is the geographic zoning in the regional economic models, these models normally address land-use and transport at a much aggregated level of a region and a network is often absent. It is unclear to what extent projections of these models are affected by such aggregation.

From the perspective of an overall analytical framework and policymaking process a better integration of these instruments is a real challenge. Integration is this context does not mean the construction of one instrument including an in depth modeling of all markets and effects. These types of modeling efforts, attempting to model a broad set of issues in depth, are a well-known receipt for "disastrous" model development. Integration in this context refers to the linking of the "existing" instruments in a realistic way and at the same time improving consistency, exchanging data at a more detailed level, and taking advantage of the strengths of each of the instruments. A clear understanding of the relationships and interactions, including spatial scale level of interaction and time dynamics, between the various parts of the system, is crucial information to integrate models which address parts of the system.

Table 1: Overview of transport-space analyses at different levels

Transport & Spatial Policies	Level of analysis	Markets/processes	Tools	Effects
High Speed train Airport Zoning Land-use plans Densities Road Public transport Noise regulations Air regulations	National/regional	Labor Market Transport market	Macro economic models Regional economic models	GDP Income (Un)-Employment
	Regional/Zonal	Housing market Real estate market Land Market Transport market	LUTI models Sector models	Vacancy/shortage housing Vacancy/shortage office space Green/brown field
	Micro level	Demolition/construction Change of land-use parcel	Micro models (e.g. cellular automata)	Noise pollution Air Pollution

Recent progress, in addressing the different levels and market processes, has been made with the realization of TIGRIS.XL:

> the modeling explicitly considers links with a specific transportation model (the national transportation model) and a regional economic assessment module (still to be implemented). For this it uses the 40 Corop regions, frequently used in planning studies in The Netherlands, and the 1308 zones used by the national transport model. This allows to address markets (labor, housing). The Corop level is an appropriate level to analyze macro/regional economic impacts. For the zones a balance is kept of stocks of different land uses. This forms a link to the micro-scale level. Scenario's from a national scale form an input to the model.

Several types of interactions with the different levels can be considered for the water sector. Water resources development is more closely (than transport) related to the physical characteristics of terrain, type of land use and topography. Fairly detailed physical conditions are important as an input to water resources analyses and impact evaluation (damages, environmental quality). Water resources form to a lesser extend than transport a direct factor in economic activities (except irrigation), but provide basic needs such as sufficient water supply and drainage. Interactions with spatial development occur predominantly in the form of reservations for space. Such reservations create opportunity costs for other uses of space.
Water resources development exhibits very large economics of scale, and costs are strongly dependant on the spatial outlay of the system. This makes the costs for water resources development highly sensitive to regional/spatial development.

Considering similar spatial levels as in Table 1 the interactions with the water sector can be summarized as in Table 2.

Table 2: Overview of water-space analyses at different levels

Water/space relationship	Level of analysis		tools	effects
	water	space		
Water space claims; effects on other space users	micro	regional	Spatial model followed by regional impacts assessment	Opportunity costs
Terrain conditions – attractivity for settlement	micro	Micro/regional	Mapping (e.g. land development costs)	Attractivity: forms input to spatial model
Demand projections (water supply, environmental quality	micro	micro	Demand projection models	Basic input for the design of water systems
Spatial impact(damage, environmental)	micro	micro	GIS type impact maps (e.g. flood damage)	Provides spatially determined impacts from interventions on water systems
Risk based planning	micro	Micro/regional	Risk zoning maps	minimization of risks/reduction of costs

It can be observed that for water the level of analysis is carried out mostly at the micro level. Of particular interest is the need to make rational decisions (on the basis of opportunity costs) about the different claims on space. This will depend on the possibility to incorporate the different claims in a spatial arrangement (modeling) and determine the welfare effects.

An important target for spatial planning is to improve the projection of spatial development and consequently support the projection of the demand for infrastructure. This requires not only a prediction at the regional level but also a consistent projection at the micro level.
For orientation, the LOV (Leef Omgevings Verkenner) modeling focuses on the micro level and uses a shift and share approach at the regional level, which limits the "explaining power" at that level; a useful feature is in particular the use of policy maps which allow to add a spatially differentiated valuation of a certain feature to the overall evaluation process.
Risk based planning involves increasingly spatial implications, as the infrastructural measures become increasingly expensive, see for example Verhaeghe et al, 2005.

Each of the above relationships requires a separate adapted modeling. A variety of models, linked to the micro level (spatial information as input and for impact assessment), exist. What is largely lacking is the translation of the space requirements at micro level into a spatial modeling incorporating all land use. The spatial modeling developed for the transport-space interactions may be adapted for this purpose. Subsequent translation of spatial effects into economic/welfare effects (opportunity costs) remain a challenge also for transport-space interventions.
Based on the above overview of aspects the main water-space interactions at different levels are presented in Figure 4 : a two-way interaction between regional- and micro level can be observed, this concerns

- input of spatial requirements from the micro level to the regional level, and
- translation of market based allocations to the micro level in order to determine sufficiently detailed projections for infrastructure planning.

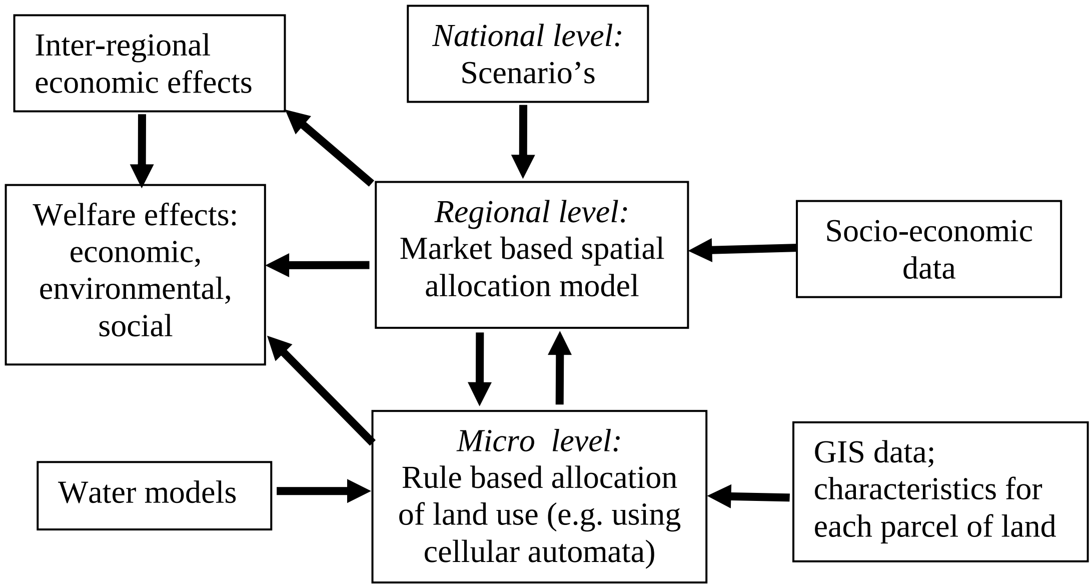

Figure 4: Water-space models, interactions and data input at different levels

3.3 Preliminary Jabotabek spatial model

Development of a spatial model for the case region (Jabotabek), including demand for settlement and the associated markets (labor, housing) is hampered by available data. An approach in several steps is followed: at present a modeling of the allocation of space has been realized; attractivity, based on a multi-attribute score, is used to allocate space. This model is briefly discussed below.

Analysis of land use evolves about development and allocation of stocks of different kinds of land to various functions (housing, industry, etc). Attributes of the site itself as well as spatial relationships (e.g. accessibility) characterize the particular site. In general both kinds of attributes contribute to a composite attractivity of the site, determining its potential for development. Different potentials will be considered for different functions.

Simulation of the spatially differentiated balance of the supply of different types of land and projected demand for different functions forms an essential element in land-use planning. Measures (spatial plans, regulations, infrastructure) influencing the supply and demand form a necessary input to realize an optimum potential. In particular demand management refers to the variety of infrastructural (e.g. roads) and regulatory measures which influence the attractivity of the spatial units and/or restrict the use for particular functions.

The general modeling concept is presented in Figure 5: two main parts are differentiated, viz. projection of the total need for space in the particular region over a selected time period, based on its internal socio-economic characteristics and in relation to the surrounding region(s), and a simulation of the allocation of this total requirement to different parts within the region.

The modeling of the total projection has followed a fairly standard approach, containing three sectors: population, housing and business; those are linked to each other through various (feedback) relationships. The population sector as well as the housing sector differentiates a low and upper income group. The business sector differentiates between industry and commerce.

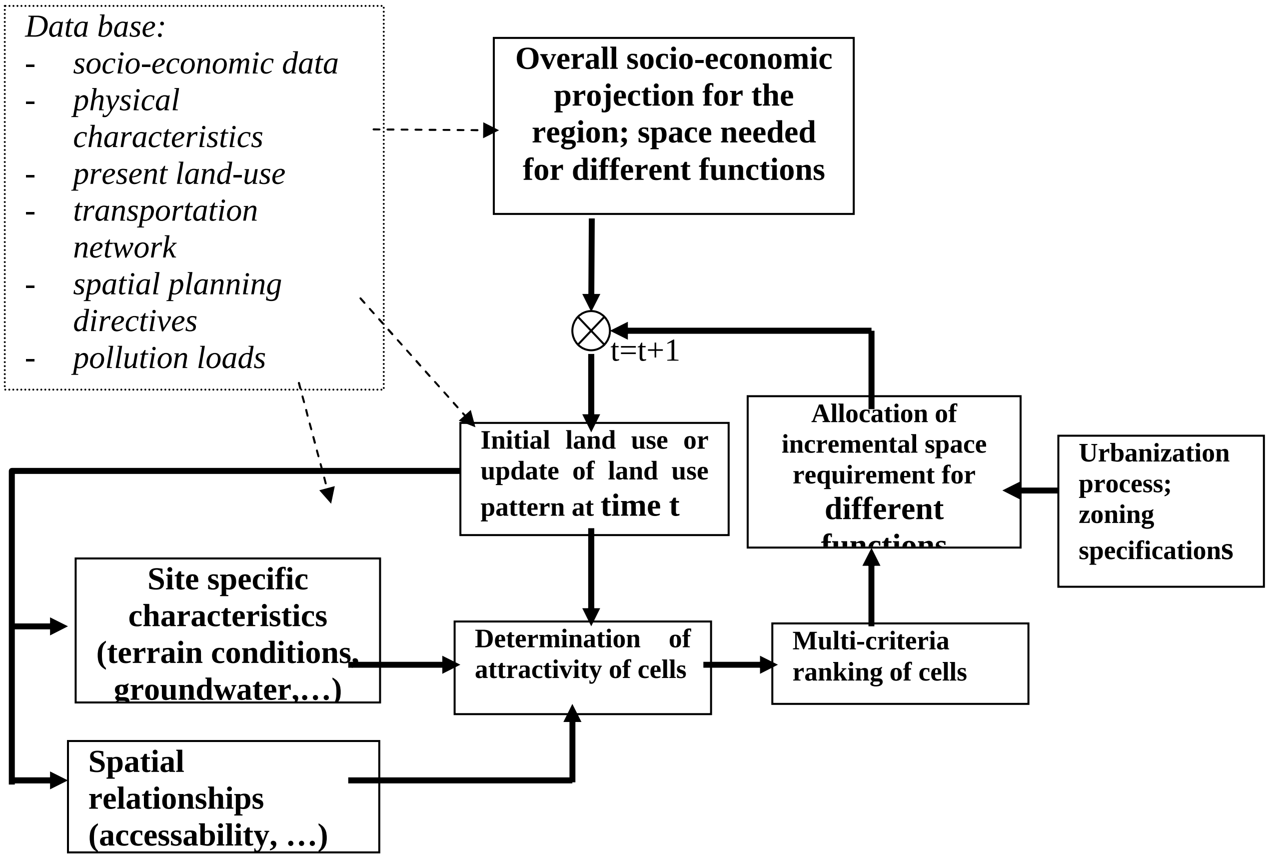

Figure 5: Allocation of space : main components in the preliminary modeling

The dynamic allocation within the region is based on an inventory of available space (land-use) and a determination of overall attractivity for the different land parcels or cells of the region. 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 preferences of consumers, determining the attractiveness for settlement. The total increment in space requirement for a particular simulation interval is allocated proportional to this ranking.

Figure 6 illustrates the results of application of such model to the region surrounding Jakarta (Jabotabek). The smallest administrative – Kecamatan - level was used as elementary spatial unit for which stocks of available and allocated land were computed.

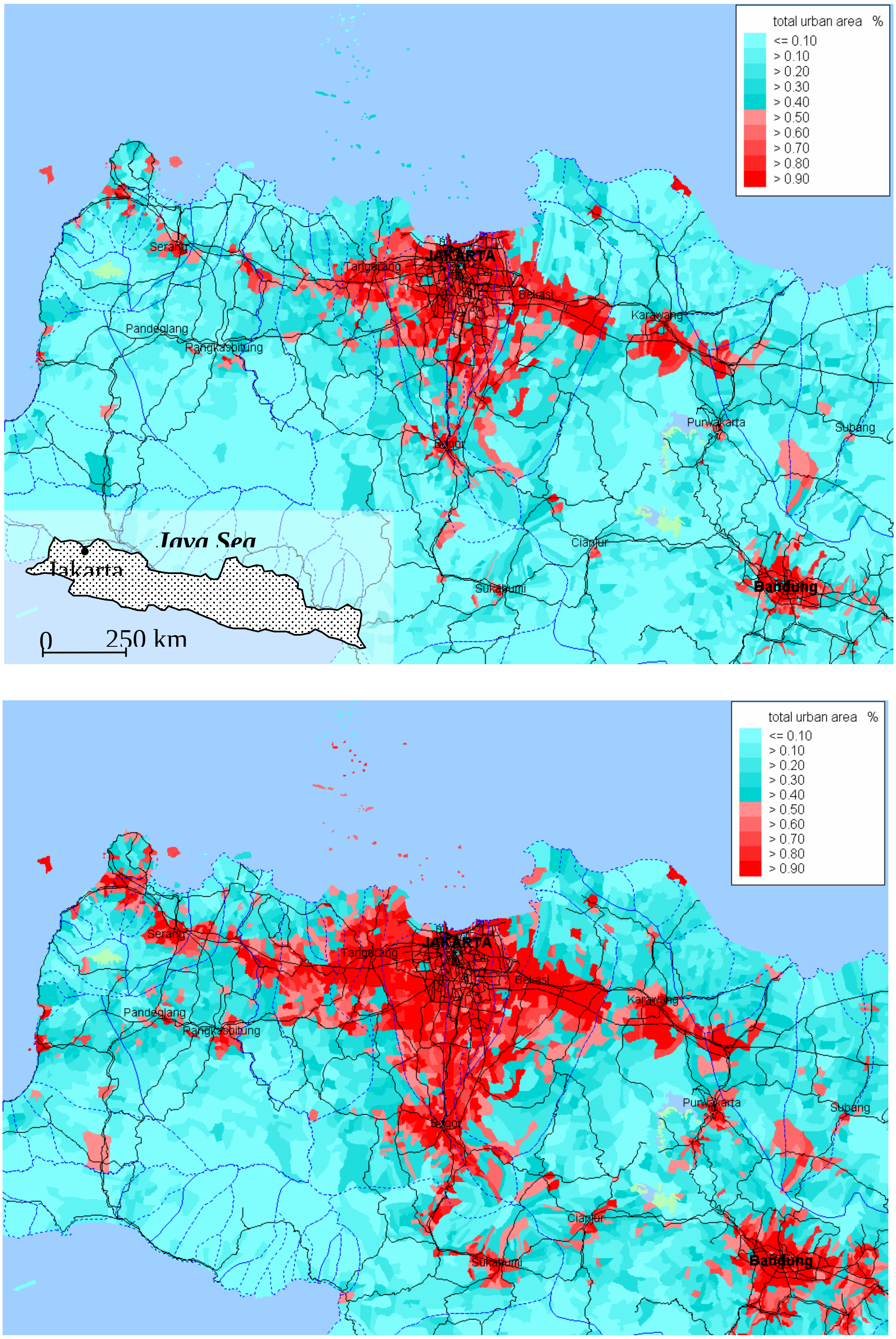

Figure 6: Urban expansion for the Jabotabek region (2000-2025)

In a next step the weights in the multi-criteria score for attractivity are being calibrated using observed changes in settlement. Subsequently an attempt will be made to include aspects of the labor and housing market using available data.

4. Strategic planning for the different infra sectors

4.1 Mobility

In view of the expected further drastic changes in the Jabotabek region and the large infrastructure investments which will be required in the mid and long term future, there is a strong need to make effective strategic choices in settlement and transport infrastructure development. Accessibility is a main factor in the preferences for settlement ; congestion has

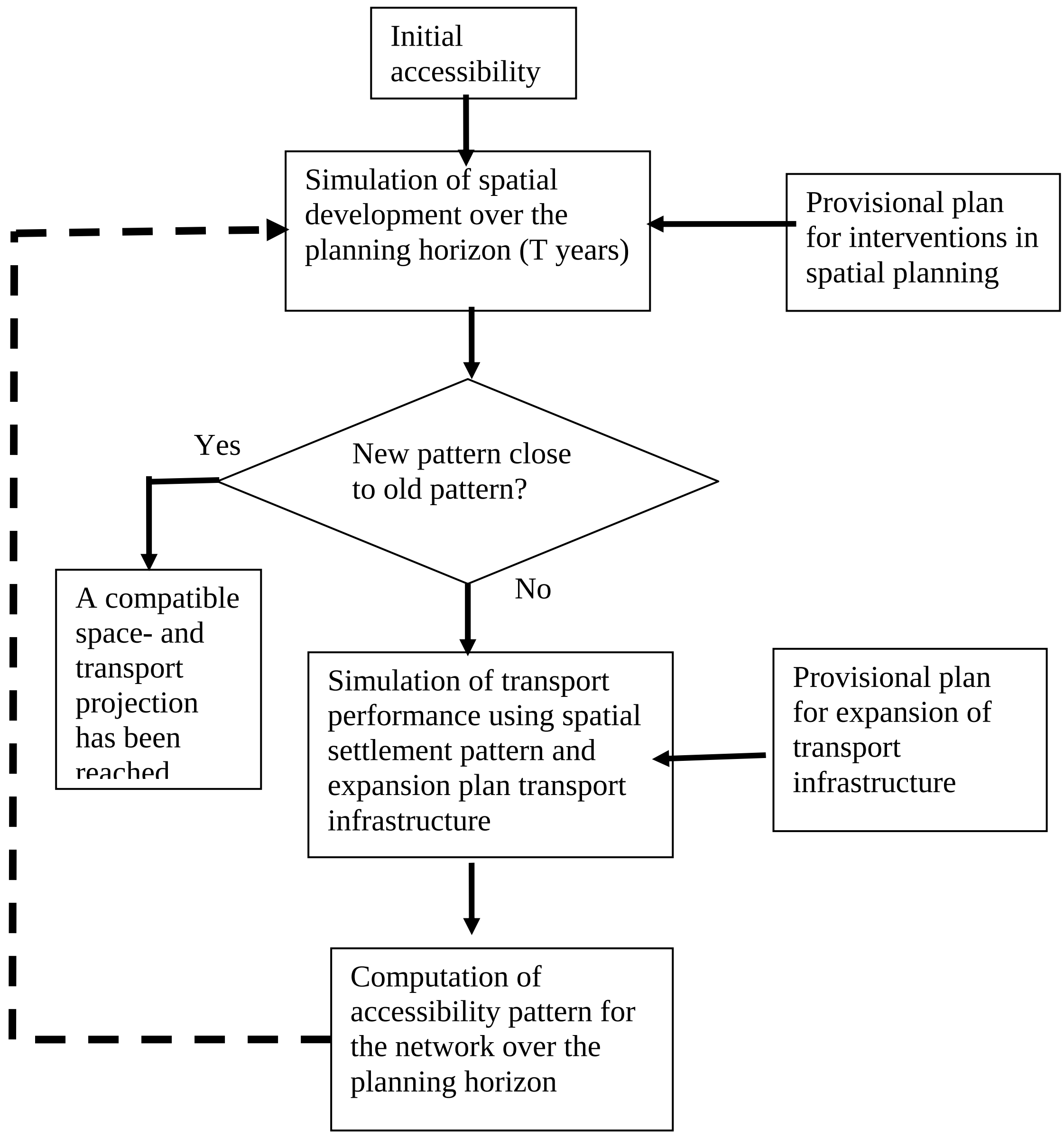

Figure 7: Computational framework for an interactive space-transport simulation

reached high levels and the demand for mobility (trips per person) is likely to rise in the future.
The settlement pattern and transport possibilities jointly determine the mobility performance. The level of congestion, for example in terms of total actual travel time compared to a free flow travel time, can be used as a performance indicator for the joint space-transport system. This can be used to estimate an indicative economic value using time value estimates.

For a given spatial configuration and transport network configuration the mobility performance can be determined. However because of the strong influence of the spatial configuration (as generated by the spatial model) and the transport facilities an interactive simulation of spatial development and the transport facilities may be necessary. Figure 7 presents a flow diagram of such interactive simulation of space and transport. Such simulation maybe carried out first to determine a spatial configuration based on space-transport, which is subsequently used in the impact evaluation for the other sectors (flood risk, water supply, emissions).

4.2 Water supply

There is large variation in demand and supply sources for the case region. Groundwater is the preferred source of supply where it is available; groundwater availability varies strongly for the different parts of the region, it is conditioned by salinity (coastal areas) and geological conditions. Figure 8 sketches major clusters of water demand based on a particular settlement pattern and surface water sources and associate conveyance systems (Ministry of Public Works (MPW), 1994). The cost for extra water supply, from surface water, will strongly vary for different parts of the regions : the cost for extra supply from the existing Citarum system in the eastern part of the region will be much less expensive than from the new sources to the

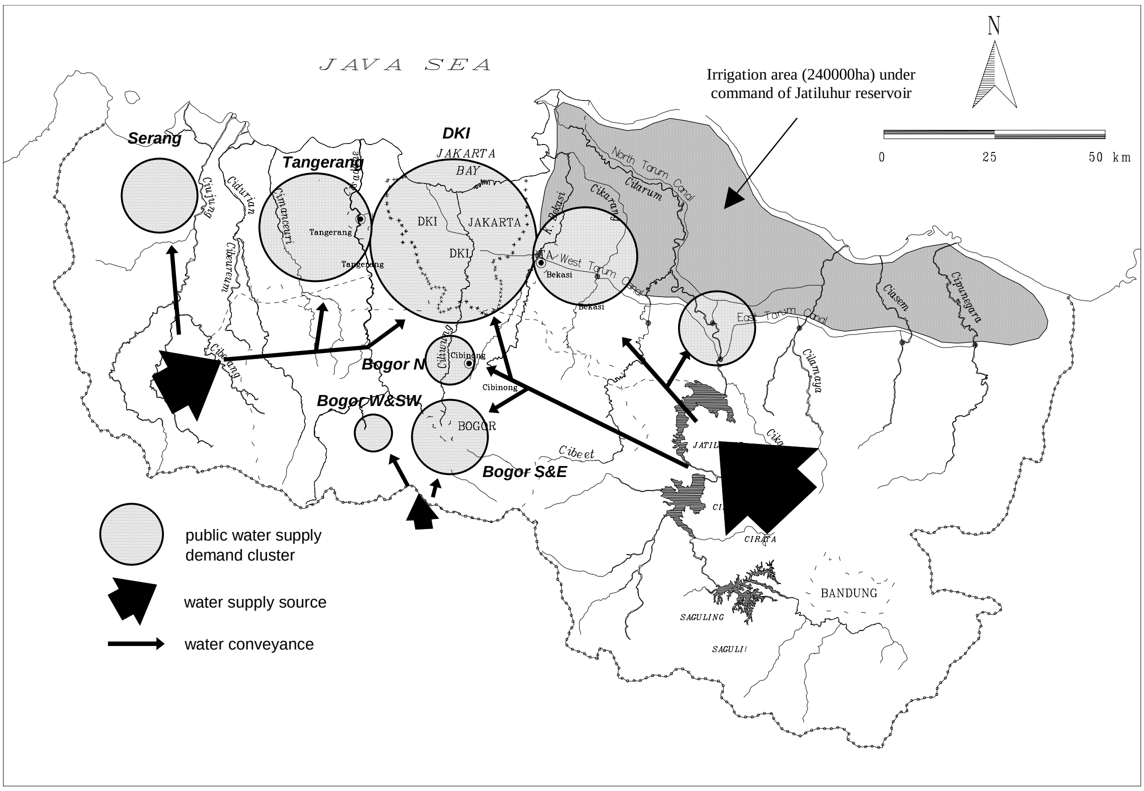

Figure 8: Water demand clusters and surface water supply sources for a particular spatial settlement pattern

west, and the supply to the middle of the region (little supply possibilities) will be more expensive due to the long conveyance lines. Different settlement patterns will result in different costs for provision of water supply; inversely different settlement patterns will require development of different sources.
The impact assessment module will require a translation of different settlement patterns in spatially differentiated water requirements, matching of supply and demand, and estimation of water supply investment costs.

4.3 Environmental quality - Emissions

The Jabotabek region faces severe water quality problems, in particular in the downstream parts, because of the dense human settlement and associated pollutant emissions. Emissions are particularly extensive, and strongly accumulate, along the central Bogor-Jakarta axis of the region. Emissions are projected to further increase in the future with a further increase in settlement, and depend strongly on the spatial planning for the region and regulations to control these emissions. Figure 9 illustrates the projected increases in pollutant concentrations at a location on the Ciliwung (at Depok) and Cisadane (at Serpong) rivers (MPW, 1994). The projection for the future indicates a remaining virgin flow during the dry period of about 10 to 20%.

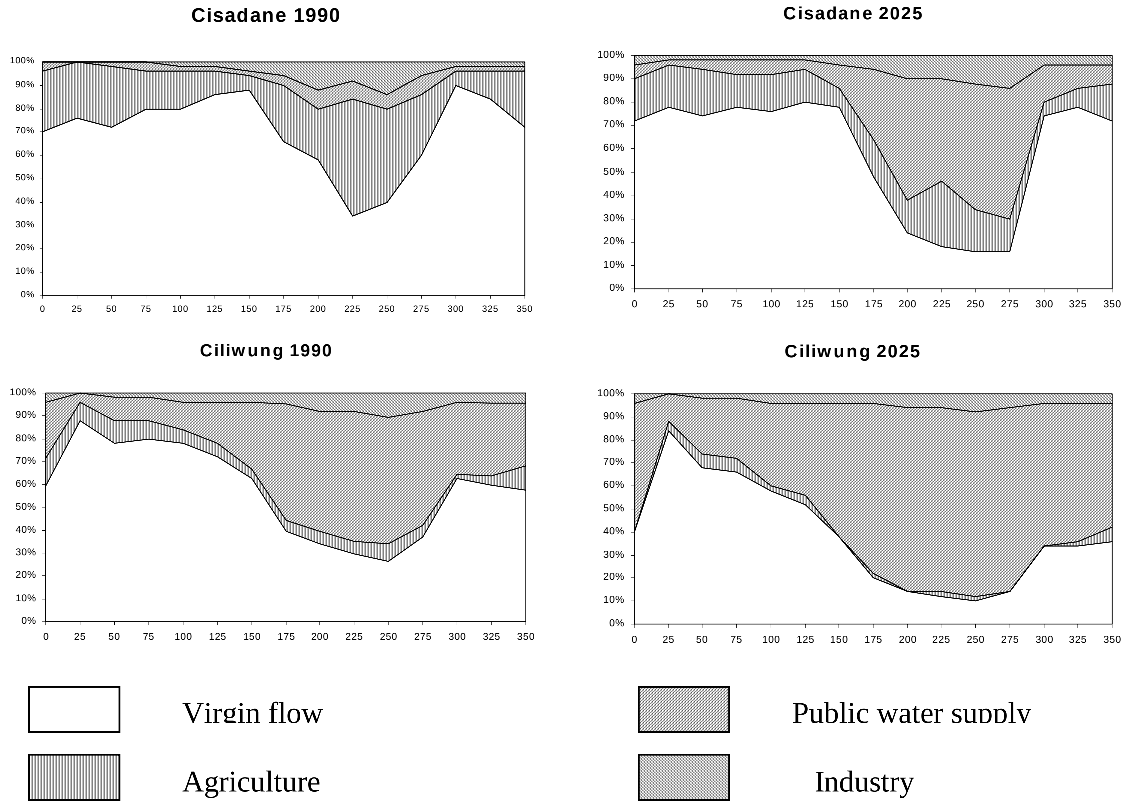

Figure 9: Projected pollutant concentrations (type of runoff as fraction of total) for Cisadane and Ciliwung

A considerable difference can be observed between the pollutant concentrations for the two rivers. For the particular projected settlement pattern the Ciliwung has much more settlement, no drinking water extraction is at present considered for the mid- and downstream section of this river. An increase in settlement is also projected for the Cisadane basin, the particular future composition will make the river water unsuitable for drinking water preparation. This will have particularly grave consequences for the current drinking water extraction for Jakarta at Serpong.

Impact assessment will involve derivation of emissions based on economic activities and empirical emission rates, and tracing of those pollutant substances through the drainage system. Description of the distribution of the pollutant substances and comparison with standards associated with the functions of the different water bodies allows estimating the surplus of pollutants; such surplus is indicative for the pressure of emissions on the environment and its intended use, and indicative for the need for sanitation and its cost.

4.4 Flood risk

Flood risk has a strong inter-relationship with land-use because it is the combination of the spatial arrangement of settlement and economic activities and the physical hazards, which determine risk. Such risk will usually strongly vary for different (sub-) areas.

Javanese river basins, in particular the downstream parts, have become increasingly sensitive to flooding (Verhaeghe et al, 2005). Increased population pressure has induced urbanization and watershed degradation, reducing natural retention for storm water run-off, and causing encroachment on the space available to rivers and drainage channels. Higher population density and economic activity have increased numbers of casualties and value of losses. High intensity local rainfall, versus the on average poor internal drainage of urbanized areas, has become a strong risk factor for flooding, next to the traditional river dependent flood risk based on highly peaked flood waves. The Jabotabek region with its high rate of increase in settlement can be considered a most typical illustration of such developments.
The traditional flood defense approach, focusing on infrastructure development, has become costly and may in several cases have become economically infeasible. An integrated flood management is required in which structural and non-structural measures are combined and balanced to provide an optimal solution for an efficient protection at minimal costs.
Risk based planning, combining different flood management measures, based on a systematic analysis of the risks of flooding as well as possibilities for minimizing and spreading of these risks, forms the heart of an integrated flood management.
Risk based planning should include appropriate trade-offs between risks, infrastructure costs and spatial alternatives (and their opportunity costs). For this, assessments at micro level should be complemented with regional allocations of space following the framework in Figure 4.

Impact assessment will require a fairly detailed mapping of topography and inventory of damage prone objects, and an assessment of excess water for the two causes of flooding: rainfall and river flow flood peaks, and their frequency of occurrence; excess water is determined by the size of the hydrologic event affecting a certain (sub-) area and the drainage condition of this (sub-) area; confrontation of excess water conditions with topographical condition results in flood levels; application of typical damage relationships for types of objects results in damage assessment for the particular excess condition; elaboration for the

different possible hydrologic events and application of their probability of occurrence results in an expected damage. A combination of static water balance and dynamic flow computations can be used to represent the excess water condition (Verhaeghe, 1988)
Different spatial patterns cause a different presence of damage prone objects in the flooded areas and will result in a different damage computation, the excess water conditions stay the same unless specific drainage measures are taken to improve drainage.

5. Observations & conclusions

Infrastructure development for a high growth, dynamic region such as Jabotabek, Indonesia, requires huge investments in basic infrastructure. Two major sectors for infrastructure development are water (drainage, sanitation, water supply) and mobility (transport).
The effectiveness of investment in infrastructure is highly sensitive to the settlement pattern. The rapid development of the Jabotabek region over the last 20 years shows a strong need to include the settlement patterns as an explicit design variable in the design of future infrastructure.

A modeling framework is being worked out to support such integrated planning. The total analytical framework comprising modeling modules, data bases, and user interfaces will provide a platform to analyze, at a strategic level, packages of policies/measures in infrastructure development.
Generation of alternative spatial configurations, as input to impact assessments for water and mobility forms a most important component in the modeling framework. Modeling of spatial development should take into account as much as possible the demand for settlement. In a spatial modeling for The Netherlands (Tigris.xl) the markets for housing and labor have been included to represent this demand. In The Netherlands elaborate data are available to estimate consumer preferences in those markets. For the Jabotabek case region less data are available; for this case it is attempted to estimate preferences at a more aggregate level using a multi-criteria approach. The weights are estimated from observed changes in the region.

There is considerable modeling experience for the different impact categories, they should however be updated/adapted to consider explicitly a variable spatial pattern; impact evaluation of infrastructure needs a fairly detailed spatial specification in terms of networks and physical/terrain conditions; this leads to very large data bases and the requirement for adequate tools to create and use them in the modeling.

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