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## **Integrated planning of water and land-use**

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### **Abstract:**

The role of water in spatial planning has received increasing attention in recent years. It was, for example, one of the leading motives in the preparation of the latest National Spatial Planning Note for The Netherlands. For the preparation of such spatial plans, and to support the associated policy analysis, there is a need to fully identify and characterize the interactions between the water sector and spatial planning and establish the process for making consistent joint projections for the water sector and land-use. This should account for spatial claims from the water sector, balance those claims with claims from other sectors, and feed back spatial constraints and opportunities. Land-use markets and government policies (translated e.g. in spatial reservations) form an important input in this balance.

Modeling is indispensable to keep track of spatial characteristics and trace changes; a framework is proposed which includes three levels of detail, modeling of spatial allocation of functions, representation of markets, links with sector specific modeling, sufficient linkage between micro and regional level, and a link with impact assessment at macro/regional economic level as well as on micro level. This should allow to: determine opportunity costs for claims on space, prepare reliable projections for infrastructure development, and investigate alternative configurations of spatial- and sectoral development in order to minimize costs and realize economies of scale .

The framework is illustrated with three present day planning problems involving a mix of water-space-transport aspects.

**Keywords:** integrated planning, spatial modeling, land-use, analysis framework

## **1. Water and land use interactions**

Water and land-use are presently high on the political and scientific agenda in The Netherlands. Recently the 5<sup>th</sup> “National policy note for spatial planning”, the 4<sup>th</sup> “National note on water management”, and the special report of the “Commission on water management for the 21<sup>st</sup> century”, concluded that a much stronger integration of both policy disciplines is required.

Historically water has strongly steered the spatial development of The Netherlands. With a strong increase in population and economic activities in the last century, space has become a scarce commodity and attention focused on minimizing the space for water related functions (e.g. reducing retention area and increase dikes). Recently, due to the emergence of some physical factors such as rising sea level, land subsidence, and dropping groundwater levels, the approach of constraining water to facilitate (other) spatial development is no longer considered the best approach. A more pronounced role for water as a steering factor in spatial development is now considered a more optimal direction.

The main themes for water as elaborated in the 4<sup>th</sup> “National policy note on water management” are security, drought alleviation, emission control, sanitation of polluted water bottoms, and water excess. The total claim on space associated with these themes is about 500,000 ha. This constitutes a strong increase over the present 765,000 ha of (allocated) space claims by the water sector.

It is further foreseen that over the coming 30 years about 200,000 ha will be necessary to absorb extra space for settlement and infrastructure. It will therefore be a challenge to resolve the competing claims on space.

A rational basis, using quantified information, will be required to prepare for decision making. This means a quantification of interests and impacts. An essential role in this quantification will be played by a spatial modeling by which shifts and substitutions in the use of space and associated socio-economic impacts can be traced associated with a particular alternative in water- and spatial plans.

Up to now spatial – or land use models have been developed primarily in relation to transport; accessibility is key factor in the economic activity pattern and spatial development of a particular region.

In the following sections of this paper a review is first made of existing land-use models (section 2). In a subsequent section the water-land use interactions are reviewed and an analytical framework is proposed to support integrated water-land use planning (and other sectors). The application of this framework to several present day planning challenges is reviewed in the next section. This is followed by observations and conclusions.

## **2. 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 representing 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 labour 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 MarketA 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<sup>1</sup> system are:
  - Land
  - Objects
  - Activities

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<sup>1</sup> 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 1 illustrates the functional design of TIGRIS.XL.

In figure 1, 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 loops between demand and supply are available. 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.

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 strengthen 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.

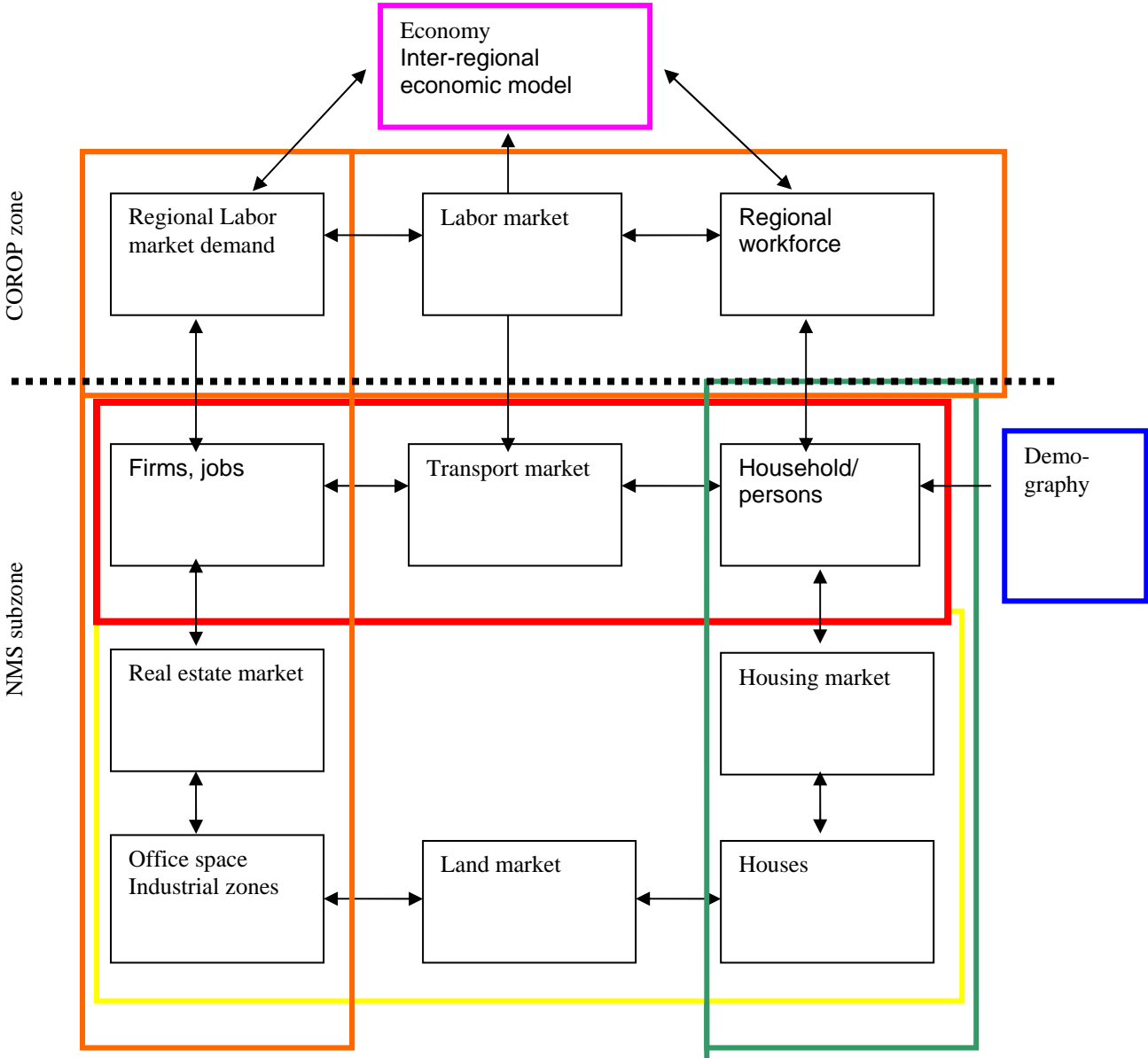


Figure 1: Components in the functional design of TIGRIS.XL

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. Analytical framework**

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 very 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 very 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 in 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*

<b>Transport &amp; Spatial Policies</b>	<b>Level of analysis</b>	<b>Markets/processes</b>	<b>Tools</b>	<b>Effects</b>
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
Densities Road Public transport Noise regulations Air regulations	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
Noise regulations Air regulations	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 – attractiveness 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 for the near future will be 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.

Physical terrain conditions, determining the attractiveness for settlement, vary widely for different areas. Figure 2 illustrates for example the cost for land preparation in The Netherlands.

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

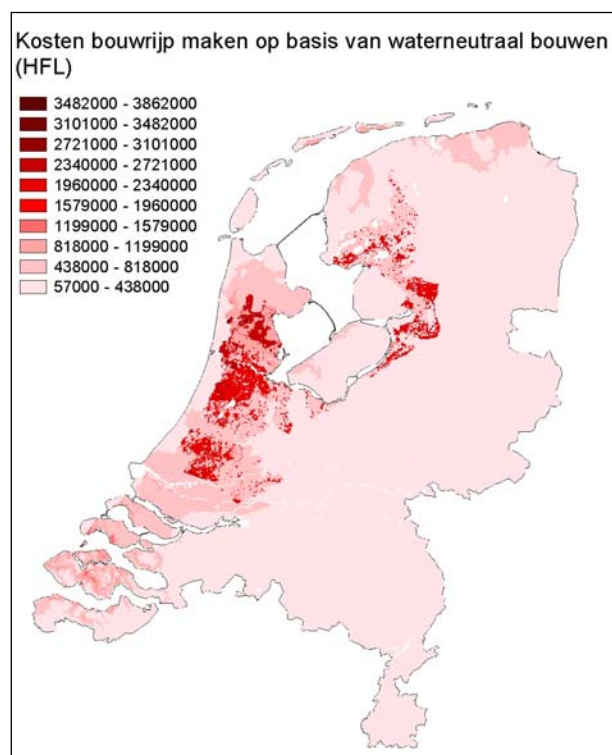


Figure 2: Costs for land preparation on the basis of “water neutral’ settlement



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 gets increasingly spatial implications as the infrastructural measures become increasingly expensive, see section 4.

Each of the above relationships require a separate adapted modeling. A variety of models exist linked to the micro level (spatial information as input and for impact assessment). 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) remains 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 3.

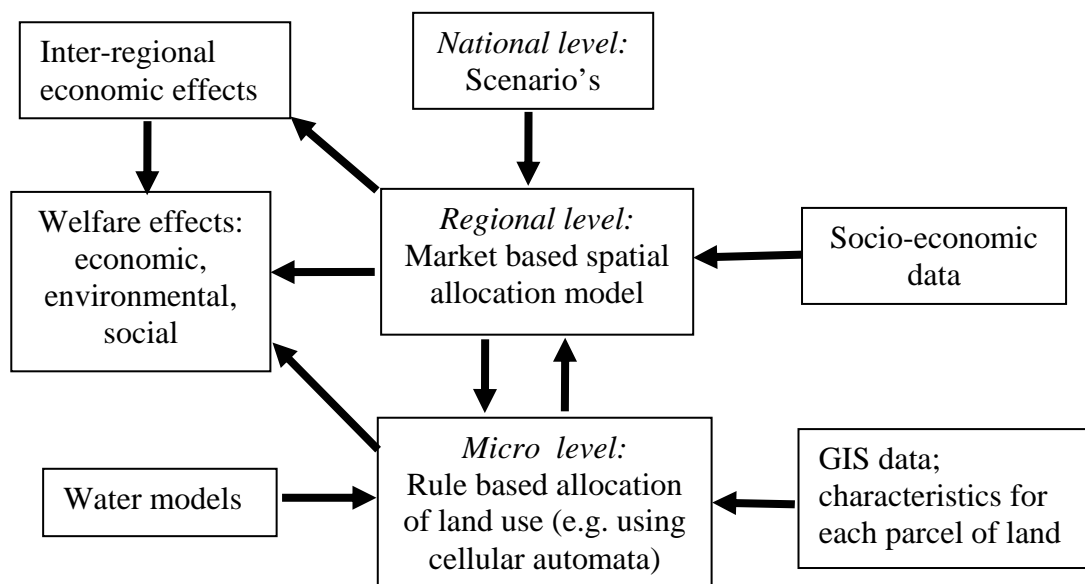


Figure 3: Water-space models, interactions and data input at different levels

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.

The framework is further elaborated using three cases in the following section.

#### 4. Potential applications of the framework

Three planning examples in which space, water and transport strongly interact are described below. Application of the proposed framework is indicated.

### ***Water claims on space in the 5<sup>th</sup> Dutch national policy note on spatial planning***

Large claims on space associated with challenges in water management have been discussed in section 1. In a situation with strong competition for land this leads to opportunity costs associated with other land uses.

Applying the framework, such claims, identified at the micro scale level, should form an input to a space allocation modeling at the regional level, together with existing land/use and identified claims from other sectors. Simulations with different proportions of allocation of land to the various sectors should enable to determine (various levels of) opportunity costs.

As indicated in section 2 and 3 the regional level is an appropriate level to represent and combine a variety of processes determining land/use, such as supply-demand relationships, accessibility, attractiveness (costs, environmental quality, ...), policy maps, etc.

Subsequent to the spatial modeling an overall assessment of alternative water & space plans comprising information at the macro/regional – and at micro scale, need to be prepared. This involves a wide range of indicators (for an overview see Propolis, 2004) which can be broadly categorized into “economic”, “environmental”, and “social”.

It remains a challenge to prepare a representative evaluation involving a variety of indicators with spatially differentiated impacts, in particular the macro economic effects are difficult to quantify (see also section 2). The evaluation should further include regional distribution effects (e.g. on labor market) and should differentiate short and long term effects. A practical level of detail needs to be found to present all of this information in order to differentiate alternative water-space plans. A comprehensive evaluation is being addressed in ongoing research at Delft University of Technology.

### ***Space for the river – risk based planning***

Flood risk has a strong inter-relationship with land-use. The spatial arrangement of settlement and economic activities, determines risk and in turn the level of infrastructure investment needed to reach a sufficient protection level.

Two main types of (flood related) risks can be differentiated in The Netherlands: risk from flooding from the sea and from rivers. Figure 4 indicates the large part of The Netherlands affected by those risks. A large variation in economic and personal risk can be observed in Figure 5. Optimization of spatial planning with the aim to reduce risk can have a large effect on protection investment costs. Costs for flood protection through improved



Figure 4: Flood prone areas in The Netherlands – options for flood diversion

infrastructure have been rising and alternative means to control floods such as flood diversion and subsequent retention are being considered. Such options are indicated in Figure 4.

Spatial options to help minimize investment costs have become essential in countries such as Indonesia: for some river basins (Verhaeghe et al, 2005), due to conditions, infrastructure interventions have become economically infeasible. Spreading of risks and use of retention based on an integration of flood risk planning/management in spatial plans has become a most important non-infrastructure measure.

Risk based planning should therefore 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 proposed framework

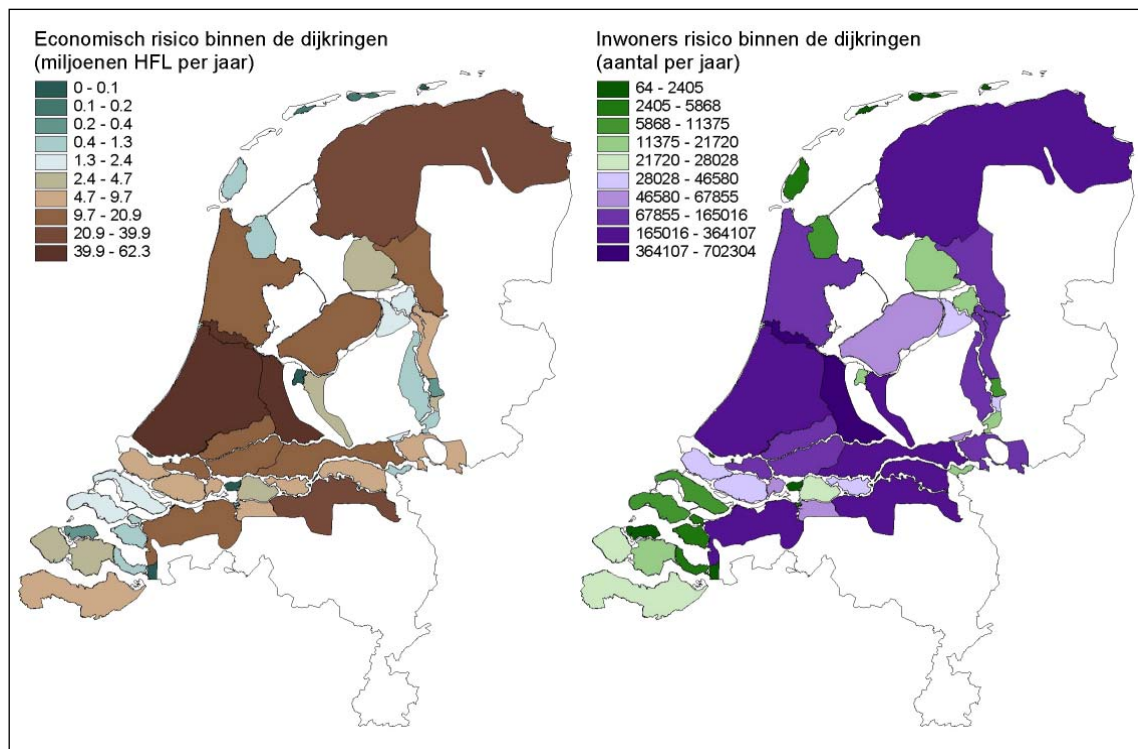


Figure 5: Variation in economic and personal (flood) risk in The Netherlands

### ***Transport-space-water interactions in the Jabotabek region (Java)***

This application focuses on the influences of spatial development on the water systems; also transportation/accessibility has a very strong interaction with spatial development.

Because of rapid industrialization and development of the service sector, the current population of 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. There appears to exist a very strong latent demand for economic opportunity/activity waiting for a final trigger through infrastructure development. Figure 6 illustrates the further anticipated

increase (Sanders et al, 1998) in urbanized activity in the region. This will further intensify the present problems as described below.

The strong urbanization has strong effects on drainage/flooding of the region. The following points can be mentioned

- increased urbanization (from 5 to 20 % over the last 20 years) in the hilly upstream part has caused a strong increase in flood peaks: about double for the same hydrological event (reference!)
- drainage in the downstream region has been affected by a set of processes related to the settlement, such are
  - o reduced retention: strong increase in impervious area and in particular reclamation of natural depression areas
  - o land subsidence due to over-abstraction of groundwater
  - o insufficient upgrading of capacity of drainage facilities in the older urban sections located downstream of extensive new urban development
  - o encroachment on space available to river channels
  - o insufficient maintenance to keep up with sedimentation
  - o insufficient open/green space (only 5 %)

All of this resulted in a strong change in flooding: twenty years ago flooding in Jakarta and surroundings was largely limited to occasional flooding close to the rivers associated with high river flow. The above processes have 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 a local drainage problem. 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 of flooding of the rivers was negligible.

The cost for infrastructure development to remediate a certain problem situation will usually be strongly different for alternatives with a different spatial concept; e.g. a diversion tunnel at Bogor (point infrastructure) to divert high flood peaks will cost about 200 million US\$ while changing the run-off properties through an implementation of specific building codes in the upper catchment and an upstream/downstream financial cooperation, can achieve the same effect with an estimated investment of 50 million US\$.

An effective and sustainable solution to the sanitation/environmental problems will require a similar distributed approach.

In summary: land use changes over the last 20 years (and the lack of compensating/controlling measures) have completely changed water systems and the flooding pattern.

Similar drastic changes can be observed in the concentration/accumulation of emissions.

The costs to remediate the present situation are huge and action to prevent further escalation in the future is urgently required. A satisfactory/affordable solution will require interventions in spatial development and associated regulation.

It can be concluded for the Jabotabek region that the proposed framework can cover the driving forces and inter-relationships between spatial development and the water- and transport sectors, the labor and housing market, and the claims on limited space. Such framework, implemented with a sufficient data base and institutional backing, could strongly support important strategic decision making for development of this region.

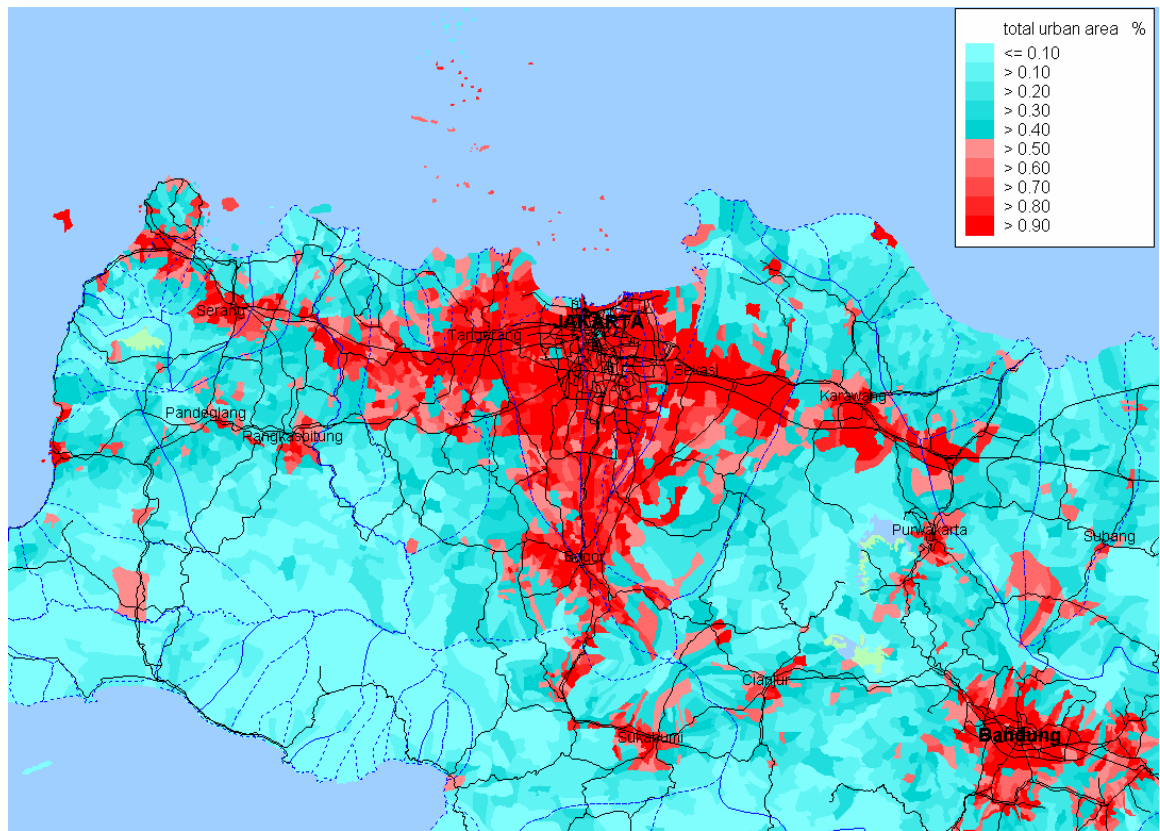
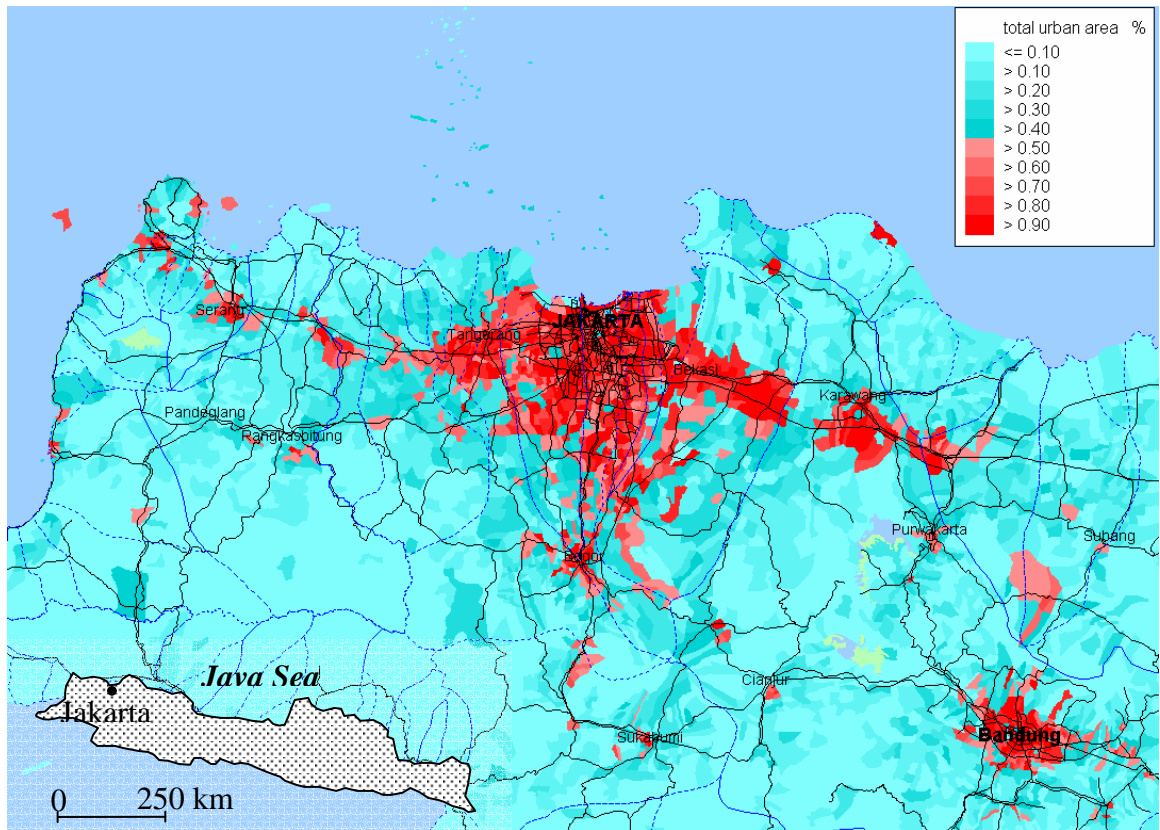


Figure 6: Urban expansion for the Jabotabek region (2000-2025)

## 5. Observations & conclusions

A framework is proposed to deal with integrated planning of land use in combination with water and other sectors (such as transport). This includes three levels of detail, modeling of spatial allocation of functions, representation of markets, links with sector specific modeling, sufficient linkage between micro and regional level, and a link with impact assessment at macro/regional economic level as well as on micro level.

This should allow to

- determine opportunity costs for claims on space,
- prepare reliable projections for infrastructure development, and
- investigate alternative configurations of spatial- and sectoral development in order to minimize costs and realize economies of scale .

For The Netherlands, following from several national policy notes, there appears an immediate need to determine opportunity costs associated with the large claims on space by the water sector. Modeling of spatial allocation will be a necessary step to determine those, followed by impact assessment both at the macro/regional level and at micro level.

For modeling of spatial allocation of functions, convenient use could be made of progress made in the analysis of the integration of the transport- and spatial planning sectors.

The interactions between the space- and water sector would seem to be more sensitive in humid tropical conditions with high intensity rainfall. The ongoing very fast and extensive changes in urbanization in developing countries further intensifies problems. An integrated planning, to which the proposed framework could contribute substantially, is urgently needed.

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