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INFORMATION SYSTEM FOR COST ESTIMATION OF COMMUNAL INFRASTRUCTURE

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Abstract
As in many industrialized countries, the population of Germany is constantly getting older and smaller nowadays. These demographic changes cause adaptations of technical and social infrastructure in both quality and quantity, to ensure their aspects of economy and usability at long term. Therefore, urban development planning and municipal infrastructure planning have to work closely together. Decisions like expansion, renovation, re-dimensioning or even closing of municipal infrastructure should be based on long term strategies of urban development, in order to meet the budget of future remaining costs. For this reason, development strategies and important new projects have to be evaluated within their infrastructural running and life cycle costs.
A current research project in cooperation with a German Municipality will enable the involved planning teams to systematically integrate the consequences of demographic changes in their infrastructural projects in terms of supply quality and cost efficiency. As part of the project, this first study prepares the database of cost indicators and their drivers for municipal infrastructural project cost estimation in early project phases.

Keywords: Urban Infrastructure, Costs Planning, Demography

INTRODUCTION

As in many industrialized countries, the population of Germany is constantly getting older and smaller nowadays. These demographic changes cause adaptations of technical and social infrastructure in both quality and quantity, to ensure their aspects of economy and usability at long term. Therefore, settlement development planning and municipal infrastructure planning have to work closely together. Decisions like expansion, renovation, re-dimensioning or even closing of municipal infrastructure should be based on long term strategies of settlement development, in order to meet the budget of future remaining costs. As well as development strategies and large new projects have to be evaluated within their infrastructural running costs.
In 2009, two Institutes within the University of Stuttgart started a research project together with the City Administration of Stuttgart (Department for Urbanism and Urban Redevelopment) that will enable municipal planning teams to systematically integrate the consequences of demographic changes in their infrastructural projects in terms of supply quality and cost efficiency.

If for example urban planners have the opportunity to (re-)develop two different industrial wastelands (brownfields A and B) as well as one greenfield (C) within the city limits by installing residential wards, the tool to be developed at the end of this project will help to understand the specific financial input in the case of developing each area. These investment and occupancy costs include all necessary social and technical infrastructure by taking into account possible capacities of existing surrounding infrastructure, as long as these assets are integrated into a Geographic Information System (GIS) database. On the other hand, planners will get information on financial output from these new developments, based on e.g. real estate sales and future tax incomes.
These estimations demonstrate financial input and output of possible infrastructure investments over a timeframe up to 20 years and thus represent an adequate planning tool for variations within a single project as well as being a helpful tool for decision making when comparing two or more alternative developments. It might even allow them to fit the financial characteristics of a certain project into the complex municipal budget by finding the right schedule for project start.

The first idea of the proposed tool is based in on a series of precedent research projects in Germany [Preuß et al. 2009], [BMVBS 2011], [Planersocietät 2011]. And the aim of this study is to contribute to this special kind of research while developing a specific and localised tool ready to use together with and for our public partner.

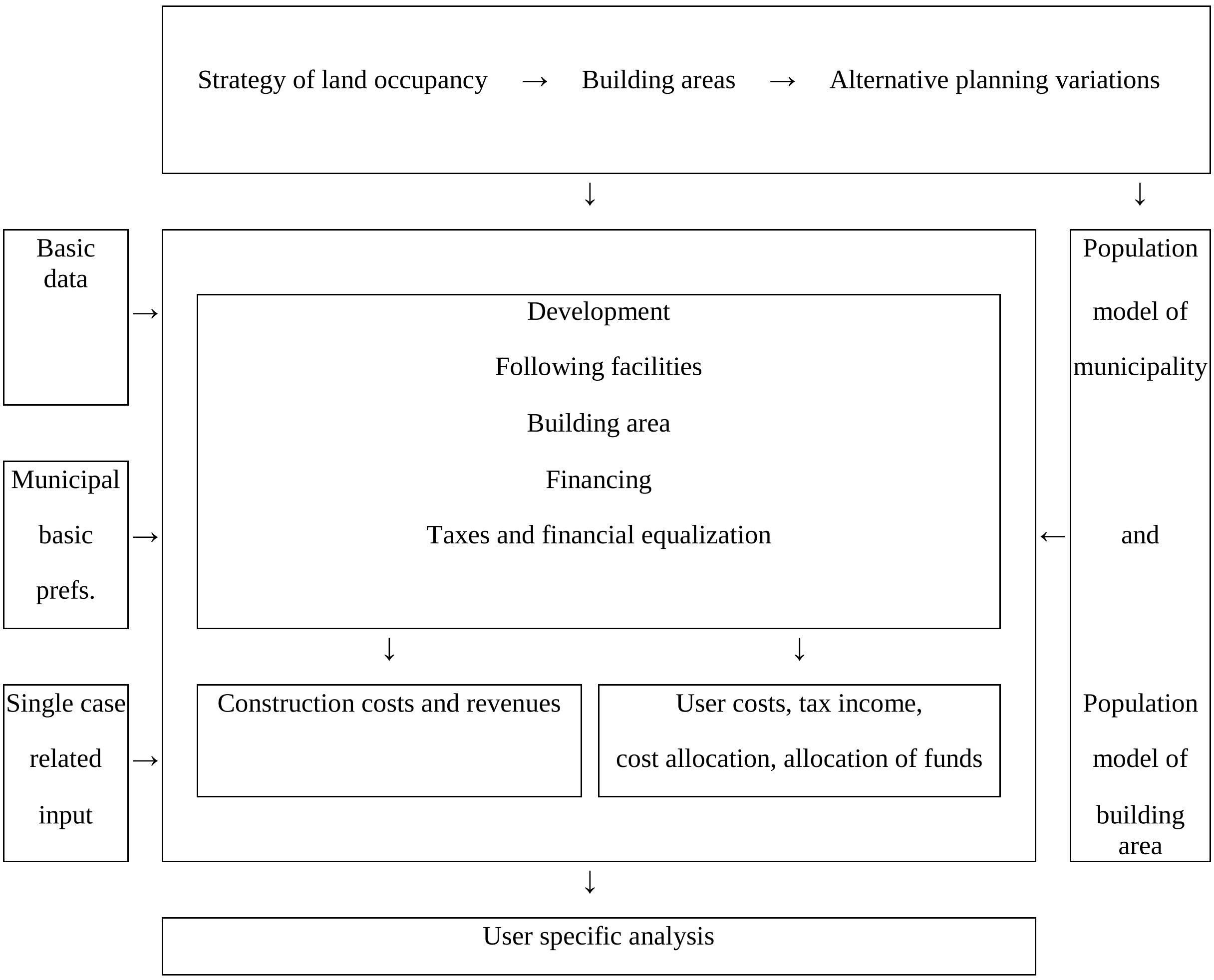

Figure 1 : *System concept and modules; example based on LEANkom [Planersocietät 2011]*

As part of the larger project (compare figure 1), this first study prepares the database of construction cost indicators as well as user cost indicators and their drivers for municipal infrastructural project cost estimation in early project phases.

PROBLEM STATEMENT

Municipal infrastructure in Germany consists mainly of two main types called social infrastructure and technical infrastructure, subdivided in their subtypes as shown in table 1.

	Type	Subtype	Example
Infrastructure	Social Infrastructure	Institution for Education	Kindergarten, School, University, etc.
		Institution for Health Care	Hospital, Rescue Institution, etc.
		Institution for Culture	Museum, Library, etc.
		Institution for Public Administration	Governmental /Municipal Administration, etc.
		Institution for Public Security	Police, Fire Department, etc.
	Technical Infrastructure	Transportation	Public Transport, Facilities for Private Transport
		Communication	Telephone, Internet, Broadcast, etc.
		Supply and Disposal	Water / Sewage, Energy, Waste, etc.

Table 1: *Types of infrastructure*

In order to enable our model to calculate construction and user cost estimations of social and technical infrastructure elements in the area to be developed, we need the necessary quantities and related cost indicators based on the same unit:

Equation 1: $Ce = q_y \times ci_y$

Ce = Cost estimation (construction costs, user costs at a single point in time)
q_y *= quantity (based on unit y)*
ci_y *= cost indicator (based on unit y)*

We will learn in a later part of the project how quantities will be defined and managed by the model, so at this stage the correct value of a quantity is taken as given. But it is important to pay attention to the unit of this quantity, as the cost indicator to be chosen has to be based on the same unit. This might be obvious in theory, but in many cases it happens to be rather difficult in real life.

As far as buildings are concerned, measurement of quantities and the related units are defined in detail in the German standard “DIN 277: Areas and volumes of buildings” [DIN 2005]. The corresponding standard “DIN 276-1: Building costs – building construction” [DIN 2008-12] defines the related cost groups for each quantity based on corresponding units for construction costs. And the standard “DIN 18960: User costs of buildings” [DIN 2008-02] defines cost groups for user costs. In addition, cost indicators for building construction costs are largely known and published, e.g. by Building Cost Information Center of German Architectural Associations [BKI 2011], and BKI just published its first user cost indicators for schools and kindergartens [Stoy et al. 2010]. All of this published data by BKI is based on above mentioned DIN standards. This means that most part of the database of cost indicators for social infrastructure types (buildings) are well defined by specific standards, already collected or published and ready to use for early phase cost estimation.

But it is obviously different in the case of technical infrastructure. Only since two years now, there exists a German standard named “DIN 276-4: Building costs – Part 4: Civil constructions” [DIN 2009], and its corresponding standard of measurements still is missing totally. And nearly every technical infrastructure project in Germany seems to be calculated in a more or less execution oriented way. In that case, some types of technical infrastructure like roads and bridges may be based on a publication called “Catalogue of Typical Specifications for Road and Bridge Construction (Standardleistungskatalog für den Straßen- und Brückenbau)” [BMVBS 2009], but its execution oriented structure makes it quite difficult to use it for early phase cost estimation. In addition, there is no known published German data yet that might be used as cost indicator, neither for construction nor for user costs of technical infrastructure types. Construction companies seem to keep the data as their secret.

Even the German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen, DGNB) – the institution of the German label for sustainability in building construction – would need a reliable database of technical infrastructure cost indicators when it comes to their new label for sustainable neighbourhood development, especially in terms of life-cycle-cost analysis. But their experts who are just about to finish the development of this special type of DGNB label, can only confirm the lack of this kind of published cost data and structure in Germany.

This means that in order to enable the model to estimate construction and user costs of technical infrastructure projects, we have to provide reliable and publicly available cost indicators as well as define the unit definitions both indicators and quantities are based on.

When looking abroad for existing similar and maybe inspiring equivalents, the Swiss CRB (Center for rationalisation in building construction) seems to have one of the most promising systems. By publishing its eBKP-T (SN 506 512) [CRB 2010a] together with eBKP-T Bezugsgrössen (unit definitions) [CRB 2010b], CRB is offering a system to structure infrastructure cost groups and have their relevant measurements clearly defined. Another quality is its accurate and detailed definition on the level of elements, often with the possibility to sum detailed elements up to a higher level of hierarchy, which can be very useful for early phase cost estimation. However, this Swiss system is quite new and cost indicator based on its new structure are still to be developed.

Concerning our project in Germany, the idea of Swiss definition quality and structure has to be transferred and integrated into the existing German landscape of standards, of course.

PREPARATION OF DATA COLLECTION

In the case of the database for estimating social infrastructure, the large quantity of cost indicators published by BKI had been chosen in addition to the corresponding values based on city administration´s own experiences. So far, both datasets had shown to be quite correlative in first tests. The only remaining tasks concerning the non BKI data are to verify the correct measurements of quantities according to DIN 277, the correct cost grouping according to DIN 276 and DIN 18960, as well as the correct application of the construction price index to projects finished in the past years.

The units for cost indicators of social infrastructure might be described in different ways:

Equation 2: ci (Institution for Education) = EUR / m² GFA (BGF)

ci = cost indicator (unit: EUR per m² of gross floor area GFA (Brutto-Grundfläche BGF))
EUR = capital (VAT excluded)
m² GFA = unit of gross floor area GFA (Brutto-Grundfläche BGF) as defined in DIN 277-1

Nearly the whole BKI cost indicator database supplies at least GFA based construction cost indicators of published projects. But in addition to this equation 2 it would also be possible in some cases it to use another approach, depending on the availability of adequate data:

Equation 3: ci (Institution for Education) = EUR / c

ci = cost indicator (unit: EUR per capita of children visiting this type of institution for education, e.g. kindergarten, school, etc.)
EUR = capital (VAT excluded)
c = unit of the number of children visiting this type of institution in the planned area (possible capacities or existing need of education institutions in the surrounding area have to be taken into account)

Concerning the cost indicator database for estimating all types of technical infrastructure, clearly more research is needed. Because of the lack of published data in Germany, together with municipal representatives we decided to take the existing raw data from the specific city administration departments and transform them into compatible cost indicators for our model.
First step: measurement of quantities. Due to governmental regulations, all types of technical infrastructure networks had been integrated into a GIS database only recently. But these real length network measurements sometimes are quite filigree and quite complex structures so that their cost indicators need another unit than "EUR / linear m" in order to be applicable in early project phase cost estimations. This is the case for the subtypes "Communication" as well as "Supply and Disposal". The question remains how to handle a road within an area of a new development that is used by a high percentage of people not living or working in this area, e.g. a thoroughfare. Therefore, as far as "Transportation" is concerned, we decided to execute a test drive with "linear m" as unit to be independent of this kind of interfering effects:

Equation 4: ci (Public Road, Type Z) = EUR / linear m

ci (Public Road, Type Z) = cost indicator valid for construction costs of a certain type of public road (types are still to be defined by section measurements, material qualities and other details)
EUR = capital (VAT excluded)
linear m = unit of the quantity, to be measured as middle axis of road section [CRB 2010]

This means of course that the subtype of "Transportation" has to be planned up to a certain level before we are able to get quantities and apply adequate cost indicators. But maybe we will achieve a good range of per capita cost indicators over time.
When it comes to a special kind of infrastructure as for example "Water Supply" and "Sewage", the idea of "Total Population (TP)" is integrated into the equation in order to understand the real requirements concerning this infrastructure network. Total Population represents the sum of inhabitants and the so called "population equivalents" (Einwohnerwert [DIN 2007]) that might be e.g. industrial companies within the examined area that are

consuming water and / or producing sewage equivalent to a population of x members. This value of total population is used to obtain a base for demand planning of the network layout and its dimensions.

As a result, the equation for water supply cost indicators is the following:

Equation 5: ci (Water Supply) = EUR / c

ci (Water Supply) = cost indicator (unit: EUR per capita)
EUR = capital (VAT excluded)
c = unit of the total population [DIN 2007]

It still has to be defined how to handle special punctual facilities within a certain type of network, for example in the case of sewage. What if a new area will accommodate 400 new households and the clarification plant attached to this network is able to integrate this additional load without extra construction costs. And what if, on the other hand, these 400 new households will cause the decision to build a new clarification plant that has capacities for far more than just the 400 x 4 = 1600 total population units (if the architecture of this area is meant to accommodate families). One possible way would be to divide theoretically the construction costs as well as the user costs of these punctual facilities by all possible users, even if the facilities are not always working to their full capacities.

In summary, table 2 provides an overview of the different proposed units allocated to the different subtypes of infrastructure.

Type	**Subtype**	**Example**	**Unit**
Social Infrastructure	Institution for Education	Kindergarten, School, University, etc.	m² GFA (BGF) [DIN 2005]
	Institution for Health Care	Hospital, Rescue Institution, etc.	m² GFA (BGF) [DIN 2005]
	Institution for Culture	Museum, Library, etc.	m² GFA (BGF) [DIN 2005]
	Institution for Public Administration	Governmental /Municipal Administration, etc.	m² GFA (BGF) [DIN 2005]
	Institution for Public Security	Police, Fire Department, etc.	m² GFA (BGF) [DIN 2005]
Technical Infrastructure	Transportation	Public Transport, Facilities for Private Transport	linear m (meter) [CRB 2010]
	Communication	Telephone, Internet, Broadcast, etc.	per capita
	Supply and Disposal	Water / Sewage, Energy, Waste, etc.	per capita of total population [DIN 2007]

Table 2: *Proposed units for early phase cost estimation*

Second step: creating the cost indicators. Fortunately, nearly all elements of the technical infrastructure GIS database in the Stuttgart Department of Civil Engineering have construction costs allocated to them. So we are able to calculate cost indicators for construction costs as soon as we have the measurements in combination with the specific cost totals of the measured areas.

As far as the user cost indicator is concerned, the Department of Civil Engineering did not yet start to integrate these cost types into their GIS database. It is said to be done only within the next two years. So, in order to be able to run the model soon as a test drive, we decided to take a few but typical examples from the recent years and try to calculate these cost indicators manually.

Finally it should be possible in some of the above mentioned cases and under certain circumstances to change the unit of a cost indicator by applying an adequate coefficient. If for example a new development needs a kindergarten for 80 children, but our cost indicator´s unit is "EUR/m² GFA". In that case, the tool should be able to convert either the 80 children into the adequate value of GFA (200 m² GFA at a ratio of 2.5 m² GFA / child), or to convert the value and unit of the cost indicator to get the same result in the end.

CONCLUSION AND NEXT STEPS

The presented research project in cooperation with the City of Stuttgart will enable the planning teams to systematically integrate the consequences of demographic changes in their infrastructural projects in terms of supply quality and cost efficiency. As part of the larger project, this first study prepares the database of cost indicators for municipal infrastructural project cost estimation in early project phases.

Based on specific German standards for cost estimating of building construction and user costs, as well as the large published database available for construction cost indicators and the coming up data for user cost indicators, the integration of estimation construction and user costs of social infrastructure within the model seems to be unproblematic. Concerning the different types of technical infrastructure, the lack of standards comparable to building construction in terms of measurement, unit definition and cost allocation makes it necessary to develop adequate own definitions. The proposed system will soon be applied in order to produce cost indicators for use in early phases cost estimation. As soon as possible, the results should then be tested in one of the next projects to get real life feedback.

A test drive demonstration of the whole model is planned to start April 2011. And we will be glad to present first results and experiences to CIB in June 2011.

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