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# FACILITIES DEVELOPMENT AND PLANNING MODEL – A MANAGEMENT TOOL FOR THE STRATEGIC PLANNING PROCESS AND APPLICATION THEREOF

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## ABSTRACT

The comprehensive content of the planning process for wastewater conveyance and treatment facilities, and the optimization thereof, resulted in the development of the Facilities Development and Planning Model (FDP). The FDP model was developed for the operators of wastewater care facilities in order to obtain an efficient and dynamic means of assessing the regional inputs, evaluating the existing system and situation, and for considering various generic scenarios.

The FDP model can be adapted to be utilized for the planning of facilities for other bulk services infrastructure.

The paper describes the application of the FDP model in an wastewater treatment environment. 

## KEYWORDS

Computer modeling; planning of infrastructure; regional wastewater treatment; strategic planning.

## INTRODUCTION

During the early nineties, a strategic investigation was initiated for the evaluation of the optimum manner in which to extend the existing water care facilities in a metropolitan area in South Africa. The total metropolitan area consists of six drainage regions. At that point in time these facilities were managed and operated by a number of local authorities. The process included an evaluation of the best management model to compliment the findings of the strategic investigation. Due to this strategic investigation, as well as other detailed studies, a regional organization was established to manage wastewater treatment, as well as the bulk conveyance of wastewater in the study area. The regional metropolitan organization subsequently formed, namely ERWAT, is responsible for the conveyance and treatment of wastewater in the East Rand Region of the Gauteng Province, South Africa. It is responsible for the management and operations of 19 wastewater treatment facilities in the metropolitan area.

This model can further be extended and adapted to include other utility services, such as power supply, bulk water supply, solid waste handling and can further be used for regional water resource planning.

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In short this paper is a discussion of the problems related to the strategic planning of bulk infrastructure for a region. It refers to the complexity of such an evaluation process and the resultant model to simulate the various conditions applicable to such a problem.

## PLANNING UNDER UNCERTAINTY

The planning of infrastructure for urban development in a regional context is a typical example of decision-making under conditions of uncertainty. The period for which infrastructure must be evaluated is often of the same order as the expected lifespan of the infrastructure under consideration. On the other hand, it is at least equal to the financing period. In the case of wastewater treatment facilities, the evaluation period is normally twenty years. When one takes the environment into account, it is not possible to make accurate predictions of service demand so far into the future with a high degree of certainty. On the other hand, infrastructure must be optimally deployed for demand that will only manifest itself at some time in the future. Any optimal plan, without reservations and qualifications, carries a high risk.

For the planning of infrastructure a procedure was developed whereby the variation in optimality can be rapidly calculated as a function of the variations in the major environmental variables influencing the decision-making process - such as cost of capital, inflation rate, population growth, relative affluence of the population, and other factors that can influence the decision-making process. This, coupled with a range of management options and strategic alternatives for a given region, results in a number of solutions, which can be compared for optimality and for resistance to variation or sensitivity to environmental changes. The final decisions are made on the basis of these quantitative comparisons.

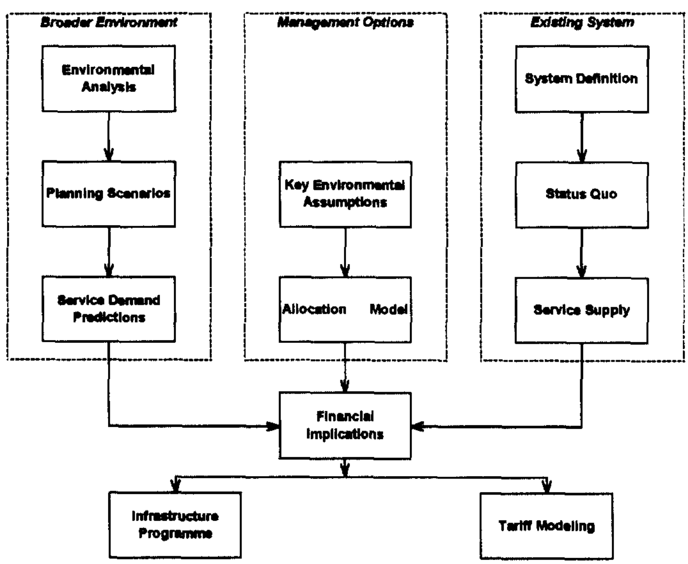


Figure 1. An overview of the main processes incorporated in the FDP model.

## MODELING OF INFRASTRUCTURE SUPPLY AND DEMAND

The modeling of supply and demand of infrastructure and wastewater facilities is based on a well defined and logic process that has to date been successfully employed for the management of wastewater conveyance systems and treatment facilities of ERWAT. Initially a spreadsheet-based model was employed to do the modeling. This model was extended and the process has since been automated and refined by the development of the **Facilities Development and Planning (FDP) Model**. The model is based on Microsoft Access and the aim is to do analysis and to give financial and spatial solutions in a relatively short time span.

In the modeling process **three main streams** are considered to determine the current and future deployment of infrastructure and services, namely:

- Broader Environment
- System Definition
- Planning Scenarios

*Firstly*, the need exists to understand the **broader environment** : how will population grow in the future, where will new development take place and to what extent will infilling and higher densities affect existing infrastructure and facilities?

*Secondly*, one needs to understand the **existing system** : what is the capacity and extent of the existing infrastructure and facilities, what is the current usage of these facilities, historically how fast does demand on these services grow and at what cost?

*Thirdly*, **management or political input** often influences the way in which demand and supply are reconciled. In cases where many optimal technical solutions exist, the philosophy of management or qualitative issues or both are important in determining the correct planning approach. Management may also pre-qualify the types of solutions to be considered, for example the use of labor-intensive development options only or expanding the reach of services before expanding the quality of the service. The latter is however not recommended since the cost of such qualifications must first be determined.

## ANALYSIS OF THE METHODOLOGY OF THE FDP MODEL

The following specific tasks are performed as part of the analysis process employed by the FDP model:

### Environmental assessment

This step involves the selection of and a sensitivity analysis on key environmental variables normally included but not limited to: population growth, inflation, interest rates, economical growth and trade-weighted exchange rates. The selection process is determined by the parameters used by the model for wastewater services demand forecasts and by the methods used for financial calculations.

### Planning scenarios

The planning scenario module documents and uses the sensitivity suggested by historic changes in key variables, together with management input to provide for four of the planning scenarios used as a basis for modeling.

It must be taken into account that the forecasts based on these scenarios are not used to predict what ***will*** happen in the future - the approach is to ***test plans*** for infrastructure and facilities development ***if*** the stated scenario should materialize. A good infrastructure plan remains fairly optimal for as many planning scenarios as possible.

### Service and infrastructure demand forecasts

The planning scenarios are used to generate a number of forecasts for the demand for infrastructure and facilities. The models used for these forecasts are normally based on tried and tested empirical methods with widespread acceptance in the planning and civil engineering field. Typically, the present demand as well as future demand is a function of the population in a given planning area, together with their relative wealth.

The demand forecasts are normally based on census information derived from a spatial representation such as a suburb, a magisterial district or the area of jurisdiction of a local authority.

The basic but most significant input required by this module are the aspects relating to **flow and load prediction**. The model supports three basic flow and load input methods, namely:

- A one-off figure combined with a growth factor.
- A series of independent figures for the entire horizon period.
- A series of figures commencing at any year and combined with a relevant growth factor.

System definition

The system definition module documents the nature, extent and capacity of **existing infrastructure and facilities** and provides a link between these entities and their spatial representations.

Inputs required by this module are:

- The **flow and load capacities** of existing water care works.
- The **geographic locality** of existing water cares works.
- The relative localities of sub-drainage areas in respect to wastewater care facilities, pump stations and possible future discharge points.

Status quo

The status quo module documents the current operational statistics for the facilities in question. It calculates unit costs of the service in ways that allow determination of economy of scale, if any exists, and that serves as calibration for modeled values.

Service supply and technology options

The service supply module aims to provide an indication of the expenditure involved in creating new capacity at existing and new facilities. In most instances, the cost of new capacity is a function of the extent and technology of the new capacity and the sustainability of the new capacity. As an example, for short periods it may be possible to extend the capacity of wastewater treatment works through chemical dosing. In these cases, a "technology option" that extends water care works capacity in the interim can be provided for. This module also discriminates between technology options. Some technologies are low capital cost solutions that have high operational and maintenance costs, while others work the opposite way. Depending on the cost of capital, cost of energy and such, one can use this planning tool to determine the most appropriate technology.

Allocation model

The allocation model is, in many respects, the most important module of all. In essence, it translates predicted demands in given areas, with management inputs, into the demand on a specific infrastructure component or facility at a given time.

Essentially, the allocation module considers the following: **what should be done with infrastructure and wastewater facilities when capacity has been reached?**

Four typical options are available:

- **Extend the capacity** of the facility to last for a time into the future dependent on economy of scale factors.
- **Close the facility** and route the wastewater to a different facility where capacity exists or will exist at the time required.

- Operate the facility at or **near its capacity** and **route the balance** of the wastewater to where capacity exists or will exist when required.
- Extend the capacity of the facility **temporarily**, using appropriate measures, until one of the other options can be implemented.

These options occur at some stage in the future, typically when capacity is reached, but the decision may be overridden by other considerations such as closing a facility that is too old and/or too costly to maintain and operate. The time at which these events occur is moved forward and backward by different scenarios, and may change in the order of occurrence that leads to a completely different chain of events resulting from separate scenarios. Into this situation, one can then also introduce the problem of dealing with additional choices, such as a management option to eliminate wastewater pump stations at some stage in the future, which complicates the allocation of demand to facilities.

Financial implications

The financial implication of each combination of scenarios, management options, technology selection and strategic approach, regionalization of services and decentralization, can be evaluated on a basis of equal over capacity at the end of the planning horizon. This, if calculated in present value terms, provides a good indication of the cost of various infrastructure management options. The input costs, while not always accurately available for some services, such as solid waste removal, are combined with cost curve models to discriminate between the long-term costs of various options. From this it is possible to make recommendations with respect to optimal infrastructure development plans.

A sensitivity analysis on the evaluation outcome tests the dynamic influences of the inputs and their impact on the best option. The possible changing effect of the flow and load predictions are analyzed by assuming three possible wastewater generation growth scenarios, which could include normal, low and high growth for the entire region. The impact of the economical assumptions on the present value cash flows can be evaluated by the selection of different values of capital and inflation rate.

Tariff modeling

Because of the equal over-capacity rule in the financial evaluation modules, the tariff calculations based on the cost of service per capita or per household become increasingly skewed as time into the future increases. This can be corrected for selected optimal facilities development plans, and calculated as a real, inflation-corrected cost of service into the future with the result that long term tariff planning can be done.

## KEY ENVIRONMENTAL ASSUMPTIONS

The application of the systems theory indicates that wastewater conveyance and the wastewater treatment system is positioned in an **open and continuously changing environment**. In the analysis process, cognizance must be taken of the key environmental assumptions, the influences from the direct and indirect environment. Typical key environmental assumptions applicable for an analysis by the FDP model are briefly discussed below.

Economic assumptions

The inflation rate.
Assumed cost of capital.
Assumed return period for the financial evaluation, normally 20 years.
The assumption that the area under consideration will be able to afford the service for the evaluation period.
Funds are available as and when needed for the implementation of projects.

Other general financial assumptions and criteria used are:

All regional outfall sewer costs are included.
Cost savings resulting from certain alternatives are included.
Existing fixed and variable operating and maintenance costs for each water care facility are included.
Capital, variable and fixed operating and maintenance costs for extensions to water care works - where available the actual variable and fixed costs are used as a base for future predicted costs.

Demographic environment - wastewater generation growth

Typical assumptions for the demographic environment can be summarized as followsy:

The extent and rate of new development.
Rate of improvement of service levels.

Social environment

Assumptions with regard to the social environment are:

The average household size.
The average sewage flow per household.
The effects of external factors on growth such as AIDS.
The perceived ability of residents to afford services.

Political and legal environment

The effect of political issues on the system and insofar as it affects the economy.
The present customer base of the management and operating company.

Effluent criteria

A prediction must be made on the possible changes to the general standards for effluent quality.

Physical environment

It is assumed that the physical environment will be able to **support the future development,** with the increase in environmental demands. Cognizance must be taken of the fact that environmental awareness from some pressure groups will increase, and could result in the increased cost of existing and future wastewater care facilities. Environmental Impact Assessments (EIA) and Integrated Environmental Management (IEM) became a standard practice for extensions to existing and new facilities.

Technology

Technological developments are assumed to match the environmental needs. The impact of the employment of more sophisticated **biosolid management techniques** which will take place in areas of high-density development can be accommodated in the modeling. In addition, processes such as bio-chemical and high rate can be incorporated. Emphasis could also be on affordability and developing rural type technologies.

## OUTPUTS

The outputs of the model are as far as possible formatted to facilitate both graphical and tabular displays.

Typical outputs are:

- The **flow and load prediction** for any given water care works, drainage district or the entire region for any of the chosen alternatives.
- The **present value cash flow** for any given water cares works, drainage district or region, for any of the chosen alternatives.
- **Economic cleanup costs** for any given water care works, drainage district or region for any of the chosen alternatives.

Both a graphical and tabular comparison of total present value cost for each alternative is given.

## FLOW AND LOAD PREDICTION MODEL EVALUATION

If the system is considered in totality, then the most important impact on the system is the prediction of wastewater flow generated and the linked organic loads. The organic load estimates include chemical oxygen demand (COD), suspended solids, ammonia-nitrogen and phosphate. Provision can be made for other load parameters. The prediction for each sub-drainage can be estimated with the aid of this dynamic computer based prediction model.

These details are available in a variety of levels of aggregation, varying from the results for a single water care works, through drainage areas to the total area under investigation.

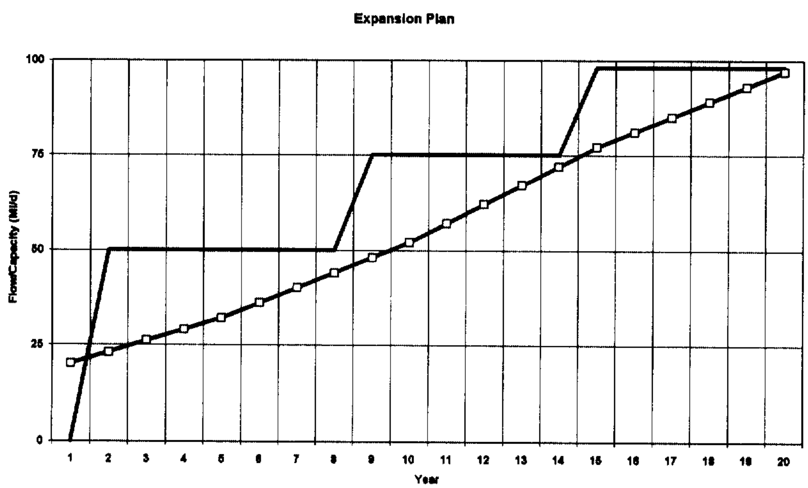


Figure 2. The capacity development plan for a new wastewater treatment facility.

## MANAGERIAL APPLICATION OF THE MODEL AS A MANAGEMENT TOOL

The ease of application of this powerful analytic and economic evaluation and planning tool, can be utilized by management in the planning, as well as in the managerial decision-making process, especially if the FDP model is linked to the Management Information System of an organization. After the first planning evaluation process of a system, the financial outcome can be used to develop a long-term tariff forecast. This forecast can be adjusted to develop an acceptable financial plan for the organization to accommodate the broader needs of the of the system in which it operates.

As a management tool the FDP model can also be utilized to do:

- financial structuring of projects
- risk analysis and evaluation

- alternative funding sources
- sensitivity analysis of options
- evaluation of project formats such as Build Operate Transfer, Design Build Operate Transfer, etc.
- the optimization of other organizational resources including human resources and equipment.

## CONCLUSION

This paper demonstrates the effective use of the Facilities Development and Planning computer model to undertake the comprehensive planning of bulk infrastructure and facilities for wastewater conveyance and treatment. It was also pointed out that the model can with ease be adapted and applied for the planning and provision of other bulk services. Although the model was developed as a planning tool, it is also used in the managerial decision-making process as it can be linked to the management information system of an organization.