SYSTEM FOR THE INTEGRATED MANAGEMENT OF URBAN SETTLEMENT AND INFRASTRUCTURE DEVELOPMENT*

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The overall economic, physical and decision-making environment in South Africa's urban areas has changed dramatically in recent years. This paper provides a brief overview of these changes and then proceeds to describe a new approach towards urban management, and the development of a modular decision support system which can contribute to the management of urban settlement and infrastrucutre development within the framework of an integrated approach. This system includes modules for the indentification of potential urban settlement sites (both for new development and re-development/densification of existing developed areas), exploring the likely development of these areas (given certain urban/infrastrucutre management scenarios), and analysing the resource consumption impacts (both in terms of physical resources and financial resources) associated with each scenario. The system provides the ability to rapidly compare and evaluate the impacts of alternative approaches to accommodate the various development pressures within a scenario-based approach.

Die ekonomiese, fisiese en besluitnemings omstandighede van Suid-Afrikaanse stede het oor die afgelope aantal jare dramatiese veranderings ondergaan. Hierdie referaat gee 'n kort oorsig van hierdie veranderings en beskryf voorts 'n nuwe benadering tot stedelike bestuur, asook die ontwikkeling van 'n modulêre besluitnemings ondersteuningstelsel wat 'n bydrae kan lewer tot die bestuur van stedelike vestiging en infrastruktuur ontwikkeling binne die raamwerk van 'n geïntegreerde benadering. Hierdie stelsel sluit in modules vir die identifisering van potensiële gebiede vir ontwikkeling (beide vir nuwe ontwikkeling en vir herontwikkeling/verdigting van bestaande gebiede), die ondersoek van waarskynlike ontwikkelings in hierdie gebiede (gegewe sekere scenario's vir stedelike- en infrastruktuurbestuur), asook die verbruik van hulpbronne (in terme van beide fisiese bronne en finansiële bronne) wat met elke scenario gepaard gaan. Die stelsel verskaf dus die vermoë om die verwagte impakte van verskillende benaderings tot die hantering van stedelike ontwikkeling vinnig te kan vergelyk en evalueer deur die gebruik van 'n scenario-gebaseerde benadering.

INTRODUCTION

The overall economic, physical and decisionmaking environment in South Africa's urban areas has changed dramatically in recent years. Our cities have changed from being well-funded and strictly controlled by standards, regulations and central government policies, to an environment where there are ever increasing financial affordability constraints, a general lowering of standards, and tremendous coordination problems among different tiers of government and the multiplicity of departments, municipalities, and development agencies.

The logical starting point to address these problems would be to attempt closer integration of the various urban planning and infrastructure provision agencies. This is however notoriously difficult to achieve, and thus, under the circumstances, a more practical course of action is the establishment of various consultative forum, and the coordination of planning and development activities via these forums. It is now also increasingly being accepted that traditional forms of blueprint planning need to be replaced by a series of more continuous and participative '*management activities*', each of these then supported by an *appropriate management or decision support system.*

The system described in this paper is aimed at providing a tool for managing urban settlement and infrastructure development in a more integrated manner, while also allowing for direct participation via consultative forums, inter-departmental committees or similar participative planning arrangements. A further key feature of the system is that it provides direct 'what-if' information on the financial and other resource consumption impacts of alternative settlement and infrastructure provision scenarios. In accordance with the latest developments in modelling systems, the system is moreover also closely interfaced with a geographic information system (GIS).

URBAN MANAGEMENT CHALLENGES IN SOUTH AFRICAN CITIES

Apart from the financial and institutional difficulties described above, the task of urban management forums and operational management executives are further complicated by the difficulty of balancing affirmative demands for structural change and urban densification with concerns about the sustainability of sensitive urban environments and the capacity of infrastructure systems.

Affirmative demands for structural change and densification are primarily a response to the structural distortions caused by past separatist policies and planning practices. At the macro level these distortions are well recognised.

They include *low-density sprawl, fragmentation,* and the *excessive separation* of different land uses, urban settlements and income groups (Dewar 1992). The transport consequences have been described as excessively long, costly and automobile-dependent urban travel patterns.

There are also several lesser recognised structural deficiencies which are occurring *within* most of the low-income sectors or sub-regions of South African cities. Most of these areas have been planned as separate, inwardly-focused townships each with its own 'town centre'. In practice we found that this pattern of compartmentalisation repeats itself in the economic and social spheres with the result that there is often a high level of protectionist competition and even conflict between different disadvantaged communities. A segmented economic structure tends to develop, reinforced by the resistance of business interests in each community to open and link its retail, transport and other markets to the business interests in other communities. At the same time there is resistance against formal sector entrepreneurs from the outside. For the low-income sub-region as a whole, the end result is typically high prices, low variety, and the leakage of a high proportion of purchasing power to the CBD or established nodes and shopping centres in other sub-regions. Moreover, the continuation of such a state of affairs tends to seriously erode the medium and long-term viability of such low-income sub-regions and their constituent communities.

In addition to the need for structural changes to address the above problems within low-income sub-regions, a need has also been expressed for infilling, densification and related structural changes in the higher income sub-regions in South Africa's metropolitan areas. Such changes will have to be accompanied by middle and low income settlement in those pockets of land that could potentially be 'filled in' or 'densified'. Resistance by so-called NIMBY's (not in my backyard) and environmentalist pressure groups against these changes can therefore be expected. In most cases the counter arguments would essentially be based on concerns about the sustainability limits of the local property industry and other environmentally sensitive industries (e.g. tourism) in the areas that are likely to be selected for infilling and densification.

In the absence of properly institutionalised consultative or local government structures at a sub-regional level, these issues would be very difficult to resolve. One of the challenges for metropolitan urban management forums would thus be to begin building the necessary institutions at sub-regional level. This will avoid the typical situation where local pressure groups are fighting against what they consider to be the top-down metropolitan or provincial planning decisions. For urban management to become truly participative, the necessary consultative structures and decision support would thus have to be established for at least two levels - the metropolitan level and the sub-regional level. The term 'metropolitan level' refers to the total area under consideration (e.g. Central Witwatersrand or PWV-area). Sub-regions on the other hand refer to areas within the metropolitan structure which can be delimitated based on a combination of administrative boundaries, physical factors, broad accessibility factors, and other criteria (e.g. the nine sectors in the Central Witwatersrand land availability study) (Rosmarin 1992). As indicated in Figure 1 the delimitation of these sub-regions are part of the negotiation processes within the proposed procedural framework.

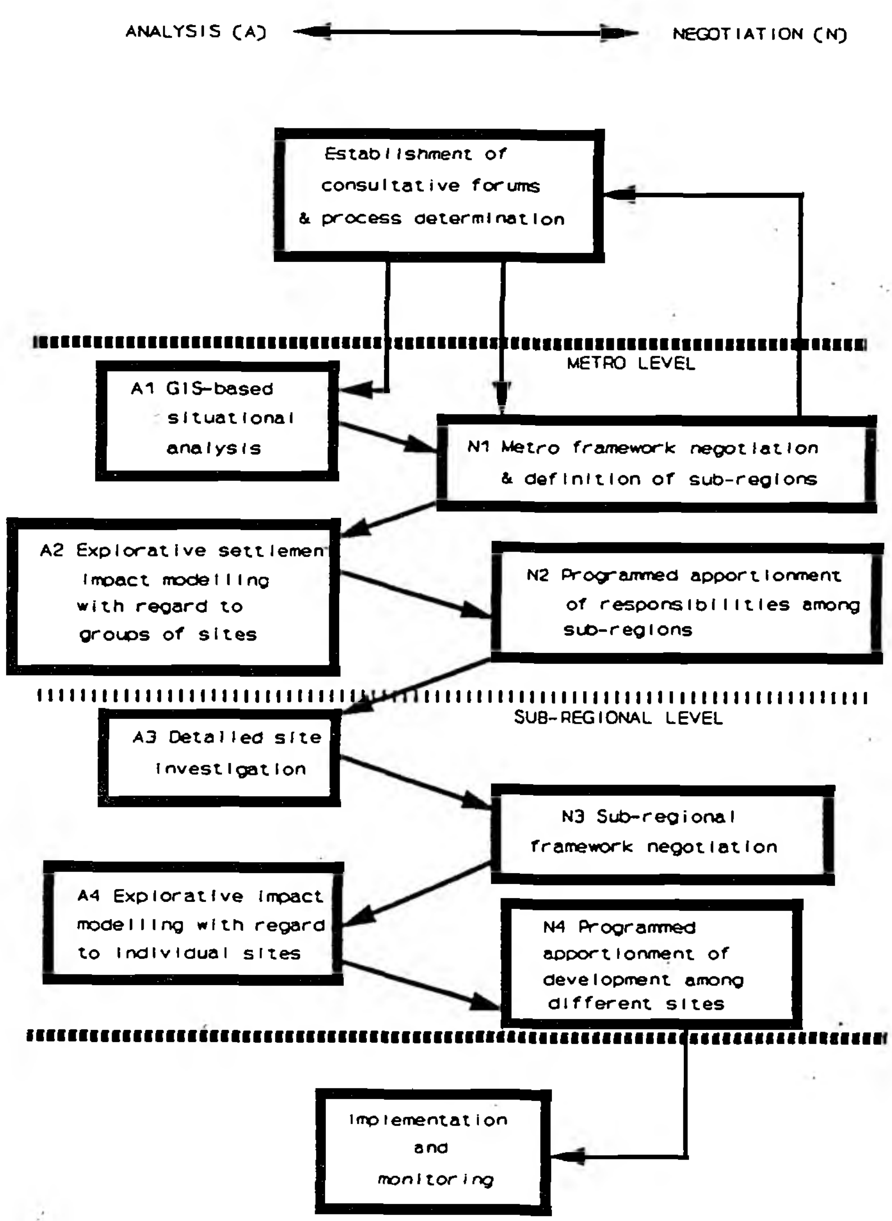

FIGURE 1: *Institutional and procedural framework for the decision support system.*

NEW URBAN MODELLING PHILOSOPHY

Changing approach towards modelling urban systems

The invalidity of forecasting long term urban change in the present era of flux has culminated in a reassessment of the planning horizon and a need for more adaptive and explorative modelling. Explorative modelling focuses on 'what if', questions of various urban futures planned or unplanned. The aim is to analyse pro-active change in a changing environment by considering various options and/or futures. It should be relatively quick and simple to use and able to produce output readily useful to decision makers.

Implicit to this flexible process of urban modelling and management is the need to achieve an improved balance and linkage between 'hard' or technical decision making (frequently orientated around sophisticated mathematical models) on the one hand, and 'soft' or negotiated decision making on the other. This requires a tool for sharing information openly and quickly without technical complexity and jargon in a forum open to shared learning and consensus building between diverse societal groups. An appropriate tool complying with these prerequisites is an interactive, modular decision support system.

What is a decision support system

Decision support in its broadest sense involves direct support to decision makers in dealing with specific problems. If decision support can be utilised it will produce *objective, logical and consistent decisions* (supported by 'what-if' analysis), *provide new insights and perspectives* on problems, and *facilitate communication.* The rationale behind the development of a decision support system is that it is designed to support semi-structured decision-making tasks, a class of problems for which no automatic algorithm exists. Rather the solution procedure consists of exploring various alternatives to find a good solution as opposed to the 'optimum' solution. The premise underlying this is that there are important aspects of the problem that cannot be adequately captured in the mathematical formalism of the problem, but which can be incorporated in a more general solution procedure using mathematical models as elements in the solution process.

Characteristics of a decision support system

The recognisable characteristics of a decision support system include the following (Densham and Rushton 1988):

- They are designed to be easy to use. The often sophisticated computer technology is accessed through a user-friendly front end.
- They are designed to enable the user to make maximum use of the data and models that are available. Interfacing routines and database management systems are important elements.
- The user develops a solution procedure using the models as decision aids to generate a series of alternatives.
- They are designed for flexibility of use and ease of adaption to the evolving needs of the user.

Development of a decision support system

The development of a decision support system is best conceptualised as an iterative mutual learning process. The decision-maker defines his or her needs imperfectly at the outset. The programme developer creates a system that meets those needs. The decision-maker, in using the system, develops a better understanding of the needs and the potential of the system, thus leading to a redefinition of the system requirements. This process can go through several cycles, resulting in the evolutionary development of the decision support system (Langendorf 1985).

Key elements of change

The key elements of change distinguishing the conventional methods from this new approach to urban modelling, and new institutional frameworks for urban management (described in the next section) can be summarised as follows (Sikiotis 1992):

- Needs assessment alters from the conventional household survey, extensive traffic counts and limited consultation to a procedure of low cost scanning with more extensive data gathering in areas identified as problem or need areas. This data gathering exercise is accompanied by intensive consultation with community players.
- Policy formulation alters from sophisticated longer term demand estimation and forecasting to short term sketch planning based on 'what if' analysis of alternative options and policies formulated through judgement and negotiation.
- The actual plan alters from being a coercive plan supported by extensive regulation and control to a more, participative, persuasive and coordinated statement of intent influenced by the cooperation of official and community liaison groups.
- Implementation alters from a regulated formalized procedure to one which explicitly respects the communities rights and needs and functions as an organizational and community building process which extends to incorporate learning by assessing past and present performance.

INSTITUTIONAL AND PROCEDURAL FRAMEWORK FOR THE DECISION SUPPORT SYSTEM

Against the background of the urban management challenges in South Africa, a decision was made to specifically develop the decision support system for a two-tiered urban management process. A general procedural framework was developed that would moreover allow for the utilization of various other models and decision support systems. The basic philosophy of the procedural framework can be described with reference to Figure 1. Apart from drawing a distinction between issues to be addressed at the metropolitan and sub-regional levels respectively, the philosophy is that 'analysis' and 'negotiation' activities have to be distinguished from each other, yet closely linked as part of an iterative process.

The system is intended to be used as a decision support tool to assist with the four analysis activities indicated in Figure 1. It should however be noted that the procedural framework allows for other analyses procedures and systems to be used for activities such as the GIS-based situational analysis (A1) and detailed site investigations (A3).

The negotiation activities N1 and N3 are similar in the sense that they both involve the negotiation of a framework of agreements between relevant stakeholders. Typically these activities would be the main foci of the decision-making processes undertaken at metropolitan and sub-regional consultative forums respectively.

The resulting framework at the metropolitan level should not dwell too much on abstract goals and principles. It should rather focus on clarifying basic responsibilities for accommodating development pressures and making other development contributions (e.g. financial contributions to an urban development and maintenance fund). A general framework of agreements of these responsibilities should then be followed up by exploring different settlement and development scenarios (Activity A2) after which a more specific programmed apportionment of responsibilities among different sub-regions should be negotiated (Activity N2). This apportionment of responsibilities should specify when and in which sub-regions certain amounts of land will have to be released, and contain general provisions on how the necessary infrastructure and funding should be provided.

A similar set of procedures and agreements should then be established at the sub-regional level, in this case then focusing on site specific development programmes and associated agreements. The main advantage of leaving site specific decisions to be taken at the sub-regional level should be to break the typical bottom-up, top-down cycle of conflicting arguments about the specific location and timing of certain types of developments. In terms of the proposed procedural framework arguments would be broadly resolved at the metropolitan or inter-subregion level, leaving stakeholders and consultative bodies at the sub-regional level to negotiate the details among themselves.

DECISION SUPPORT SYSTEM FOR THE INTEGRATED MANAGEMENT OF URBAN SETTLEMENT AND INFRASTRUCTURE DEVELOPMENT

Objectives of the system

Given the urban decision-making environment as sketched earlier and the institutional and procedural framework for the decision support, the system being developed is intended as a tool to:

- *support* hard-pressed decisionmakers with fast, interactive, and graphically illustrated information;
- *estimate* low-income settlement pressures and competing or complementary development demands;
- *trade off and allocate* different types of development on a what-if basis;
- *explore* a wide range of immediate as well as cumulative development impacts;
- *learn* about pro-active management policies and development programmes that will prevent the accumulation of unmanageable, unaffordable and/or unsustainable impacts.

Use of a scenario-based approach

The system being developed is a modular, GIS-based decision support system for managing urban settlement and infrastructure development in a more integrated manner within a scenario-based planning and management framework. The basic rationale behind this scenario-based planning and management process is that decision-makers can often not afford to learn through experience. In this sense the term 'scenario' does not only refer to uncontrollable or external phenomena, but as being at least partly manageable through the learning and contracting taking place between the interdependent actors. A comprehensive scenario-based planning and management approach - the ultimate purpose of which may be to achieve the 'high road' - is seen to comprise of four generic activities:

- Contextualisation/environmental scanning
- Explorative modelling
- Strategy development
- Evaluation and impact analysis

The role of each of the activities and the types of scenarios forming part of this interactive strategy development and evaluation process are illustrated in Figure 2.

Context scenarios describe the possible developments of the environment in which the central system under consideration (e.g. urban system) functions. This normally entails certain developments of the variables and processes which are beyond the direct control of the decision-makers. These can include demographic trends, social developments, economic developments and political developments. A specific combination of these developments will constitute a context scenario.

The development of *strategy/policy scenarios* are based on an understanding of important variables and processes which are likely to influence future developments of the central system. In contrast to the variables associated with the development of context scenarios, the variables and processes associated with the development of strategy scenarios are controllable, partially controllable or at least capable of being influenced by decision-makers (individuals, institutions or stakeholder groups). As is the case with the development of context scenarios, a thorough understanding of the interrelationships between the different variables are of extreme importance. Each strategy scenario thus provides a set of associated assumptions which plays an important role in the explorative modelling and impact analysis process for evaluating these strategy scenarios.

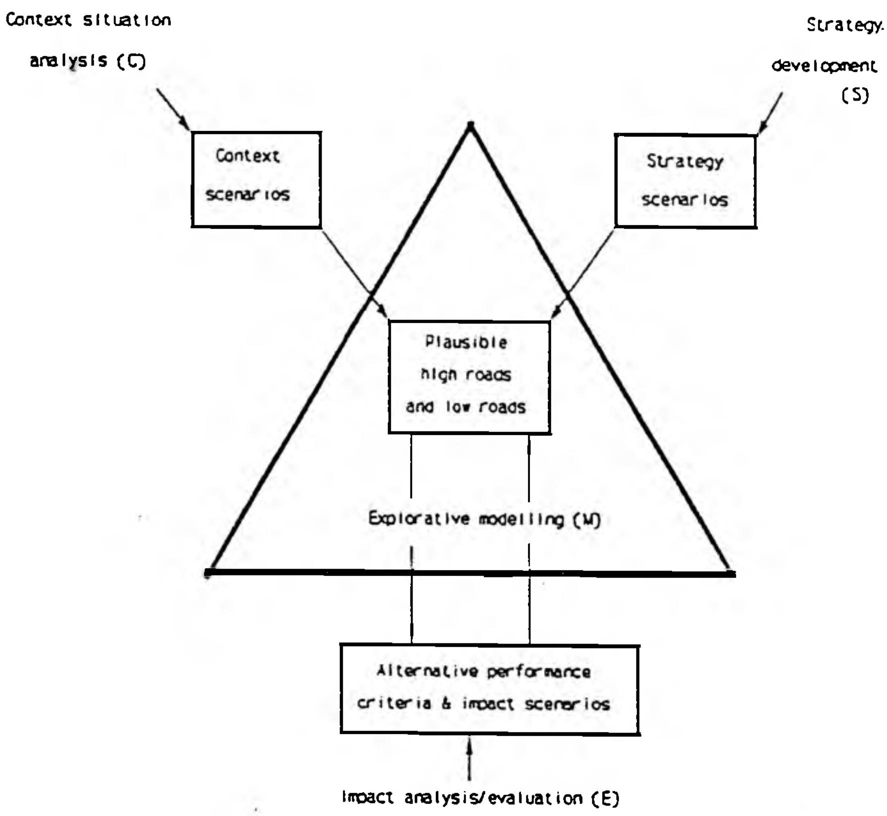

FIGURE 2: *Generic activities of a comprehensive scenario-based planning and management approach.*

Plausible future scenarios (high roads and low roads) are the result of evaluating the alternative strategy options under different context scenarios through explorative modelling and impact analysis. They thus describe the *development* (unfolding) of the central system (e.g. urban system, transport system) over time under specific combinations of context and strategy scenarios. It also includes a description of the resulting *end state* of the central system at the end of the time period under consideration.

Requirements of the system

In order to satisfy the objectives of the system it must be able to:

1. identify all potentially developable areas (given certain criteria), as well as existing settlements according to a specific typology;

2. store a 'profile database' on each of these areas;

3. determine the demand pressures for specific types of development at a macro/sub-regional level;

4. determine the suitability of the various sites within each sub-region for different types of development;

5. apportion the competing demands to the various sites within each sub-region by simulating likely trade-offs on the basis of suitability for specific types of development, capacity constraint considerations and urban management policies regarding investment programmes, pricing and standards; and

6. determine a range of immediate as well as cumulative development impacts (e.g. financial and physical resource consumption impacts associated with the provision of local infrastructure services, impacts on bulk infrastructure networks, cumulative impacts on natural sub-systems, impacts on accessibility).

Issues to be clarified in appropriate forums prior to application of the system

Consistent with the approach outlined in Figure 1, a number of important issues need to be discussed in appropriate forums prior to the application of the system. This includes the development of a settlement typology, the identification of settlement criteria and their associated weights, and the identification of appropriate performance indicators.

Development of a settlement typology

The aim of developing a settlement typology is to quantify the extent of specific dominant settlement types for each region in a manner which is quick, relatively accurate and, importantly, up to date. The assumption is that settlement of particular types will have similar physical resource consumption impacts, and maintenance and infrastructure improvement needs, which can then be quantified in the multi-year accounting framework and displayed spatially with the use of a GIS or through a graphical user interface. In a recent study conducted by the CSIR, five typology types were identified and the spatial extent of each one was assimilated for formal and informal urban developing communities in the PWV. The method proved to be quick, cost effective and relatively accurate. The profile of developed sites identified by this procedure provides the decision support system with a strategic metropolitan wide indication of existing conditions.

Identification of settlement criteria and performance indicators

This step involves identifying a set of criteria which forms the bases of determining the suitability/ attractiveness of specific sites or areas for a particular type of development. These may include both 'engineering criteria', and importantly (specifically in the case of low-income housing) criteria as identified by the community. Examples of planning criteria may include general characteristics such as size/capacity, ownership of land, opportunity cost of land, cadastral composition, access characteristics (e.g. average commuting times/ distances, accessibility to local transport infrastructure and access to urban facilities) and the availability of infrastructure. Examples of 'engineering' criteria may include the physical and geotechnical characteristics of the site/area and the way it impacts on the provision of infrastructure services. Important criteria as identified by the relevant communities normally focuses on access to job opportunities, urban services (e.g. water, sanitation), and other urban amenities (e.g. schools, clinics).

Performance indicators are a set of indicators against which the performance/impacts of various strategy scenarios and settlement patterns can be evaluated. These may include the consumption of land, resulting improvements/deterioration of accessibility, cost of providing local and bulk infrastructure, number of people service by a specific combination of services, and environmental impacts.

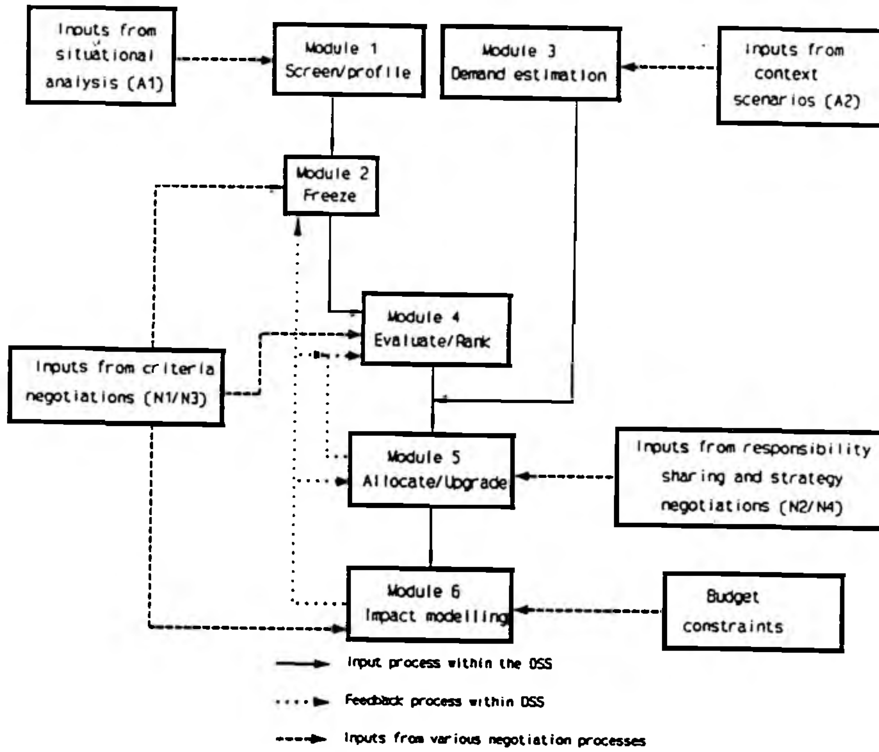

FIGURE 3: *Modules of decision support system applied within a scenario-based approach.*

System modules

The functioning of the system is now analysed in more detail by describing the individual modules of the system. Each of these modules are described in terms of the *purpose* of the module, potential *decision support tools* which may be utilised, and the *outputs* of each module. Figure 3 also indicates the inputs from the various negotiation processes into the system.

<u>Module 1: Screen and profile</u>

The purpose of this module is twofold. *Firstly* it is intended to identify all potentially developable areas and *secondly* to identify all existing settlement areas according to the identified typology. These activities are undertaken as part of the standard GIS-functions including the use of overlaying techniques. Information needed to undertake this process include data on natural features (e.g. water systems, drainage, geology, topography, environmental sensitive areas and mineral deposits), man-made physical features (e.g. existing settlements, transportation systems, bulk infrastructure systems, social infrastructure like schools and hospitals), and data on the status of the land (e.g. land tenure, cadastral boundaries, statistical boundaries). Relevant information of each site/area is stored in an attribute database. The output of this module is thus a spatial database indicating all potentially developable areas and existing settlements according to the defined topology, as well as an associated attribute database of these sites/areas.

<u>Module 2: Freeze</u>

In Module 1 all land which is potentially developable are identified. Some of these sites or areas may however be classified as 'marginal' sites. This means that although a site may be potentially developable, development on these sites may incur severe negative externalities, e.g. environmental sensitive areas, high cost of providing services, etc. The system therefore provides the user with the option to 'freeze' certain 'undevelopable' sites or areas for a specific scenario. Those areas are then excluded from any further consideration under that scenario and it is assumed that no development will be allowed to take place in those areas. It may also be necessary to 'freeze' a site or area for specific time periods only and then make it available for development at a later stage.

<u>Module 3: Demand estimation</u>

During this phase of the system future urbanisation pressure is estimated. This estimation procedure may be based on a number of studies of population pressure at the metropolitan level and may be influenced by a variety of future scenarios. This estimation may be based on either of the following two procedures:

- Existing estimates of population growth as identified by the metropolitan authority itself, or estimates identified by the Urban Foundation, the Development Bank and others.
- Estimates based on a specific modelling procedure for urban growth. The CSIR's EDIS population forecasting model has been successfully used in a number of urban and regional applications in South Africa.

In case of the former option, development pressures are entered into the system as an exogenous input while in the latter case these estimates are produced by a specific modelling technique.

<u>Module 4: Evaluate/rank</u>

The purpose of this module is to determine quantitatively the suitability or attractiveness of vacant land for specific types of development as perceived from different viewpoints. The various criteria identified in the negotiation forums are used in a computerised multi-criteria evaluation system for this purpose. The relevant criteria and their associated weights are used together with the necessary data (contained in the profile database) to evaluate the sites. The module produces a ranked list of the various sites (within each sub-region (from most to least suitable/attractive) and a suitability index score (a measure of suitability/attractiveness of the sites relative to one another). This information can be further utilised in one of two ways depending on the procedure which is to be employed for the apportionment of demand pressures.

Module 5: Apportion/upgrade

The apportionment of demand pressures involves the allocation of the pressures identified in Module 3 to the various vacant or densifiable sites. This allocation process takes place successively at two levels - firstly at the metropolitan sub-regions and subsequently at the individual sites within each sub-region. Two alternative types of procedures can be followed to undertake this process:

- A specific type of *automatic allocation* procedure may be utilised. An example of an automatic allocation procedure is to utilise the site suitability indexes (derived in Module 4) in a Monte Carlo type stochastic allocation procedure (Sieg 1988).
- If the system is to be used interactively in a negotiation forum to evaluate the impacts of various settlement/urban management strategies, the development pressures are allocated 'manually' to the various alternative areas. In this instance the participants in the forum decide through a process of discussion and negotiation how to allocate the pressures to the sub-regions and the individual sites within the sub-regions. Decisions regarding upgrading of existing settlements also forms part of this activity.

Various factors, including the cost of infrastructure provision, the impact on surrounding development and the opportunity cost of developing the site for alternative land uses, may alter the decision to allow the site to be developed for a specific type of development. Based on the subsequent phase of impact modelling these factors may be traded off with one another to identify a more optimal stratification of future urban development.

Module 6: Impact modelling

The impact analysis module essentially forms the 'core' of the system. The purpose of this module is to provide a range of immediate as well as cumulative *impacts* associated with various development scenarios. The impacts are essentially focused on the following aspects:

- *Local infrastructure network (LIN)* impacts both in terms of physical resource consumption impacts (e.g. water usage, length of roads to be provided, sewerage effluent) and financial impacts associated with providing the local infrastructure and the maintenance thereof in new developments, as well as the upgrading and maintenance of local infrastructure in existing areas.
- Impacts on the bulk infrastructure networks (BIN) are determined by aggregating the effects of the specific new or existing settlements falling within each bulk catchment area to determine if the capacity/sustainability limits of the system in that catchment area is exceeded. If the capacity is exceeded it will provide an indication of the additional bulk infrastructure provision costs that are likely to be incurred by further developments.
- The macro/accessibility impacts associated with each settlement/development scenario *are indicated* in the form of average commuting distance/time maps.
- *Environmental impacts* in terms of aspects such as ground water runoff, air pollution, groundwater quality can also be determined by linking the system with certain environmental impact models.

This impact module is in the form of a *multi-year settlement* and *impact auditing table.* This table provides a period by period overview of *population numbers, physical resource consumption* impacts, financial resource consumption impacts and *environmental impacts*. This information can be displayed graphically to illustrate the immediate impacts, as well as the cumulative impacts over time associated with each alternative 'what-if' settlement pattern. The impacts are calculated and displayed at three levels:

- Site specific level
- Sub-regional level
- Metropolitan level

This information will assist decision-makers to take well-informed and consistent decisions by enabling them to rapidly compare and evaluate a range of impacts associated with each alternative settlement/development option. This may lead to a re-apportionment of the pressures to achieve a more sustainable development process in terms of the range of indicators identified earlier. This feedback process is illustrated in Figure 3.

CONCLUSIONS

In order to address the *urban management* challenges of South African cities effectively, this paper calls for a new approach to both urban modelling and to the institutional and procedural frameworks for urban management. An integrated approach towards the management of urban settlement and infrastructure development is seen to be essential if the necessary momentum for substantial structural change, sustainable development, and social upliftment are to be achieved in our cities. A modular and interactive decision support system to undertake explorative settlement impact modelling is currently being developed to enable rapid comparison and evaluation of the impacts of alternative courses of development. This system will support the analysis activities described in the institutional and procedural framework for urban management in South Africa. The system can also lead to an improved balance and linkage between 'hard' or technical decision-making on the one hand, and 'soft' or negotiated decision-making on the other.

Two important issues which require further research and development work lie with *improved economic accessibility modelling* and *improved environmental modelling*. Despite the criticism of Lowry-type models and the required need to model both the upper circuit (formal sector) and lower circuit (informal sector) of the urban economy, the system described in this paper does not actually provide any model of the urban economy. As noted in Chadwick's international review of urban modelling in developing countries (Chadwick 1987), this remains an unresolved and daunting task. In the meanwhile the most practical course of action would be to continue broadening the range of employment accessibility measures. A particularly important focus in this regard would be to improve the measures of accessibility to informal sector, economic opportunities.

In terms of environmental impact modelling there are numerous issues that merit attention. These would for instance include the development of methods to distinguish clearly between 'environmentally disastrous' and 'environmentally undesirable' consequences. In the interim the system provides at least a starting point for dealing with potentially controversial environmental assessment issues. This is centred around Module 2 (freeze), in terms of which it can be decided to temporarily 'freeze' areas that are still subject to detailed environmental assessments. Other issues which may also need to be further investigated include the transferability of data between different GIS platforms and the various processing modules, appropriate levels of data accuracy, and linkages with transport and other bulk network planning models.

* This paper was adjudged as the best paper presented at the Thirteenth Annual Transport Convention, 28 June - 1 July 1993, University of Pretoria.

REFERENCES

CHADWICK GF (1987). *Models of urban and regional systems in developing countries*, Oxford, Pergamon Press.

DENSHAM P & RUSHTON G (1988). 'Decision Support Systems for locational planning', In: Goliedge RG and Timmermans H, *Behavioural modelling in Geography and Planning*, London, Croon Helm pp 56-90.

DEWAR D (1992). 'Planning for urbanisation: A conceptual framework', *Journal of the Institution of Municipal Engineers of South Africa*, Vol 17:1, 17-20.

LANGENDORF R (1985). 'Computers and Decisionmaking', *Journal of the American Planning Association*, Vol 51:4, 422-432.

ROSMARIN & ASSOCIATES (1992). *Report A: Land Availability Study*, Central Witwatersrand Metropolitan Chamber Land Task Team, Johannesburg.

SIEG SM (1988). *Residential development in the Johannesburg metropolitan region: and analysis of the dynamics of urban sprawl*, Pretoria, UNISA, Unpublished MSc Thesis.

SIKIOTIS L (1992). *The ORMET approach to transportation planning in a rapidly urbanising environment*, Paper presented as part of SAICE lecture course programme, Johannesburg.