An Integrated Multi-Scaled Decision Support Framework Used in the Formulation and Evaluation of Land-Use Planning Scenarios for the Growth of Hervey Bay

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Abstract: This paper investigates how demographic (socio-economic) and land-use (physical and environmental) data can be integrated within a multi-scaled decision support framework to formulate and evaluate land-use planning scenarios. A case study approach is undertaken using 'what-if' planning scenarios for a rapidly growing coastal area in Australia, the Shire of Hervey Bay. The town and surrounding area requires careful planning of future urban growth between competing land-uses. Three potential urban growth scenarios are put forth to address this issue. Scenario A - 'business as usual' is based on existing socio-economic trends. Scenario B – 'maximisation of rates base' has been derived using optimisation modelling of land valuation data. Scenario C – 'sustainable development' has been derived using a number of environmental layers and assigning weightings of importance to each layer using a multiple criteria analysis (MCA) approach. The 'what-if' planning scenarios are presented through the use of maps and tables within a geographical information system (GIS), which delineate future possible land-use location-allocations. Work is currently being undertaken to evaluate the effectiveness of each of the three modelling approaches utilised in formulating the different scenarios using both comparative analysis and a goals achievement matrix (GAM), based upon a number of criteria which are derived from key policy objectives outlined in; the regional growth management framework for the Wide Bay Region, and the Hervey Bay City Planning Scheme. The outcomes of this paper discuss the advantages and disadvantages of each of the three modelling approaches with respect to formulating future urban growth scenarios.

Keywords: land-use modelling; planning support systems; 'what-if' planning scenarios

1. INTRODUCTION

The principal aim of this paper is to develop a methodology for investigating the research question: how can demographic (socio-economic) and land-use (physical and environmental) data be used to efficiently plan for future urban growth? In order to validate the methodology a case study approach is used to develop and test a number of 'what-if' planning scenarios.

The methodology is formulated in terms of a number of land-use planning scenarios for the future growth of Hervey Bay, a rapidly urbanising coastal town in Australia. An integrated multi-scaled decision support framework to evaluate different planning techniques is described. The framework incorporates predictions and tactical planning for land-use change based upon: i) projections from existing trends, ii) optimising socio-economic output, and iii) decision trade-offs on a variety of factors. This paper briefly describes the modelling parameters underlying all three techniques, whilst map results are given only for the third technique. This is because the results of the first technique have already been described in previous papers [Pettit, 2001] and [Pettit and Pullar, 2001] and the results of the second technique are to be discussed in a future paper. Despite focussing upon one technique, the paper does elaborate on the framework for making land-use change predictions and evaluating planning scenarios using spatial analysis in a GIS. These spatial analysis methods include assessing land requirements, development constraints, land-use transition rules, and urban expansion based upon accessibility to services. The evaluation of the planning scenarios uses a goals-achievement matrix (GAM), which brings to light how a particular planning scenario performed against local and state planning policies and objectives. Finally, the outcomes of this paper will discuss the advantages and disadvantages of each of the three modelling approaches with respect to formulating future urban growth scenarios.

2. METHODOLOGY

2.1 Introduction

An integrated multi-scaled decision support framework is used to formulate and evaluate three 'what-if' planning scenarios. A number of aggregate and disaggregate environmental, social and environmental data layers feed into the model in order to generate different land-use planning scenarios. The methodology developed in this paper is based upon the scenario planning approach as advocated by [Stillwell et al., 1999]. Scenario planning focuses upon map representations developed through the employment of analytical 'what-if' functions and spatial modelling usually undertaken in a GIS. It is closely connected to the view that planning should offer inspired visions of the future, based upon likely or preferred scenarios which are either founded upon existing planning policy or used to formulate planning policy.

2.2 The Scenario planning methodology

The scenario planning approach applied to the case study area of Hervey Bay is shown in Figure 1. The principal planning task is to bring about the efficient planning of future urban growth in Hervey Bay. The core objectives and policies which assist in the formulation of different planning scenarios are derived from the Wide Bay 2020 Regional Growth Management Framework – RGMF [DCILGPS, 1999], and the Hervey Bay Town Planning Scheme [HBCC, 1996]. The objectives from each of these plans assist in deciding upon the socio-economic, physical and environmental data required to formulate the different planning scenarios. The objectives are also used later in the methodology to evaluate the efficiency of each proposed 'what-if' planning scenario.

A number of socio-economic, physical and environmental data inputs are required to drive the land-use planning scenarios. Core socio-economic data inputs include: population projections, industry employment projections, projected average household size and the projected number of dwellings. Core physical and environmental data inputs include: cadastral land parcels, building footprints, road, sewer, water, land-use, remnant vegetation, national parks, riparian vegetated areas, coastal wetland, areas of prime agricultural land, and existing open space.

The next step of the methodology is to formulate possible 'what-if' land-use scenarios. Three land-use planning scenarios are formulated for Hervey Bay. Scenario A - 'business as usual' is based on existing socio-economic trends. Scenario B – 'maximisation of rates base' has been derived using optimisation modelling of land valuation data. Scenario C – 'sustainable development' has been derived using a number of environmental layers and assigning weightings of importance to each layer using a multiple criteria analysis (MCA) approach.

As previously mentioned the evaluation of each of the three land-use scenarios is undertaken using the core planning strategies. The objectives and policies contained within these strategies are used in evaluating the efficiency of each proposed land-use scenario, through the use of a GAM. The process of evaluation is considered iterative in that the results found through preliminary evaluation of the scenarios can lead to the re-working of a scenario. The end result of the scenario planning approach is the formulation of a final plan, to be implemented and reviewed accordingly.

The next part of this paper will investigate in further the underlying models associated with each of the three 'what-if' planning scenarios formulated for the Shire of Hervey Bay.

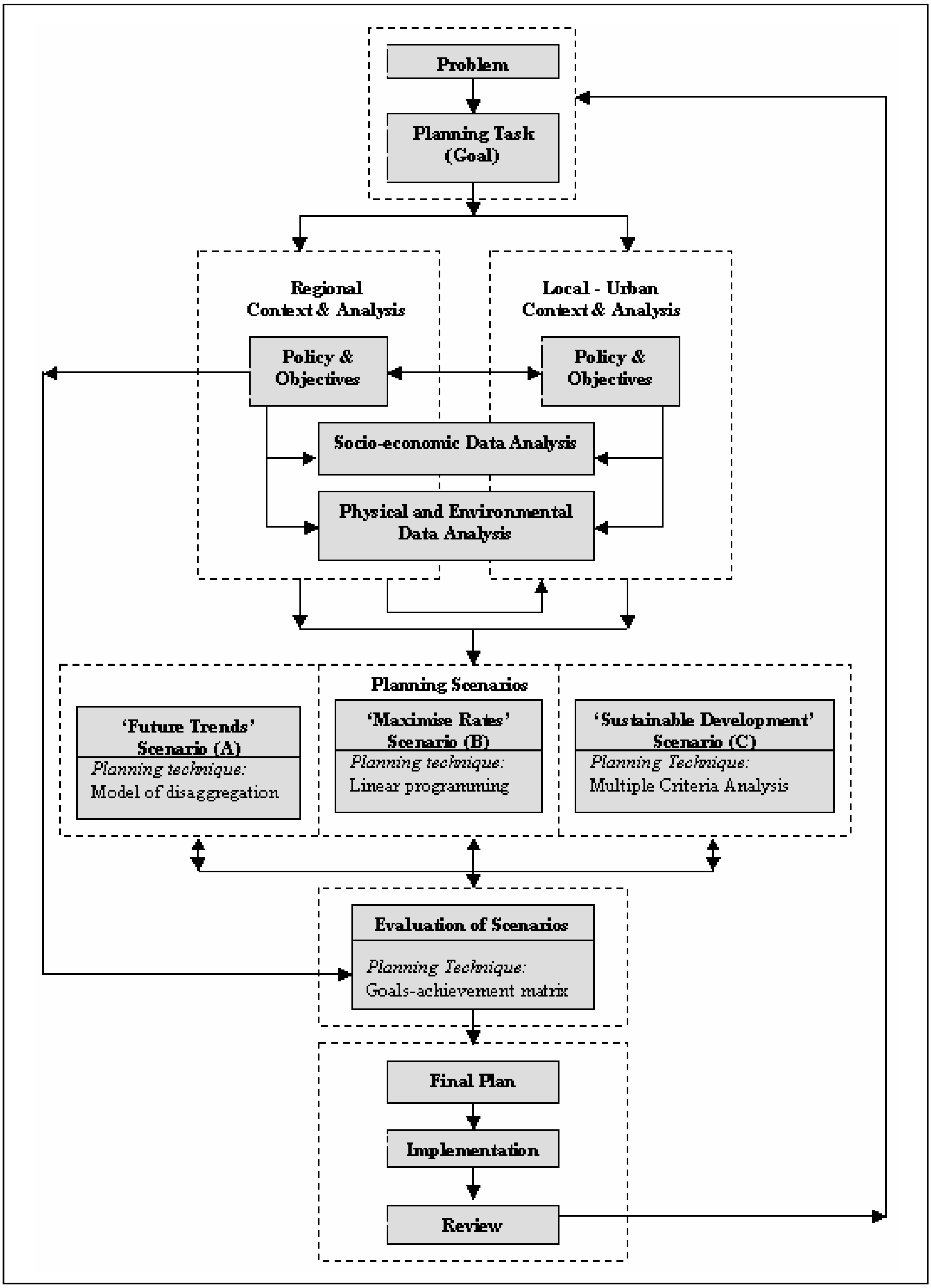

Figure 1. Scenario Planning Framework

3. 'WHAT-IF' PLANNING SCENARIOS FOR HERVEY BAY

3.1 Introduction to Hervey Bay

The Shire of Hervey Bay is situated within the Wide Bay-Burnett region along the east coast of Australia in the State of Queensland and occupies an area of approximately 2,340 square kilometres – see Figure 2. Hervey Bay includes North Fraser Island (World Heritage area) and its neighbouring islands, which account for nearly half of the shire's total land area (1,010 square kilometres).

Socio-economic characteristics of Hervey Bay include: strong population growth, high levels of unemployment and an economy dependant upon the tourism industry and settlement driven by retirees.

The planning issues for Hervey Bay are: to support the growth of the area, provide a balanced socio-economic climate, and protect the existing environmental amenity. Each of the planning scenarios takes into account the various problems and issues facing the Shire in planning for future urban growth up until 2021.

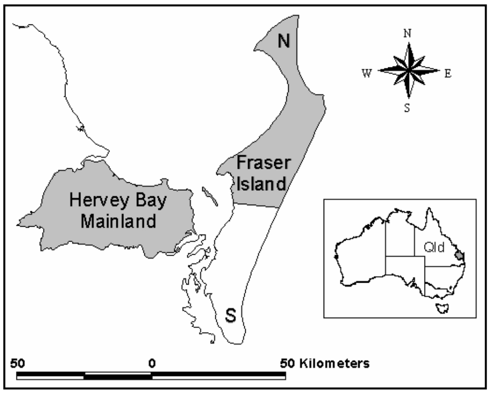

Figure 2: Shire of Hervey Bay Locality Diagram

3.2 Business as Usual Scenario (A)

The first of the scenarios makes predictions of land-use change based upon existing socio-economic trends. This is essentially a 'do-nothing' scenario that takes a business as usual approach based upon existing regional and urban trends. Equations (1) and (2) are used to formulate the land-use requirements for this scenario. Equation (1) has been adapted from [Peckol and Erickson, 2000] in their analysis of industrial land supply and demand in the Central Puget Sound Region of Washington and is used here to calculate the required projected land for light industrial, general industrial , and commercial purposes in Hervey Bay 2021. Equation (2) is used to calculate the required residential land, including: park residential, low-density residential and medium density residential required in Hervey Bay 2021.

$$L_j = (Eg_{ij} \times Er_i) \div Cr_i \qquad (1)$$

$$L_j = AvP_i \times Dw_{ij} \qquad (2)$$

Where L_j is Land required, Eg_{ij} is employment growth, Er_i is employment ratio (total area (m2) per employee), Cr_i is the coverage ratio, AvP_i is the average land parcel size (m2), and Dw_{ij} is the projected number of new dwellings.

To decide the most suitable location of the projected land demand with respect to land supply in Hervey Bay up until 2021, an accessibility index and land transition rules using a land-use/compatibility matrix have been used. The accessibility index is measured using three parameters: distance to the CBD, distance to the harbour, and distance to major roads (arterial and sub-arterial). The accessibility index has been formulated within a GIS, using programs to calculate distances from each developable land parcel to each of the three attractors using equation (3) expressed below:

$$Ac_{i,jkl} = \frac{1}{w_j}.(\Sigma_{ij}\, d_{ij}) + \frac{1}{w_k}.(\Sigma_{ik}\, d_{ik}) + \frac{1}{w_l}.(\Sigma_{il}\, d_{il}) \qquad (3)$$

Where Ac = accessibility index for available land parcel i; j = major road; k = Central Business District; l = Harbour; w = weighting; R = accessibility to major road; C = accessibility to CBD; H = accessibility to Harbour; d = distance.

Also within a GIS a number of transition rules, such as proximity restrictions (i.e. outer limit for which a particular land-use could be located from similar existing development) and a land-use / zoning compatibility matrix are used to formulate the final land-use allocation map.

3.3 Maximisation of Rates Scenario (B)

The objective of this scenario is to establish the optimal land-allocation for each of the competing land-uses within the Shire of Hervey Bay, in order to maximise the Council's rate base. The scenario utilises linear programming, based upon a similar methodology put forth by Chuvieco [1993], which integrates linear programming and GIS for land-use modelling.

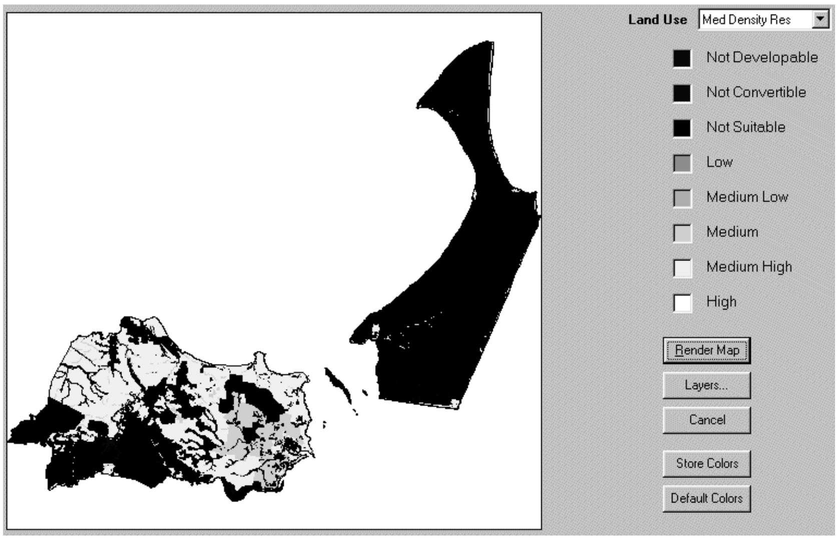

Figure 3. Medium Density Residential Land Suitability Map

The result of the linear program is an optimal land allocation for each of the land-use categories within Hervey Bay, based upon the constraints put forth in the model which include: environmental protection, minimum labour supply, desirable land-labour usage, economic industry clustering, existing agricultural land, minimum open space, and maximum available water supply.

Similarly to Scenario A, an accessibility index equation (3), land transition rules and a land-use/compatibility matrix have been used to decide the most suitable location of the projected land demand with respect to land supply in Hervey Bay up until 2021.

3.4 Sustainable Development Scenario (C)

This scenario focuses upon the principal of environmentally sustainable development (ESD) and takes into account areas of both environmental and economic significance and allows trade-offs to occur between these sometimes-conflicting areas. The What if? collaborative planning support system (PSS) developed by Klosterman [1999] has been used to formulate the ESD scenario. What if? uses a MCA, weighted linear combination (WLC) technique, in formulating land suitability maps – as shown in equation (4).

$$S = \sum (w_i x_j).\prod c_j \quad (4)$$

Where: S = suitability, $_{i}$ = a decision factor, $_{j}$ = a constraint, c_j = the criterion score of constraint; w_i = weight such that a value of 1 is important down to a value of 0; x_i = criterion score of factor $_{I;}$ Σ = the sum; and Π = the product.

The technique allows the user to assign various weightings of importance to different land-use factors and examine the results both in report and map form. Environmental layers including; remnant vegetation, riparian vegetation, national parks, state forests, coastal wetlands, and good quality agricultural land are assigned appropriate weightings of importance in order to produce land suitability reports and maps. Figure 3 illustrates a suitability map for medium density residential land created using What if?.

4. EVALUATION

The planning scenarios A, B and C and the underlying techniques used to formulate each scenario are comparatively evaluated in terms of their advantages and disadvantages in Table 1. The ‘business as usual’ scenario provides a good measuring stick for which to compare the results of scenarios B & C. The ‘maximisation of rates’ scenario is based upon a sound economic objective and uses linear programming, a proven management decision tool to optimally define projected land-use demands. The disadvantage of using the disaggregation equations, accessibility indices, and linear programming structure associated with Scenarios A & B is that these are top-down approaches which do not incorporate community consultation into the scenario building process. In contrast, this is in-fact one of the significant strengths in using the What if? PSS software, used to formulate the ‘sustainable development’ scenario. The principal limitation in using the What if? package is that to date, there are limited real world applications of the software to gauge the success and robustness of the results.

Scenario	Technique	Advantages	Disadvantages
(A) Business as Usual	Disaggregation equations, Accessibility Index	Good yard stick	Top-down
(B) Maximisation of Rates	Linear programming, Accessibility Index	Proven Management Decision technique	Top-down
(C) Sustainable Development	Multiple Criteria Analysis (WLC)	Bottom-up, flexible	Limited Real World Applications

Table 1. Comparison of 'What-if' Planning Scenarios

Evaluation of each of the scenarios using a GAM is currently being undertaken and will be based on the methodology discussed in section 2.2 of this paper.

5. CONCLUSIONS

This paper has presented an integrated multi-scaled decision support framework in the form of the scenario planning approach, and has briefly outlined the three future land-use scenarios comprised within the framework, as formulated for the Shire of Hervey Bay.

Each of the scenarios and their underlying models has been demonstrated to the Hervey Bay City Council Town Planning Department. Collaborative work is now underway with the Council in order to formulate the draft 2021 strategic plan for the Shire of Hervey Bay, based upon the sustainable development scenario, using the What if? PSS package. Further work is required in 'tweaking' the input parameters of each of the scenarios and undertaking sensitivity analysis. Also a comprehensive quantitative comparative analysis of the results of each of the three scenarios, using a GAM, is yet to be finalised.

6. ACKNOWLEDGEMENTS

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