Coastal Management Issues in Queensland and Application of the Multi-Criteria Decision Making Techniques



ABSTRACT

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Coastal management in Australia has been improved over late 20th century. As it is known, Australia has a three-tier system of government. These tiers include the Commonwealth, the State and Territory governments, and local governments. The Commonwealth Coastal Policy has been released by Government in 1995. Despite this Policy, it should be considered that the Commonwealth has historically played no significant role in coastal management in Australia and it has been characterized by state domination and, local governments are empowered by state legislation to exercise certain planning controls in coastal area. In Queensland, Coastal Protection and Management Act has been established in 1995 and consequently the State Coastal Plan commenced on 27 February 2002. This plan describes how the coastal zone of Queensland is to be managed. For more detailed planning and management, the Queensland Coastal Management Plan has been divided into eleven regions. In order to remain relevant, these regional coastal plans have to be reviewed every seven years. This paper presents an application of Multi-Criteria Decision Making Techniques as an approach to deal with reviewing regional coastal plans. Two techniques including of Analytic Hierarchy process and Fuzzy AHP have been selected to obtain preference weights of land suitability criteria in a case study area located in south-east Queensland. These techniques have proved useful to handle the problems which involve the design of alternatives which optimize the objectives. On the other hand it enables researchers to put more experts' knowledge together to make more precise decision and moderate personal judgments.

ADITIONAL INDEX WORDS: Multi-criteria Decision Making, coastal area, land suitability criteria, preference weights, AHP, Fuzzy AHP.

INTRODUCTION

The Australian coastline is about 36,700 kilometers long (Commonwealth of Australia, 1995). It is estimated that about 86 per-cent of Australia's total population, including nearly half of the nation's indigenous people live within coastal zone.

This coastal area contains a wide range of climatic, geological and oceanographic regions which house a very rich store of biological diversity. On the other hand, there is a diverse and interacting mixture of terrestrial, estuarine and marine ecosystems, ranging from coral reefs to coastal forests, which directly or indirectly provide many of the resources needed for a broad range of commercial and non-commercial uses and activities. This coastal zone also contains the largest area of coral reefs and the third-largest area of mangroves of any nation, and it has globally significant populations of a number of endangered species.

Following the international acceptance of the need to improve coastal management practices, coastal management in Australia has been improved over late 20th century. In Australia, coastal management underwent a period of extensive review in the early 1990s at both Commonwealth and State levels. At the national level, this culminated in the production of the *Resource Assessment Commission's Coastal Zone Inquiry*, Final Report. The RAC recommended a national approach to coastal zone

management because of the increase in both population and development along the coast. It proposed a *Commonwealth Coastal Resource Management Act* to incorporate the objectives and principles of coastal management agreed to by the states and the Commonwealth (THOM and HARVEY, 2000). Therefore, following *the RAC Inquiry*, a foundation existed for Commonwealth action. Finally the government released the *Commonwealth Coastal Policy* in May 1995. The purpose of this Policy was to provide a clear statement of the Commonwealth Government's position on coastal management matters and to identify the initiatives that the Commonwealth will take to help improve the management of the coastal zone.

Despite the Commonwealth Coastal Policy, it should be considered that the Commonwealth has historically played no significant role in coastal management in Australia and it has been characterized by state domination. In Australia, State governments are statutory authorities for coastal management (HARVEY and CATON, 2003). On the other hand Local governments are empowered by state legislation to exercise certain planning and management controls in coastal area. Hence, in the presented research Multi-Criteria Decision Making techniques have been introduced to deal with coastal planning in local government levels.

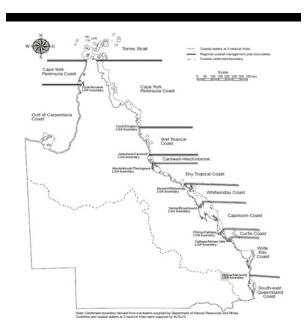


Figure 1. Coverage of Queensland regional coastal management plans (Queensland State Government, 2002).

COASTAL MANAGEMENT IN QUEENSLAND

Coastal Protection and Management Act, has been established for Queensland in 1995. According to this Act, coastal management is to be achieved by coordinated and integrated planning and decision making, involving, among the Coastal management plans, Coastal management districts and use of other legislation. As a statutory instrument under section 29 of the Coastal Protection and Management Act 1995, the State Coastal Plan commenced on 27 February 2002. This plan describes how the coastal zone of Queensland is to be managed; actually it provides direction for coastal management in Queensland. Through this plan, major challenges associated with managing the long term impacts of natural events and human activities can be met to ensure the coast is protected for future generations. For more detailed planning and management, the Queensland Coastal Management Plan has been divided into eleven regions. The region's boundaries are based on coastal local government boundaries. Each of these regions is to be covered by a regional coastal management plan. In this research the selected study area is located in South East Queensland region which is covered by SEQ Coastal Plan. This plan provides specific regional direction on coastal management outcomes in support of the State Coastal Plan and aims to manage development and growth along the South-east Queensland coast in a sustainable way in order to minimise the adverse impacts on coastal resources (Queensland State Government, 2006). This plan is in accordance with SEQ Regional Plan 2005-2026 which has been prepared due to section 2.5A of the Integrated Planning Act 1997. The SEQ Regional Plan commenced on 30 June 2005 and is a statutory instrument under the Statutory Instruments Act 1992 (Queensland State Government, 2006). The Plan provides the framework for managing growth, change, land use and development in the SEQ region to the year 2026 and it is the pre-eminent plan for the SEQ region and takes precedence over all other planning instruments. Beside all these hierarchy process, regional coastal plans have to be reviewed every seven years in order to remain relevant (Queensland State Government, 2005). As it has been mentioned, this paper presents an application of Multi-Criteria Decision Making Techniques as an approach to deal with reviewing regional coastal plans by selecting a study area in SEQ region.

STUDY AREA

The North East Gold Coast in SEQ region is considered as a suitable study area. This area is situated in a highly accessible location between the two major urban areas in South East Queensland - Greater Brisbane and the Gold Coast. The study area's coastal boundary is located near the Moreton Bay Marine Park and comprises approximately 17,250 hectares of land bordered by the Logan River to the north, the Pacific Motorway on the west, the boundary of the urban footprint in the vicinity of Yawalpah Road and McCoys Creek to the south and southern Moreton Bay to the east. The majority of this area is included in the Regional Landscape and Rural Production Area regional land use category under the SEO Regional Plan (Department of Infrastructure and Planning, 2007). Most of the land in the area is used for the production of sugar cane which supplies the local Rocky Point sugar mill. The study area contains a wide range of values and natural resources which, in combination with its location and large agricultural land holdings, have meant that it has faced a variety of development pressures for many years. The SEQ Regional Plan has clarified that the majority of the study area is not intended to be developed for urban purposes. However there is still a significant number of competing rural and resource uses including sugar cane production, extraction of sand resources and potential for expansion of the aquaculture industry that need to be resolved. In addition there is a range of other land use pressures on the study area including demand for general aviation facilities, expansion of the marine industry and general expansion of industrial areas that need to be resolved through the development of a long-term strategy for the area.

In this research, in regard of worldwide use of Multi-Criteria Decision Making (MCDM) techniques in natural resource and environmental management and planning, these techniques has been utilized as an approach in order to have more sustainable development planning in coastal areas.

MULTI-CRITERIA DECISION MAKING

Decision making is an essential part of almost all human life. Making a decision involves a choice among alternatives. A decision is the point at which a choice is made between alternative options. It is stated that making decisions involves processes that includes gathering information and generating, contemplating, and evaluating alternative courses of action, as well as processes of implementation and evaluation that should follow a decision once made. In other words the problem can be abstracted as how to derive weights, ranking or importance for a set of activities according to their impact on the situation and the objective of decisions to be made. (HERATH and PRATO, 2006). MCDM techniques have emerged as a major approach for solving natural resource management problems and integrating the environmental, social, and economic values and preference of stakeholders. Based on literature reviewed among the numerous alternatives proposed, some of the most commonly used MCDM methods are:

- AH
- Weighted sum
- EIECTRE(Elimination Et Choix Traduissant la REalite)
- TOPSIS
- Fuzzy techniques

In this research the main aim is weighting and ranking the importance of the criteria which can be related to coastal management and planning and also identifieng the priorities between them. In other words, preferences information will be required. In this situation AHP can be utilized to deal with decision making problem. This technique is widely used and have been applied in some decision-making scenarios such as: selection between a set of alternatives, prioritisation, resource allocation and many other management areas.

The Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a mathematical method for analyzing complex decision problems under multiple criteria (QURESHI and HARRISON, 2003). This method is known as one of the most important MCDM techniques (TASLICALI and ERCAN, 2006). The AHP was created by Thomas Satty in the late 1960's. It is based on the well-defined mathematical structure of consistent matrices and their associated right eigenvector's ability to generate true or approximate weights. In other words it is based on simple pair-wise comparison and it means two elements at a same time can be compared. The values of the pair-wise comparison are the member of the set: {9,8,7,6,5,4,3,2,1, 1/2,1/3,1/4,1/5,1/6,1/7,1/8,1/9},9 representing absolute importance and 1/9 the absolute triviality. Since then, the simplicity and power of the AHP has led to its widespread use across multiple domains in every part of the world (KRISTOF, 2005). In general, this technique was developed to select the best from a number of alternatives with respect to several criteria. Table 1 shows the scale of AHP.

FUZZY AHP

In order to deal with problems involving vagueness of human thinking, Dr Lotfi A. Zadeh in 1965 proposed a new theory called "Fuzzy Sets". The fuzzy logic is useful to define the real world objects which are characterized by uncertainty. A main contribution of fuzzy set theory is its ability to represent unclear data. In order to improve the abilities of AHP some research has been done to apply fuzzy logic principles to deal with the imprecise and uncertain problem in the pair-wise comparison process. Laarhoven and Pedrycz in 1983 take the lead in applying fuzzy logic principle to Saaty's AHP and initiate triangular fuzzy

numbers based on arithmetic operation to express decision maker's evaluation of alternatives with respect to each criterion (CHEN, 2005). In this approach instead of a single crisp value (set of 1 to 9), Fuzzy AHP uses a range of values to incorporate uncertainties in the decision maker's opinions. This triangular fuzzy number is defined by a triplet (l, m, u) and it is defined as:

$$\mu_{\overline{\alpha}}(x) = \begin{cases} (x-l)/(m-l), l \le x \le m \\ (u-x)/(u-m), m \le x \le u \\ 0, otherwise \end{cases}$$
 (1)

This triangular fuzzy number is based on a three-value judgment: the minimum possible value l, the most possible value m and the maximum possible value u. Therefore from this rang; decision makers can select the value that reflects their confidence and it leads to have precise results.

METHODS AND RESULTS

Analysis of existing condition

In all kinds of planning approaches, considering current environmental and population situation is necessary in order to reduce the possible future conflicts. Hence, in order to address the capabilities and limitations of land with a particular natural feature to accommodate a specified type or intensity of development, current environmental situation investigated.

In this case current land use and land cover maps prepared in ArcGIS 9.2 by utilizing IKONOS satellite imageries of the study area.

The results show the majority of study area is under sugar cane cropping which comprises 7262 hectares of land. These areas are the only significant sugar cane industry in SEQ. On the other hand, natural constraints have been considered. The main physical constraint affecting the study area is flooding and the potential impacts of climate change on the flood regime. Additionally the study area contains acid sulfate soils, and several sites with potential contaminated land which are restricted for some types of land use categories.

Table 1: The fundamental Scale of AHP (SAATY and VARGAS, 2001).

Intensity of importance	Definitions	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak	Experience and judgment slightly favour one activity over another
3	Moderate importance	и
4	Moderate plus	Experience and judgment strongly favour one activity over another
5	Strong importance	u
6	Strong plus	An activity is favoured very strongly over another; its dominance demonstrated in practice
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	The evidence favouring one activity over another is of the highest possible order of affirmation
9	Extreme importance	u

The investigation on population characteristics is gathered from census data. Based on census data from 2006, 2007 and 2008, this study area comprises the four population centres of Eagleby, Jacobs Well, Ormeau and Steiglitz and a predominantly rural hinterland area.

Choosing Land Suitability Criteria

Identification of land suitability criteria is a technical activity, which is based on theory and empirical research. Literature review and the expert's knowledge are tools that assist researchers in the selection of criteria. In this research criteria which are important to allocate a specified parcel of land to the future residential uses investigated. Step one of this process was definition of criteria.

Two groups of criteria considered in this research i.e. factors and constraints. A factor is an attribute that improves the suitability of an area, while a constraint limits by enforcing restrictions to the development (MWASI, 2001). Eventually 6 factors considered as following: proximity to the transportation networks, proximity to the retail or commercial areas, existence of water resource, existence of infrastructures, proximity to the sewer districts and proximity to the one of the existing growth corridor. On the other hand, 5 constraints were identified as following: floodplain areas, fire-hazard regions, conservation areas, significant remnants vegetation regions and wetlands.

Weighting and Ranking the Criteria

As it is known, different criteria usually have different levels of importance. In this research, relative importance of each criterion evaluated by utilizing multi- criteria decision making techniques (AHP and fuzzy AHP). After identification the criteria, the research team weighted each criterion by implementation two different mathematical functions for AHP and fuzzy AHP. This process of identification the relative importance of the criteria over each other is called standardization. This process is usually done on 0 to 1 scale; it means the criteria weights need to be summed up to 1. In this approach all criteria set as a pair-wise matrix and the priority of each criterion with respect to the future residential development was calculated. As the mathematical function all the elements in the matrix's row were multiplied and the nth root were calculated and then divided by their sum to get the normalized results.

As the results showed, considering floodplain levels by 0.2841 score is the most important issue in allocating land parcels for residential uses in this particular study area. In the next level, the priorities of fire-hazard region and proximity to the existing growth corridors are 0.1802 and 0.1099, respectively. Considering conservation areas, wetlands, existence of water resources and transportation networks and significant remnants vegetation regions are placed on the next levels, respectively (0.0944, 0.8056, 0.5276, 0.0502, and 0.0487). Eventually, based on the results, criteria with less important values are existence of infrastructure with 0.0479 score, proximity to the sewer districts, 0.0287 and proximity to the retail or commercial areas in the last level with 0.02246 score.

In the fuzzy AHP approach, we used triangular fuzzy numbers in the pair-wise comparison matrix. It means that instead of one single value to address the relative importance of each criterion, triangular fuzzy number was used. For example while in AHP, 9 represents the extreme importance, in fuzzy AHP (5/2, 3, 7/2) plays the same rule. In this new matrix 3 represents the most possible value of a fuzzy number and 5/2 and 7/2 are the lower

Table 2: Fuzzy AHP weighting and ranking results

Criteria	Ranking value
floodplain areas	0.1364
fire-hazard regions	0.1187
proximity to the one of the existing growth corridor	0.1023
wetlands	0.0982
conservation areas	0.0955
significant remnants vegetation regions	0.0928
existence of water resource	0.0887
proximity to the transportation networks	0.0832
existence of infrastructures	0.0764
proximity to the sewer districts	0.0628
proximity to the retail or commercial areas	0.0450

and upper bounds. The lower and upper bounds represent the uncertainty that might exist in the decision maker's opinion.

Table 2 shows final results after implementation of fuzzy AHP arithmetic functions.

DISCUSSION

The results of the both approaches are satisfactory. Both methods showed that considering floodplain areas is the most important criteria with respect to the residential uses. In comparison it should be mentioned that a few differences observed. For example while conservation areas are placed in the fourth level of importance by utilizing AHP, fuzzy AHP considered wetlands more important than conservation areas. The same situation can be seen for significant remnant vegetation.

Based on the fact that fuzzy AHP incorporates uncertainty of expert opinions, this approach leads more precise and logic results. Hence it can be said that, the results of the fuzzy AHP in this research seems more accurate and trustable.

CONCLUSION

Uncontrolled development can rapidly exceed degrading natural resources and the quality of life for residents. Obviously any activity which occurs along the coast has the potential to be environmentally damaging; the only way to ensure that human action does not cause damaging effects along the coast is logical and wise operation under a system of sustainable management. According to the increasing need of coastal lands for urban areas applying new approaches such as MCDM techniques certainly will be useful. These techniques widely have been used as a powerful tool in land suitability analysis. In this research the strength of these techniques has been proven. The results can be used in order to make decision for future development in the area and also to review the SEQ regional plan and to guide future amendments to the Gold Coast City.

LITERATURE CITED

CHEN, X. H., 2005. A research based on Fuzzy AHP for Multi- Criteria supplier selection in supply chain. Taiwan: National University of Science and Technology. Master's thesis, 74 p.

COMMONWEALTH Of AUSTRALIA, 1995. The Commonwealth Coastal Policy: http://www.environment.gov.au/coasts/publications/coastal-policy/index.html.

- DEPARTMENT OF INFRASTRUCTURE AND PLANNING, 2007. North-East Gold Coast strategic land use, economic development and infrastructure study, Terms of References, office of urban management, 20 November 2007.
- HARVEY, N. and CATON, B. 2003. Coastal Management in Australia. Oxford University press.
- HERATH, G. and PRATO, T. 2006. Using Multi-Criteria Decision Analysis in Natural Resource Management, ASHGATE, Athenaeum Press Ltd, Gateshead Tyne & Wear.
- Kristof, G. M., 2005. Planning Business Improvement Using Analytic Hierarchy Process and Design structure Matrix. Montana: Montana State University, Master's thesis, 111 p.
- MWASI, B. 2001, Land use Conflicts Resolution in a Fragile Ecosystem Using Multi-Criteria Evaluation and A GIS-based Decision Support System. *International Conference on Spatial Information for Sustainable Development* (Nairobi, Kenya), paper TS14.2.
- QUEENSLAND STATE GOVERNMENT, 2002. State Coastal Management Plan: http://www.epa.qld.gov.au/environmental_management/coast_and_oceans/coastal.
- QUEENSLAND STATE GOVERNMENT, office of urban management, 2005. South-east Queensland Regional Plan 2005-2026., 137p.
- QUEENSLAND STATE GOVERNMENT, 2006. South-east Queensland Regional Coastal Management Plan, August 2006. 70p.

- management/state coastal management plan/.
- QURESHI, M. E. and HARRISON, S. R. 2003. Application of the Analytic Hierarchy Process to Riparian Revegetation Policy Options. *Small-scale Forest Economics, Management and policy*, 2(3): pp. 441-458.
- SAATY, T.L and VARGAS, L.G. 2001. Models, Methods, Concepts and Applications of the Analytic hierarchy process: International Series In Operations Research and Management Science vol. 34, 352 p.
- TASLICALI, A.K and ERCAN, S. 2006. The Analytic Hierarchy & the Analytic Network Processes in Multi-criteria Decision Making: A comparative study. *Journal of Aeronautics and Space technologies*, volume 2 number 4, pp. 55-65.
- THOM, B.G and HARVEYA, N. 2000. Triggers for late twentieth century reform of Australian coastal management, *Australian Geographical Studies*, 38(3), pp. 275-290.

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