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主编 罗宏杰

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（第37集）

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2015 年 1 月

谨以此书纪念本会创建人、故董事会主席王宽诚先生

王宽诚教育基金会

DEDICATED TO THE MEMORY OF MR. K. C. WONG, FOUNDER OF THE FOUNDATION AND THE LATE CHAIRMAN OF THE BOARD OF DIRECTORS

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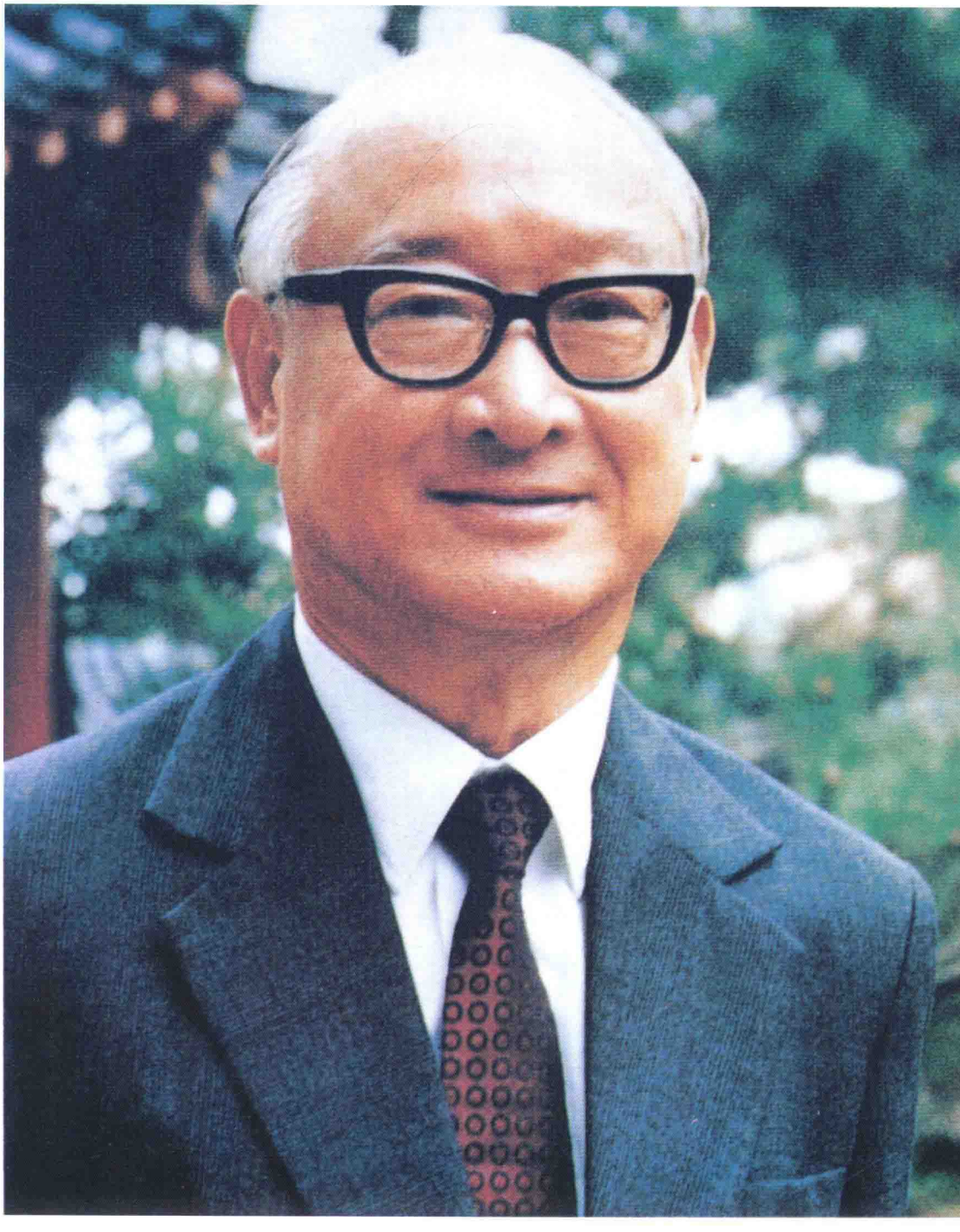

王 宽 诚 先 生

K.C.WONG(1907—1986)

王宽诚教育基金会简介

王宽诚先生(1907—1986)为香港著名爱国人士,热心祖国教育事业,生前为故乡宁波的教育事业作出积极贡献。1985 年独立捐巨资创建王宽诚教育基金会,其宗旨在于为国家培养高级技术人才,为祖国四个现代化效力。

王宽诚先生在世时聘请海内外著名学者担任基金会考选委员会和学务委员会委员,共商大计,确定采用"送出去"和"请进来"的方针,为国家培养各科专门人才,提高内地和港澳高等院校的教学水平,资助学术界人士互访以促进中外文化交流。在此方针指导下,1985、1986 两年,基金会在国家教委支持下,选派学生 85 名前往英、美、加拿大、德国、瑞士和澳大利亚各国攻读博士学位,并计划资助内地学者赴港澳讲学,资助港澳学者到内地讲学,资助美国学者来国内讲学。正当基金会事业初具规模、蓬勃发展之时,王宽诚先生一病不起,于 1986 年年底逝世。这是基金会的重大损失,共事同仁,无不深切怀念,不胜惋惜。

1987 年起,王宽诚教育基金会继承王宽诚先生为国家培养高级技术人才的遗愿,继续对中国内地、台湾及港澳学者出国攻读博士学位、博士后研究及学术交流提供资助。委请国家教育部、中国科学院和上海大学校长钱伟长教授等逐年安排资助学术交流的项目。相继与(英国)皇家学会、法国科研中心、德国学术交流中心、法国高等科学研究院等著名欧洲学术机构合作,设立"王宽诚(英国)皇家学会奖学金"、"王宽诚法国科研中心奖学金"、"王宽诚德国学术交流中心奖学金"、"王宽诚法国高等科学研究院奖学金",资助具有副教授或同等职称以上的中国内地学者前往英国、法国、德国等地的高等学府及科研机构进行为期 2 至 12 个月之博士后研究。

王宽诚教育基金会过去和现在的工作态度一贯以王宽诚先生倡导的"公正"二字为守则,谅今后基金会亦将秉此行事,奉行不辍,借此王宽诚教育基金会《学术讲座汇编》出版之际,特简明介绍如上。王宽诚教育基金会日常工作繁忙,基金会各位董事均不辞劳累,作出积极贡献。

前　言

王宽诚教育基金会是由已故全国政协常委、香港著名工商企业家王宽诚先生(1907—1986)出于爱国热忱，出资一亿美元于1985年在香港注册登记创立的。

1987年，基金会开设“学术讲座”项目，此项目由当时的全国政协委员、历任第六、七、八、九届全国政协副主席、著名科学家、中国科学院院士、上海大学校长、王宽诚教育基金会贷款留学生考选委员会主任委员兼学务委员会主任委员钱伟长教授主持。由钱伟长教授亲自起草设立“学术讲座”的规定，资助内地学者前往香港、澳门讲学，资助美国学者来中国讲学，资助港澳学者前来内地讲学，用以促进中外学术交流，提高内地及港澳高等院校的教学质量。

本汇编收集的文章，均系各地学者在“学术讲座”活动中的讲稿，文章内容有科学技术，有历史文化，有经济专论，有文学，有宗教和中国古籍研究等。本汇编涉及的学术领域颇为广泛，而每篇文章都有一定的深度和广度，分期分册以《王宽诚教育基金会学术讲座汇编》的名义出版，并无偿分送国内外部分高等院校、科研机构和图书馆，以广流传。

王宽诚教育基金会除资助“学术讲座”学者进行学术交流之外，还资助由国内有关高等院校推荐的学者前往欧、美、亚、澳等参加国际学术会议，出访的学者均向所出席的会议提交论文，这些论文亦颇有水平，本汇编亦将其收入，以供参考。

王宽诚教育基金会学务委员会

凡　例

（一）编排次序

本书所收集的王宽诚教育基金会学术讲座的讲稿及由王宽诚教育基金会资助学者赴欧、美、亚、澳等参加国际学术会议的论文均按照文稿日期先后或文稿内容编排刊列，不分类别。

（二）分期分册出版并作简明介绍

因文稿较多，为求便于携带，有利阅读与检索，故分期分册出版，每册150页至240页不等。为便于读者查考，每篇学术讲座的讲稿均注明作者姓名、学位、职务、讲学日期、地点、访问院校名称。内地及港、澳学者到欧、美、澳及亚洲的国家和地区参加国际学术会议的论文均注明学者姓名、参加会议的名称、时间、地点和推荐的单位。上述两类文章均注明由王宽诚教育基金会资助字样。

（三）文字种类

本书为学术性文章汇编，均以学术讲座学者之讲稿原稿或参加国际学术会议者向会议提交的论文原稿文字为准，原讲稿或论文是中文的，即以中文刊出，原讲稿或论文是外文的，仍以外文刊出。

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Decision Support System Based on Matrix Representation for Conflict Resolution

JU Jiang *, FAN Ya-zhuo, XIN Jun-jie, XU Hai-yan

(College of Automation Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P. R. China)

Abstract: A decision support system is designed for providing strategic advice to individuals involved in real-world conflict problems. Conflict is endemic in our world, from disputes within a family to wars between countries, so there is great demand for having a flexible decision support system for systematically investigating a rich range of real world conflicts. The graph model can provide a convenient and effective means to model and analyze a strategic conflict. To take advantage of this opportunity, a computer implemented decision support system based on the matrix representation of the graph model for conflict resolution (GMCR) is proposed in this paper. Although a decision support system, called GMCR II is available for conflict analysis, its coding is difficult to modify or adapt to new analysis techniques and new models. Compared with existing system, the proposed system is more effective and convenient for adapting to new analysis techniques and making codes.

Key words: decision support system, conflict analysis, graph model, matrix representation.

1 Introduction

Strategic conflict arises in diverse contexts, including environmental management and the economic, political, and personal relationships among individuals and organizations. Among the formal methodologies that address strategic conflict, the graph model for conflict resolution (GMCR)[1] provides a remarkable combination of simplicity and flexibility. Standard practice is

* 江驹,教授,南京航空航天大学自动化学院。由王宽诚教育基金会资助,于2011年10月赴美国安克雷奇参加"2011 IEEE系统、人与控制国际会议",此为其向大会递交的论文。

to carry out a stability analysis of a graph model, and then to follow up with a post-stability analysis which is status quo analysis[2]. In stability analysis, an equilibrium is a state that is stable for all decision makers (DMs) under appropriate stability definitions or solution concepts. Status quo analysis aims to determine whether a particular equilibrium is reachable from a status quo (or an initial state) and, if so, how to reach it.

Previously, solution concepts in the graph model were traditionally defined logically, in terms of the underlying graphs and preference relations[1]. When status quo analysis algorithms were developed, this line of thinking was retained and pseudo-codes were developed following a similar logical structure[2]. The novel matrix representation for conflict resolution (MRCR) based on the graph model was developed by Xu et al. [3] The current status of GMCR and MRCR is listed in Table 1. Compared with existing graphical or logical representation, MRCR is more effective and convenient for computer implementation and for adapting to new analysis techniques. The explicit MRCR facilitates stability calculations and status quo analysis in multiple decision maker models.

Table 1 Current status of GMCR and MRCR

Preference information	Stability and post-stability analyses	Definitions based on GMCR?	Algorithms based on GMCR?	Definitions based on MRCR?	Algorithms based on MRCR?
Simple preference	Individual stability analysis	Yes	Yes	Yes	Yes
	Status quo analysis	Yes	Yes	Yes	Yes
	Coalition stability analysis	Yes	No	Yes	Yes
Preference with uncertainty	Individual stability analysis	Yes	No	Yes	Yes
	Status quo analysis	Yes	No	Yes	Yes
	Coalition stability analysis	Yes	No	Yes	Yes
Strength of preference	Individual stability	Yes	No	Yes	Yes
	Status quo analysis	No	No	No	No
	Coalition stability analysis	No	No	No	No

Although GMCR has many advantages, it is difficult to apply in real problems without computational assistance, even to small models. With this purpose, the basic decision support system GMCR II was developed by Fang et al. [4]

GMCR II written in Visual C + +, a computer implementation of the graph model for conflict resolution, is described by Fang et al. [1]. However, as was noted in the development of the decision support system (DSS), GMCR II, the nature of logical representations makes coding difficult. How to design a new decision support system which decreases the difficulties to offer model management and stability analysis and includes status quo analysis procedures? This is essential motivation to develop a matrix-based decision support system including modeling and

analyzing procedures of the graph model in this paper. A matrix-based decision support system, called MRCRDSS, is designed for GMCR to include Nash stability [5, 6], general metarationality (GMR)[7], symmetric metarationality (SMR)[7], sequential stability (SEQ)[8], and status quo analysis. Because the new DSS is based on MRCR, it is easy and flexible to expand having uncertain preference[9] and preference with strength[10] in the near future. Compared with existing system GMCR II, MRCR is more effective and convenient for computer implementation and for adapting to new analysis techniques.

The rest of the paper is organized as follows. Section 2 describes the procedures using the proposed MRCRDSS. In Section 3, a conflict related to environment disputes is modeled and analyzed by the developed MRCRDSS. The paper concludes with some comments in Section 4.

2 Decision Support System Based on Matrix Representation

To expand the realm of applicability, a computer implementation of MRCR is developed in this research. The system based on algebraic characterization of MRCR can facilitate the development of a software package for conflict analysis. The MRCRDSS can efficiently carry out individual stability analysis and status quo analysis. The process to use the MRCRDSS is presented in Fig. 1.

A graph model for a strategic conflict consists of a set of decision makers (DMs), a set of feasible states, and for each DM, a preference relation and a directed graph. Preference information plays an important role in decision analysis. Each DM has preferences among the possible states that can take place. The ordinal preferences (ranking of states from most to least preferred, with ties allowed) and the cardinal preferences (the value of preference function for each state provided by a real number) are often required by some models. The graph model requires only the relative preference information for each DM. The steps using the DSS are as follows:

- Input the decision makers and options;
- Produce corresponding states;
- Input adjacency matrices to represent the relationship among those states;
- Output the graph model containing DMs, states, and move among states;
- Input relative preference information for each DM;
- Output the stability results including Nash, GMR, SMR, and SEQ stabilities;

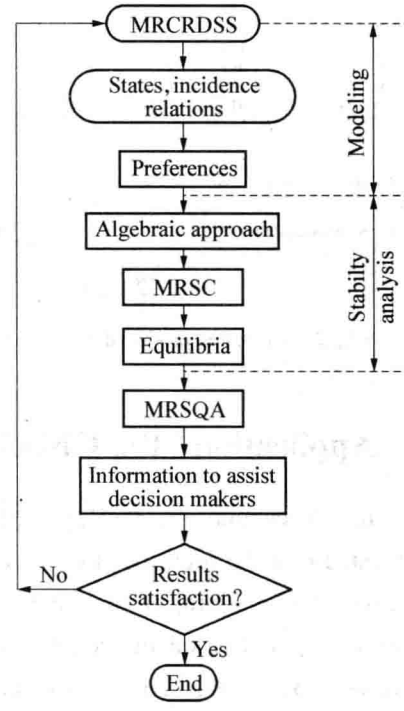

Fig. 1 The process to use MRCRDSS

• Produce all evolutional paths of conflict to take status quo analysis of stabilities.

Note that the results of stability analysis and status quo analysis are obtained using matrix representation for the conflict resolution. Status quo analysis aims to determine all paths from a status quo to a particular equilibrium. Status quo analysis of a graph model involves searching paths in a graph but an important restriction of a graph model is that no DM can move twice in succession along any path. (If a DM can move consecutively, then this DM's graph is effectively transitive. Prohibiting consecutive moves thus allows for graph models with intransitive graphs, which are sometimes useful in practice.) Therefore, if different DMs are colored by different colors, then a graph model can be conveniently treated as an edge-colored digraph in which each arc represents a legal unilateral move, distinct colors refer to different DMs. Thus, tracing the evolution of a conflict in status quo analysis is converted to searching all colored paths with some preference structure such as simple preference.

If the number of options is m, the m options combine to form 2^m possible states in principle. Usually, however, not all option combinations are feasible or logical, so the infeasible states were eliminated and feasible states remained. The MRCRDSS can eliminate the infeasible states. Figures 2 – 3 present the eliminating process. The procedures of using the system MRCRDSS in practice are described in next section.

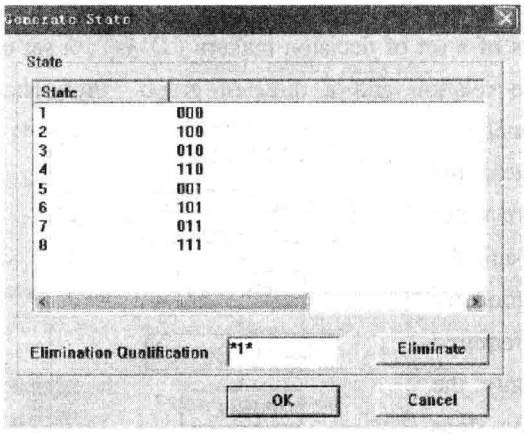

Fig. 2 All states produced by MRCRDSS

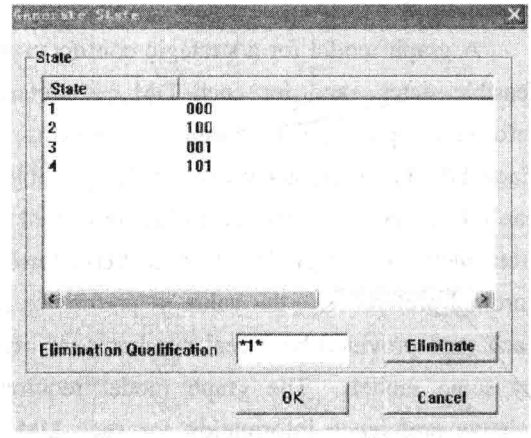

Fig. 3 The remained feasible states by eliminating infeasible states using MRCRDSS

3 Application: the Gisborne Model

In this section, the developed MRCRDSS is applied to a practical problem. Lake Gisborne is located near the south coast of the Canadian Atlantic province of Newfoundland and Labrador. In June 1995, a project to export bulk water from Lake Gisborne to foreign markets was proposed by a division of the McCurdy Group of Companies, Canada Wet Incorporated. On December 5, 1996, the government of Newfoundland and Labrador approved this project because of its potential economic benefits. However, due to the risk of harmful impacts on local

environment, a wide variety of lobby groups opposed the proposal. The Federal Government of Canada supported the opponents and introduced a policy to forbid bulk water export from major drainage basins in Canada. In response to this pressure, the government of Newfoundland and Labrador introduced a new bill to ban bulk water export from the province, forcing Canada Wet to abandon the Gisborne Water Export project (see details in Wet to abandon the Gisborne Water Export project [9, 11]).

Since several groups supported the project, an economics-oriented provincial government might have considered supporting it because of the urgent need for cash. However, an environment-oriented provincial government might have opposed it because of the possibility of devastating environmental consequences. In 1999, it was unclear which of these two different attitudes described the provincial government's thinking, resulting in uncertainty in preferences in the Gisborne conflict. The conflict is modeled using the graph model including three DMs, Federal Government, Provincial Government, and Support Groups. Three DMs' three options are to continue a Canada wide accord on the prohibition of bulk water exports, lift the ban on bulk water exports, and appeal for continuation of the Gisborne project, respectively (see Fig. 4).

The procedures of analyzing the Gisborne model using the developed MRCRDSS are presented as follows:

- Input the numbers of DMs and options and the names of the three DMs, Federal, Provincial, and Support (see Fig. 4);
- Produce 2^3 states presented in Fig. 5;

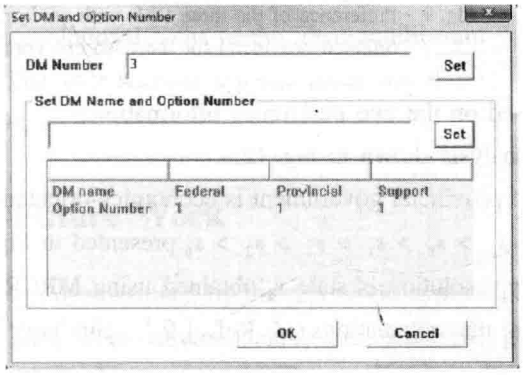

Fig. 4 The numbers of decision makers and options for the Gisborne conflict

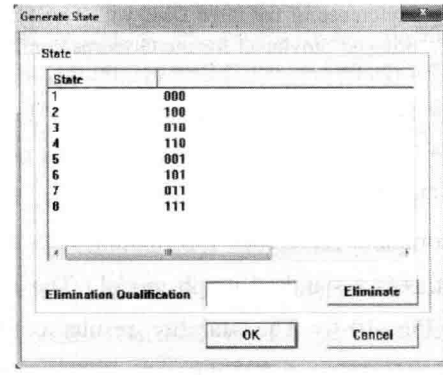

Fig. 5 Produce all states for the Gisborne conflict

- Input the adjacency matrices or reachable lists for each DM to present the relationship among states (see Fig. 6);
- Output the graph mode for the Gisborne conflict using the developed MRCRDSS (see Fig. 7);

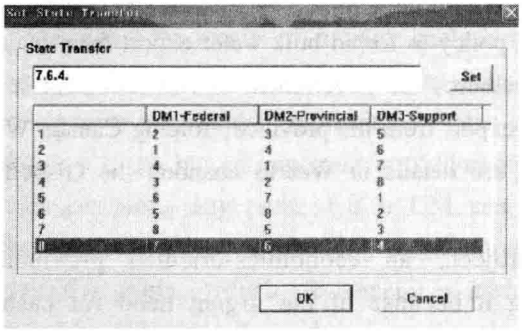

Fig. 6 Reachable lists of each state for the Gisborne conflict

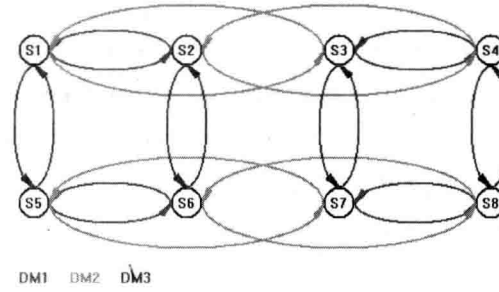

Fig. 7 The graph model for the Gisborne conflict

• Input two preference information based on the two attitudes of provincial government presented in Figs. 8 and 9 into the system MRCRDSS;

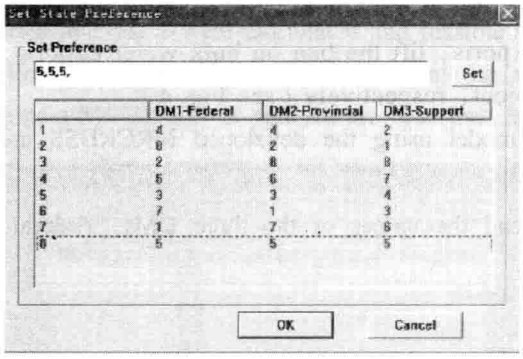

Fig. 8 Preference of the three DMs with economics-oriented provincial for the Gisborne conflict

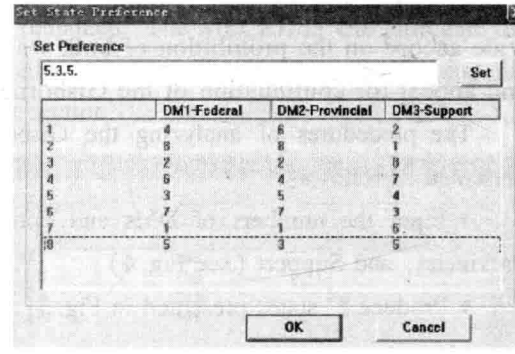

Fig. 9 Preference of the three DMs with environment-oriented provincial for the Gisborne conflict

• Output equilibria in Figs. 10 and 11 based on the two preference information;

• Trace evolutional paths for status quo analysis shown in Fig. 12.

The details are described as follows. If the provincial government is economics-oriented and has complete preference information $s_3 \succ s_7 \succ s_4 \succ s_8 \succ s_1 \succ s_5 \succ s_2 \succ s_6$ presented in Fig. 8, then this is a standard graph model. The likely resolution is state s_4 obtained using MRCRDSS (see Fig. 10). The stability results confirm the calculations of Ref. [9]. Similarly, an environment-oriented provincial government, with preferences $s_2 \succ s_6 \succ s_1 \succ s_5 \succ s_4 \succ s_8 \succ s_3 \succ s_7$ presented in Fig. 10, state s_6 obtained by MRCRDSS is the likely resolution. From the above discussions, we know that the outcome of the conflict depends on the provincial government's attitude. If the support group convinces the provincial government of the urgent need for cash, state s_4 is selected as a resolution for resolving the Gisborne conflict, which means that the economics-oriented provincial government will lift the ban on bulk water export. On the other hand, for the environment-oriented provincial government, the resolution for the

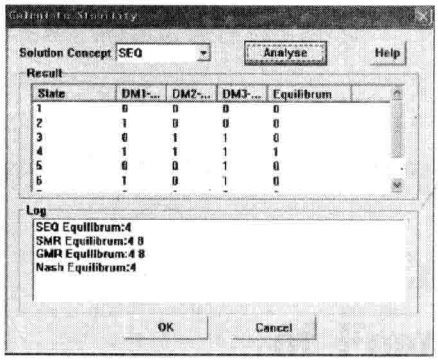

Fig. 10 Stability results with economics-oriented provincial for the Gisborne conflict

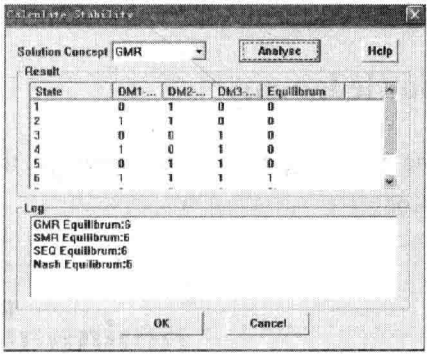

Fig. 11 Stability results with environment-oriented provincial for the Gisborne conflict

Gisborne conflict is likely to be state s_6, which means that the provincial government will not lift the ban. It is trivial to verify that the stability results for the four solution concepts are identical to the findings generated by Li et al. [9].

Status quo analysis is mainly concerned with the attainability of predicted equilibria. Therefore, stability analysis is usually conducted first. The part of results for status quo analysis is also presented in Fig. 12. When the initial state is selected as 1, there are three evolutional paths to the ideal equilibrium s_6. The two shortest colored-paths are $s_1 \rightarrow s_5 \rightarrow s_6$ and $s_1 \rightarrow s_2 \rightarrow s_6$.

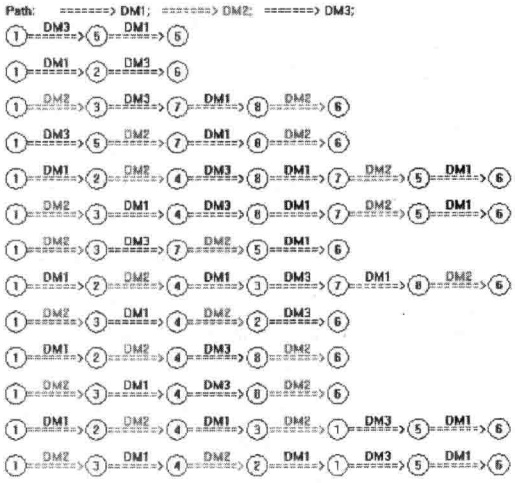

Fig. 12 Status quo analysis for the Gisborne conflict

4 Future Work

As demonstrated by the real world application discussed above in this paper, intense conflict can arise when environmental and economic goals clash. Because of the pervasiveness of conflict, there is great demand for decision aids to address conflict situations. To enhance the applicability for the graph model for conflict resolution, GMCR has been expressed using MRCR in this paper. This structure offers decision makers a more flexible mechanism for stability analysis and status quo analysis. To apply the proposed matrix methods to large conflict models, the decision support system MRCRDSS for carrying out individual stability analysis and status quo analysis for simple preference is developed in this paper. To tackle more complex problems, it would be worthwhile to extend the MRCRDSS system to contain uncertain preference[9] and