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# Fuzzy option prioritization for the graph model for conflict resolution

M. Abul Bashar<sup>a</sup>, D. Marc Kilgour<sup>b,a</sup>, Keith W. Hipel<sup>a,\*</sup><sup>a</sup> Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada<sup>b</sup> Department of Mathematics, Wilfrid Laurier University, Waterloo, Ontario N2L 3C5, Canada

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## Abstract

A fuzzy option prioritization technique is developed to efficiently model uncertain preferences of DMs in strategic conflicts as fuzzy preferences by using the decision makers' (DMs') fuzzy truth values of preference statements at feasible states within the framework of the Graph Model for Conflict Resolution. The preference statements of a DM express desirable combinations of options or courses of action, and are listed in order of importance. A fuzzy truth value is a truth degree, expressed as a number between 0 and 1, capturing uncertainty in the truth of a preference statement at a feasible state. A fuzzy preference formula is introduced based on the fuzzy truth values of preference statements, and it is established that the output of this formula is a fuzzy preference relation. It is shown that fuzzy option prioritization can also be used when the truth values of preference statements at feasible states are completely based on Boolean logic, thereby generating a crisp preference over feasible states that is the same as would be found by employing the existing crisp option prioritization, making the crisp option prioritization technique a special case of the fuzzy option prioritization methodology. To demonstrate how this methodology can be employed to represent fuzzy preferences in real-world decision problems, fuzzy option prioritization is applied to an actual dispute over groundwater contamination that took place in Elmira, Ontario, Canada.

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**Keywords:** Graph model; Preference statement; Fuzzy truth value; Fuzzy score interval; Fuzzy option prioritization; Fuzzy preference

## 1. Introduction

Decision making is a common activity in everyday life. To make decisions easier, a number of methodologies have been developed including linear and non-linear optimization [1,35], multiple-criteria decision analysis [13], game theory [38], fuzzy decision making [10,30], and the Graph Model for Conflict Resolution [11,28]. In these decision making techniques, decision makers' (DMs') preference information, expressed implicitly or explicitly, is an essential

\* Corresponding author. Tel.: +1 519 888 4567x32830; fax: +1 519 746 4791.

E-mail addresses: [mabashar@uwaterloo.ca](mailto:mabashar@uwaterloo.ca), [mabashar71@gmail.com](mailto:mabashar71@gmail.com) (M.A. Bashar), [mkilgour@wlu.ca](mailto:mkilgour@wlu.ca) (D.M. Kilgour), [kwhipel@uwaterloo.ca](mailto:kwhipel@uwaterloo.ca) (K.W. Hipel).

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1 component. Preference information may be given in various forms, for instance as utilities (as in classical game 1  
2 theory [38]), as fuzzy utilities (as in fuzzy decision making [10,30]), via option prioritization (as in the Graph Model 2  
3 for Conflict Resolution [12,22,32,33]), or simply as pairwise relative preferences over the feasible states or scenarios 3  
4 (as in a crisp or fuzzy Graph Model [2–4,11,20,28]). In whatever form a DM's preference information is provided, the 4  
5 objective is always to represent a crisp or fuzzy preference relation over the states or scenarios. 5

6 A crisp or ordinary preference relation is composed of the binary relations “is (strictly) preferred to” and “is 6  
7 indifferent to”. A crisp preference describes the certainty of the preference for one state over another which, in general 7  
8 form, may or may not be transitive. A fuzzy preference relation is expressed using numerical values between 0 and 1, 8  
9 interpreted as pairwise preference degrees. A preference degree for one state over another indicates the degree of 9  
10 certainty of the preference for the first state over the second. A degree of certainty of 1 is equivalent to the crisp 10  
11 binary relation “strictly preferred to” while a degree of certainty of 0 is equivalent to equal certainty but in the reverse 11  
12 direction. 12

13 In multiple participant–multiple objective decision problems, DMs interact through their decisions, and often have 13  
14 opposing (or inconsistent) preferences. Consequently, strategic conflicts are obvious in these decision problems. 14  
15 A number of formal methodologies have been developed to facilitate the analysis of these problems and to advise 15  
16 on possible resolutions. These methodologies include game theory [38], metagame analysis [24], conflict analysis 16  
17 [16], drama theory [25], and the Graph Model for Conflict Resolution [11,28]. These various methodologies all share 17  
18 fundamental characteristics: they represent and analyze decision situations with at least two DMs, each of whom has 18  
19 one or more options and distinctive preferences over the outcomes [27]. 19

20 This paper is specifically addressed to the Graph Model methodology. To apply this methodology, there are two 20  
21 steps: modeling and analysis. In the modeling step, feasible states and moves among them are usually constructed 21  
22 using the option form [11,28]. A feasible state is a feasible combination of options, selected or not selected. To 22  
23 make clear how a real-world decision problem is formulated within the Graph Model framework, an environmental 23  
24 conflict in Elmira (a small town in Ontario, Canada) is described here. This conflict began in late 1989 when the 24  
25 Ontario Ministry of the Environment (MoE) found that an underground aquifer in the town was contaminated by a 25  
26 carcinogen. The main suspect was a chemical company in Elmira, Uniroyal Chemical Ltd. (UR), which produced the 26  
27 same carcinogen as a by-product. MoE issued a control order demanding that UR take necessary measures to rectify 27  
28 the contamination. However, UR appealed the control order. The Local Government (LG) was another DM of the 28  
29 conflict as it attempted to represent local interests. These DMs had differing objectives; for example, MoE wanted to 29  
30 require UR to rectify the contamination, while UR wanted the control order lifted or at least modified. The dispute 30  
31 is modeled as a Graph Model, in which each DM has one or more options that it either selects or not. For instance, 31  
32 to attempt to reach a preferable outcome, UR could delay the appeal process, accept the original control order, or 32  
33 abandon its Elmira operation. 33

34 An important input to the analysis step of the Graph Model, and to GMCR II [12,32], a decision support software 34  
35 that implements the Graph Model methodology, is each DM's preference information. Modeling preferences by pair- 35  
36 wise comparison is a challenging task for DMs as well as for analysts. Rather, it is easier for a DM to provide a priority 36  
37 sequence of what he or she likes to see about the available courses of action. This idea was formalized as option prior- 37  
38 itization [12,32,33]. A DM's preference is modeled using a priority list of preference statements. These statements are 38  
39 composed of options using logical connectives, such as “and”, “or”, and “if–then”, and listed from most preferred to 39  
40 least. The option prioritization methodology relies on the truth values (“true” or “false”) of each preference statement 40  
41 at each state, where the truthfulness of a more important preference statement dominates its falsity in calculating a 41  
42 DM's preferences. For example, in the Elmira model, LG's most important preference statement is “UR does not close 42  
43 its operations in Elmira”; so any state or scenario in which UR closes its operations in Elmira is less preferred than 43  
44 any state in which UR continues its operations. 44

45 A limitation of preference modeling by option prioritization is that it assesses a preference statement based only on 45  
46 whether it is “true” or “false” at a state. For example, to model its preference in the Elmira dispute, LG may consider 46  
47 the proposition “insist on the application of the original control order” as one of its preference statements. It may be 47  
48 reasonable to restrict the truth value of this preference statement to either “true” or “false” at states in which UR is 48  
49 delaying the appeal process. However, the truth value of this statement at a state in which UR accepts a control order 49  
50 (original or modified) may not be precisely “true” or “false”; rather, it may be more reasonable to assume a fuzzy 50  
51 truth value, a degree of truth, taken from a fuzzy truth space, usually the closed unit interval [0, 1]. A truth degree of 51  
52 1 for a preference statement at a state indicates that the preference statement is true, while a truth degree of 0 implies 52

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