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Selecting a Discrete Multiple Criteria Decision Making Method to decide on a Corporate Relocation

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ABSTRACT
This paper considers a corporate relocation problem. The research considered an approach to decide on an appropriate Multi-Criteria Decision Making (MCDM) method out of a subdivision of possible methods to rank five cities in the United States of America based on their suitability. Selecting the location of corporate real estate is key to optimizing an organization's success. The new approach provides decision makers with a recommended group of potentially suitable methods. Sensitivity analysis is employed to explore the recommended group and to rate the robustness of their outputs when uncertainty and risk may be present. A suitable method is recommended that provides a robust solution. MCDM methods that can deal with a discrete set of alternatives were considered. A MCDM method was recommended based on a best compromise in the minimum percentage change required in both the evaluation criteria and performance scores of the cities with respect to the evaluation criteria to alter the ranking of the cities.

Keywords: Corporate Relocation; Multiple criteria; Analysis; Sensitivity; Decision making; Criteria; Weights; Performance.

INTRODUCTION

A corporate relocation decision is considered a fundamental and long term strategic decision in the life time of an organization. Relocation has an impact on the organization's survival and competitiveness [1; 2; 3].

Corporates relocate because of different strategic factors. Many researchers have described these factors and considered strategic repositioning, lowering operational costs and improving economic competitiveness as the main reasons for corporate relocation. Christersson and Rothe [2] identified four factors of: Economic factors; Social factors; Environmental factors; Organizational identity, culture and image factors. Hassanain *et al* [4] stressed that reducing costs could be an important factor in corporate relocation.

Arkesteijn *et al* [5] claimed that many authors considered the process of making corporate relocation decisions as a "Black Box". This paper will reveal part of this "Black Box" and help decision makers understand the corporate relocation decision process, select an appropriate location that fulfils their desired goals using Multiple Criteria Decision Making (MCDM) methods and provide a real world example concerning the ranking of five cities in the United

States of America based on their suitability for a corporate relocation [6]. Relocation to the following cities was considered: New York City; Washington D.C.; Atlanta, Georgia; Los Angeles, California; and Portland, Oregon. Two MCDM methods were applied to this problem, the Analytical Hierarchy Process (AHP) and the Preference Ranking Organization METHod for Enrichment of Evaluations II (PROMETHEE II). Sensitivity analysis was conducted on the outcomes of these methods and the most stable outcome was recommended.

The next Section provides a background to corporate relocation, Section 3 briefly explains MCDM methods and Section 4 presents a MCDM methods selection approach. Section 5 presents a real world example of corporate relocation, Section 6 discusses the results, Section 7 makes some concluding remarks and Section 8 discusses future work.

CORPORATE RELOCATION

Relocating can be an exciting opportunity for a company but it is a big decision and can be stressful. E.ON found that moving premises was the second most stressful task that managers have to deal with. As a result, 78% of companies delay moving, opting to stay in less inefficient, more cramped and more costly facilities. It is vital that suitable decisions are made that consider: Finances, Employee Availability, Support Services, Cultural Opportunities, Leisure Activities and Climate. That in turn means that a suitable decision making system is selected.

Many researcher considered the main aim behind relocation was to enhance organization profitability [7; 8], others identified other cultural, geological, and legal factors [2; 9; 10]. Relocation has a number of implications concerning an organization and the employees. Many factors should be considered when making relocation decisions, including but not limited to: cost of relocation, disruption to work, employee satisfaction, productivity, profitability and transportation.

Glatte [3] identified four theories of corporate relocation:

- Site selection theory: concerned with reasons for the selection of a location.
- Site effect theory: concerned with consequences of choosing a specific location.
- Site development theory: concerned with historic development of location structure.
- Site design theory: concerned with spatial distribution of locations.

The theory considered in this paper is a selection theory.

Rothe and Heywood [11] did not consider relocation activities as an organizations' "day-to day" activities, and considered it as a Corporate Real Estate (CRE) department activity. Christersson *et al* [10] considered relocation decision as one of the "value-adding" tasks of Corporate Real Estate Management (CREM), and mentioned four types of physical relocation: location, building, workplace, and managing work within the workplaces.

Rothe and Heywood [11] claimed that many researchers considered corporate relocation as physical relocation and stressed that corporate relocation was not just the physical move from old sites to new sites, but should include all the processes and services required to successfully complete the relocation, including:

- Relocation decision process.
- Apply relocation decision.
- Physical move.
- Post-move, settling-in and adjustments after the move.

The problem described in this paper considered the Relocation decision process.

Glatte [3] identified two different techniques to better understand relocation decisions: Qualitative techniques or quantitative techniques. He claimed that quantitative techniques focus on creating and analysing measurable key indicators that could be mathematically manipulated, while qualitative techniques focus on verbal descriptive information provided by stakeholders.

Koç and Burhan [12] highlighted the fact that corporate relocation decisions had complex structures and included both predictable and unpredictable inputs. They stressed the need to avoid intuition and instead to recommend moves using more sophisticated and complex techniques. Moreover, they considered different MCDM methods suitable for corporate relocation decisions. Glatte [3] claimed that there is no perfect method for selecting a corporate relocation from a construction or real estate perspective and recommended testing a method's suitability and stability and to apply more than one method to achieve a reliable outcome.

Glatte [3] claimed that in order to achieve stable and robust relocation decisions, regardless of the choice of method used, input data should be verifiable, reliable and valid. Moreover, Glatte [3] and Barovick and Steele [13] stressed that taking risk and uncertainty into consideration with a relocation decision can provide an appropriate relocation decision to achieve strategic advantage.

The selection of a suitable method for a corporate relocation problem is presented in this paper. The work is part of a bigger analysis of Multiple Criteria Decision Making (MCDM) methods that addresses MCDM methods characteristics and problem characteristics.

Some new propositions are proposed that are based on general MCDM problems and scenarios. These propositions have been applied to the corporate relocation problem. The results from that testing have suggested that the propositions are accurate and can predict a suitable method for some MCDM decisions.

In order to make the decision, the alternative cities need to be considered and then a choice made or course of action selected that fulfils desired goals and objectives. Suitable decision-making processes can be vital for success. The information required to make a decision and the associated problems might be vague or uncertain though and decisions can be complex. There are larger and larger numbers of alternatives and the criteria can conflict [14].

The sort of uncertainty that may be present during the making of a corporate relocation decision is stressed as being important by many researchers [15 - 19], but it is not considered in practice very often. Vincke [20] stated that decision-makers dealing with problems in the real world tended to realise that the numerical data used for their problems was uncertain. Scholten *et al* [21] said that the input data used in real wold decision-making is frequently "ill-determined". Different scenarios might be conceivable and applicable to the problem. They stressed that a decision-maker needs to provide information about the legitimacy of the problem solution, any model used, and any method applied.

Real-life problems need diverse decision-making methods, and no method is better than any other method. Poyhonen and Hamalainen [22] demonstrated that using different weights and methods of weighting variables can often lead to different outcomes.

Corporate relocation decisions become vulnerable to distortion as judgments are made in fuzzy, high risk and uncertain environments, where many assumptions may be involved, and stakes can be high. Using more complicated scientific decision-making can help. Most human beings can only deal with small numbers of criteria at the same time [23]. Decision makers can use MCDM methods to manage multi-criteria problems more efficiently. But MCDM methods have disadvantages.

MULTIPLE CRITERIA DECISION MAKING (MCDM)

MCDM methods could be traced back to 1738 when Daniel Bernoulli (1700 – 1782) when he published a decision making process based on the utility theory of an alternative rather than the expected utility of the alternative [24].

MCDM can be regarded as a sub-branch of Operational Research that can be used for complicated decisions in uncertain and risky environments [25]. Ghasempour *et al* [26] mentioned that MCDM techniques were applied for problems with conflicting and numerous goals. MCDM methods are mathematical methods. They are used to find a middle-ground solution that is based on judgments made by human stakeholders [27]. In the last twenty years, MCDM has been a fast-growing area of operational research. MCDM methods have been used in ranking alternatives, selecting best fit alternatives, sorting alternatives into pre-defined groups, and in describing the problems [28]. MCDM can be useful when criteria can be conflicting. They use methodologies and general theories to solve complicated management and business [29]. Vincke [20] claimed that MCDM methods exist to help decision makers to understand their problem (and the various factors that can influence their problems) and then to come to a "Good" enough resolution.

MCDM is used to assess alternatives in order to select a suitable alternative to fulfil a desired goal with regard to multiple and sometimes conflicting criteria [30]. MCDM is recognized as a significant branch of operational research and decision-making theory. It can be more reliable. It is a group of processes and methods through which multiple and conflicting criteria can be incorporated into a decision-making process. In addition, MCDM can be thought of as a systematic process to analyze and choose between various options. MCDM splits a problem into smaller parts, analyses assesses each part, and then aggregates the parts to choose the best answer from a set of answers using predefined criteria. MCDM helps decision makers solve conflicting real-world qualitative and / or quantitative multi-criteria problems, and to seek out a best-fit solution from a set of solutions within certain, fuzzy, uncertain, and risky situations [31]. Zeleny [32] said that single criteria problems should be considered as simple analysis and that conflict occurs because of confrontation between goals, targets, and criteria and the point of view or preferences of the human decision makers.

Durbach and Stewart [17] said that all multi-criteria methods can improve decision-making by deconstructing the assessment of the alternatives into their conflicting criteria. MCDM methods can be difficult to compare and to check their accuracy because they use a variety of methods to deal with different sets of data [33]. Razmak and Aouni [14] said that specific MCDM methods can work better for specific problems. MCDM is sequential but can go through iterations to reach robust and reliable solutions. So, methods of checking consistency and being able to of compare results has an important role. Soltani *et al* [34] encouraged an understanding of the various types of uncertainties and decision quality could be enhanced by introducing a stable decision making process.

Consistency of comparisons is important as it shows the reliability and robustness of outcomes [35], Saaty [36] stated that inconsistency is "one order of magnitude less important than consistency or 10% of the total concern with consistent measurement." So that if inconsistency is bigger than 10% then it could disrupt the process. Human judgments are prone to biases and errors. Comes *et al* [37] identified some noticeable biases in behaviour: Availability; Anchoring; and Confirmation.

There are other sources of inconsistency. Human decision makers describe criteria and alternatives in different ways and to different scales and the set of available numbers to use may be relatively small.

Beg and Rashid [38] stressed that real world decision making problems were often challenging due to the difficulty of modelling and managing uncertainty. Crespi *et al* [39] claimed that incomplete knowledge about a specific issue could be the main source of uncertainty.

Understanding the nature of uncertainty can reduce inconsistency and provide a more robust and reliable representation of performance measures and weights [20; 40; 41]. Salo and Hamalainen [42] said that better preference elicitation weighting methods were produced when decision makers were allowed to provide less precise preference statements. Scholten *et al* [21] said uncertainty in criteria weights can be produced because of imprecise estimates, personal bias, or through using imprecise weights. Danesh *et al* [43] stressed the need to understand the challenges in a decision in order to select an appropriate decision making method.

Scholten *et al* [21] stated that a thorough contemplation of the potential uncertainty can lead to poorer decisions. A detailed examination of uncertainty is often not required when stakeholders are defining their objectives but they can be used to compare solutions [44].

There is no perfect MCDM method [45] because decision-makers cannot always provide all of the information and / or dissimilar problems entail dissimilar algorithms to produce useful outcomes. In real life problems and criteria weights can be difficult to make available as "exact" numbers [46].

Sensitivity analysis needs to be undertaken to check robustness and to validate the feasibility of the MCDM solutions [47; 48]. Saltelli *et al* [49] defined sensitivity analysis as the analysis of the effect of uncertainty in the output of a model, affected by uncertainty in its inputs. Stewart [50] advised using sensitivity analysis for both the criteria weights and the performance measures so as to better appreciate the question. Robustness is an indicator of the ability of the system to tolerate uncontrollable changes [51].

Three types of sensitivity analysis can be defined for a decision [52]:

- Minimum change in criteria weights required to make an alternative ranked first.
- Effect of changes in performance measures of one alternative with respect to a criterion.
- Sensitivity of a ranking to changes in scores of all alternatives depending on a criterion.

A decision maker tends to seek out the judgment of groups and individuals who possess the specialized knowledge or the experience in the area being considered. Judgment from experts can be used at different stages improve decision-making. Although the knowledge provided by the experts might not be enough. The concept of making decisions based on some historical data is not a new one. Unknown consequences can be modelled by random variables. Using experience and historical data to predict the probabilities of these variables may not be possible. Judgments based on historical data and based on past experience might be unacceptable [53]. Tools for decision-makers exist to improve the process of decision-making.

Haddad [54] identified the following steps to reach a most suitable (best compromise) solution in any multi-criteria problem: (A) Identify the problem. (B) Define goals and targets. (C) Define a set of criteria. (D) Identify alternatives. (E) Select a MCDM method to evaluate the overall score of alternatives with respect to the criteria set. (F) Review and evaluate outcomes.

Decisions should then be reviewed and validated. Inappropriate or unsuccessful decisions should be reassessed, and then the process begins again.

Comes *et al* [37] said that strategic decisions can be difficult because strategic problems can be uncertain and ambiguous, and a large number of stakeholders can be involved who all have distinct preferences that can conflict. Grechuk and Zabarankin [53] said that analysts and decision makers can possess experimental and historical data which was insufficient. If the data were obtained from a more statistical understanding of the assumptions being made (that would depend on the underlying nature of the problem) then that could provide a better understanding of uncertainty and risk that are associated with the problem.

The solution selected can be influenced by the choice of method, and a poor choice of method can lead to poor solutions and decisions [55]. Eldarandaly *et al* [56] said that applying different MCDM methods to the same problem can generate different outcomes. The use of an incorrect MCDM method can lead to an incorrect decision [43; 45]. Ishizaka and Siraj [30] asserted the importance of making good decisions and maintained that MCDM was making things better.

The work presented in this paper describes the effect of choosing the best method when uncertainty and risk may exist. A new computer program automatically make a selection of a group of potential MCDM methods. After that, sensitivity analysis is used to identify the most appropriate MCDM method for the particular problem. Finally new propositions are described that were developed from investigating a set of generalized potential scenarios.

NEW MCDM METHODS SELECTION APPROACH

A decision making method needed to be selected for a corporate relocation problem (Expert Choice, 2013). Different ways of choosing MCDM methods have been proposed by numerous researchers [33; 45; 47; 55; 57; 58; 59; 60; 61; 62; 63]. One of the first people to identify the significance of MCDM methods selection and identify the requirement to compare different MCDM methods was MacCrimmon [64]. He recognized preference and suggested using a classification of MCDM methods based on a method specification chart. The chart was presented as a tree diagram and some illustrative examples of applications were included.

Haddad *et al* [65] mentioned that numerous researchers have compared MCDM methods depending on their final outcome. Such a comparison of the final results could be "ill-founded" [63]. Many researchers have treated MCDM methods as a means to study, explore and understand decisions, and to evaluate different possibilities, rather than just as a means to make a difficult decision. Norese [40] said that advice given to users as part of the outcome should be used within the method. Decision making is not an outcome in itself [32] but is a process that involves defining criteria, identifying alternatives, identifying criteria weights, evaluating and processing information, producing outcomes, reviewing criteria, alternatives, and analyzing bias, risk and uncertainty, then reviewing and re-validating the process until a satisfactory outcome is achieved.

Numerous factors affect the selection of a MCDM method. A method could be randomly selected, a decision maker may have some prior knowledge or experience with one of them, or a MCDM method might just be easily available [55; 60; 61]. Considering the large number of MCDM methods, some researchers have suggested some potential approaches to selecting an appropriate MCDM method. There does not appear to be a well-structured way of selecting MCDM methods in the research literature.

The authors created a new structured approach and factors that needed to be addressed when selecting a method were identified, including MCDM methods' characteristics and problem characteristics [65]. A framework was created that could provide decision makers with a group of candidate MCDM methods that were appropriate for their problem by addressing these factors. MCDM methods dealing with discrete sets of alternatives were considered and sensitivity analysis was carried out on this subset of candidate methods to select a MCDM method that delivered the most robust outcome.

Groves and Lempert [67] recommended the use of robust decision-making to address severe uncertainty and risk. Scholten *et al* [21] said that the decision-maker should deliver the information needed about the method used, the model and validity of the outcome. Providing a robust solution may not be the same as providing an optimal solution. A lot of researchers have mentioned the concept of robustness, Simon [68] said it is the "good and not too risky", Vincke [20] said it is a robust alternative that achieved "minimum performance". Comes *et al* [69] identified a robust alternative as the alternative that performed "sufficiently well" for a broad variety of scenarios i.e. achieved the minimum required thresholds of performance for a set of criteria for all scenarios. While Comes *et al* [37] identified the concept of robustness as a decision-maker preferring an alternative that guaranteed satisfactory performance over an alternative that maximized the performance in one "Best Scenario". Finally Vincke [20] said the robustness of an alternative or a method is relative, it depends on the description of the problem or the method, he stated that the concept of robustness could be used to "choose and refine" methods.

Weights allocated to the criteria can characterize the significance of the criteria, so that the critical criteria can be identified from them [70]. They said that accurately re-evaluating the weights might improve decision-making. They described a framework to determine the minimum percentage change required in criteria weights to change the ranking of any two alternatives, and, the minimum percentage change required in performance measure to change the ranking of any two alternatives "in terms of a single decision criterion at a time".

The authors have established a new set of propositions that consider three problem STATEs:
STATE ONE: Decision makers were uncertain about criteria weights and / or foresee a high severity risk factor that might affect criteria weights.
STATE TWO: Decision makers were uncertain about the performance measures and / or foresee a high severity risk factor that might affect criteria weights.
STATE THREE: If decision makers were uncertain and / or anticipate a risk factor of high severity that could affect both criteria weights and performance measures.

There are many definitions for uncertainty, Stewart [19] identified it as "At most fundamental level, uncertainty relates to a state of human mind, i.e. lack of complete knowledge about something". Walker *et al* [71] stated that uncertainty was "any departure from the unachievable ideal of complete determinism". Stewart [19] classified uncertainty to two general categories based on their location:

- Internal uncertainty associated with decision makers' preferences and judgments
- External uncertainty associated with consequences of the an outcome

Vanderpas *et al* [72] mentioned four levels of uncertainties at both locations having two extremes: from determinism to total ignorance. Different method are used to deal with different level of uncertainty ranging from handling uncertainty probabilistically to deep uncertainty. Deep uncertainty is related to level 3 and 4.
Comes [37] differentiated between two types of decision-making by identifying the type of uncertainty involved:

- Decision-making under ignorance where severe uncertainty were characterized by ignorance
- Decision-making under risk where probability functions were known

Moreover Comes [37] suggested using fuzzy set theory and rough set theory to deal with internal uncertainties. Stewart [19] suggested proper problem structuring, appropriate sensitivity and risk analysis to deal with internal uncertainty, stressed that deep internal uncertainties cannot be resolved by proper problem structuring and encouraged using sensitivity and robustness analysis to deal with it.

Vanderpas *et al* [72] claimed that if sensitivity analysis was used to deal with deep uncertainty involved in a decision process then, an understanding of the relevant uncertainty space and all the uncertainties involved in the decision process will be needed.

CORPORATE RELOCATION DECISIONS

This corporate relocation decision considered ways to determine the best city in the United States of America to relocate a corporation. A set of six criteria were identified and five cities met the minimum requirements identified by the analysts.

The set of criteria were:

- C_1: Financial Considerations
- C_2: Employee Availability
- C_3: Support Services
- C_4: Cultural Opportunities
- C_5: Leisure Activities
- C_6: Climate; Seasonal, and Year Round

The set of alternatives (cities) were:

- A_1: New York City
- A_2: Washington D.C.
- A_3: Atlanta, Georgia
- A_4: Los Angeles, California
- A_5: Portland, Oregon

Criteria weights and performance measures for all the alternative (cities) with respect to all the criteria are shown as a decision matrix in Table 1.

Table 1: Decision matrix for Corporate Relocation Decision

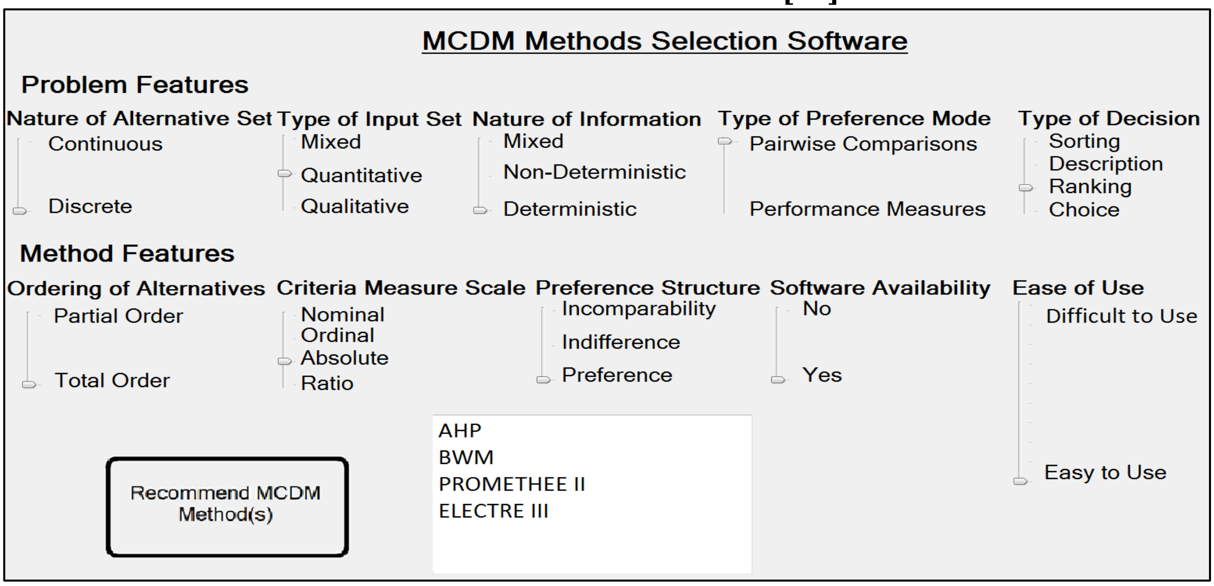
Criteria \ Alternative	A_1 N.Y.C.	A_2 Washington D.C.	A_3 Atlanta	A_4 L.A.	A_5 Portland
C_1: Financial Considerations = 0.428	0.313	0.119	0.176	0.346	0.046
C_2: Employee Availability = 0.207	0.064	0.098	0.168	0.493	0.177
C_3: Support Services = 0.207	0.416	0.062	0.116	0.284	0.122
C_4:Cultural Opportunities = 0.041	0.300	0.215	0.105	0.307	0.073
C_5: Leisure Activities = 0.063	0.060	0.107	0.160	0.315	0.359
C_6: Climate = 0.053	0.082	0.082	0.173	0.442	0.220

Haddad *et al* [66] MCDM Methods Selection Framework was applied to this relocation decision. Eight questions addressing MCDM problem characteristics and the MCDM methods characteristics were asked. The nature of the alternative set was considered to be "Discrete" because the alternative consisted of integer values. Inputs considered in this relocation decision were quantitative. All input information was deterministic. The aim behind applying MCDM methods to this problem was to rank the set of alternatives (cities) using pairwise comparisons to achieve a total order of alternatives (cities). An absolute criteria measure scale was used considering a preference structure between alternatives (cities).

A screen shot of the user interface of the structured MCDM Methods Selection Framework is shown in Figure 1. A group of candidate methods were suitable for this relocation problem as shown at the bottom left the screen shot shown in Figure 1 and listed here:

- The Analytical Hierarchy Process (AHP).
- The Best Worst Method (BWM).
- Preference Ranking Organization METHod for Enrichment Evaluations II, (PROMETHEE II).
- Elimination Et Choix Traduisant la Realite III, (Elimination and Choice Expressing Reality III), (ELECTREE III).

Figure 1: Screen shot of the New MCDM Methods Selection Framework for a corporate relocation decision model [66]



AHP and PROMETHEE II were selected for this example. AHP provided the following ranking of cities: $A_4 > A_1 > A_3 > A_5 > A_2$, with a global score of cities: $A_1 = 0.264$, $A_2 = 0.107$, $A_3 = 0.158$, $A_4 = 0.358$ and $A_5 = 0.112$. PROMETHEE II provided the same ranking of cities: $A_4 > A_1 > A_3 > A_5 > A_2$, with a net flow of cities: $\Phi(A_1) = 0.865$, $\Phi(A_2) =0.132$, $\Phi(A_3) = -0.124$, $\Phi(A_4) = -0.276$and $\Phi(A_5) = -0.596$.

Although AHP and PROMETHEE II methods delivered the same ranking of cities, sensitivity analysis was conducted on both methods' outcomes to recommend a method that best suited this corporate relocation decision and provided the most robust and stable outcome. Minimum percentage change required to alter the ranking of the cities for the most critical criterion weight and the most critical performance measures were calculated. Results are shown in Tables 2, 3, 4 and 5. N/F shown in Tables 4 and 5 stands for a non-feasible value where ±100% change in the value of that performance measure did not affect the original ranking of the cities.

The most critical criterion in this example using AHP was the first criterion (C_1) that represented Financial Considerations signified by the smallest value (bold number) in Table 2. This value represented the minimum percentage change required in the weight of the Financial Considerations criterion to change the ranking of alternatives two and five ($A_2 > A_5$). A 10.514% increase in its weight preferred Washington D.C. to Portland.

Table 2: Minimum percentage change in criteria weights for Corporate Relocation Decision using AHP

Criteria	Percentage change Ranking	New Ranking
C_1	**10.514**	$A_4 > A_1 > A_3 > A_2 > A_5$
C_2	-29.952	$A_4 > A_1 > A_3 > A_2 > A_5$
C_3	-45.411	$A_4 > A1 > A_3 > A_2 > A_5$
C_4	112.195	$A_4 > A_1 > A_3 > A_2 > A_5$
C_5	-33.333	$A_4 > A_1 > A_3 > A_2 > A_5$
C_6	-86.792	$A_4 > A_1 > A_3 > A_2 > A_5$

The most critical criterion in this example using PROMETHEE II was the first criterion (C_1) that represented Financial Considerations signified by the smallest value (bold number) in Table 3. This value represented the minimum percentage change required in the weight of the Financial Considerations criterion to change the ranking of alternatives three and five, Atlanta and Portland, ($A_5 > A_3$). Where a 25.234% decrease in its weight preferred Portland to Atlanta.

Table 3: Minimum percentage change in criteria weights for Corporate Relocation Decision using PROMETHEE II

Criteria	Percentage change Ranking	New Ranking
C_1	**-25.234**	$A_4 > A_1 > A_5 > A_3 > A_2$
C_2	78.744	$A_4 > A_3 > A_1 > A_5 > A_2$
C_3	-80.676	$A_4 > A_3 > A_1 > A_5 > A_2$
C_4	582.927	$A_4 > A_1 > A_3 > A_2 > A_5$
C_5	201.587	$A_4 > A_1 > A_5 > A_3 > A_2$
C_6	428.302	$A_4 > A_1 > A_5 > A_3 > A_2$

The most critical performance measure in this example using AHP was (A_2C_1) which represented the score of Washington D.C. with respect to Financial Consideration criterion signified by the smallest value (bold number) in Table 4. This value represented the minimum percentage change required in the value of performance measure (A_2C_1) to change the ranking of alternatives two and five, Washington D.C. and Portland ($A_2 > A_5$). A 10% increase in its value preferred Washington D.C. to Portland.

Table 4: Minimum percentage change in performance measures for Corporate Relocation Decision using AHP

Performance measure	Percentage change Ranking	New Ranking
A_1C_1	57	$A_4 > A_1 > A_3 > A_2 > A_5$
A_2C_1	**10**	$A_4 > A_1 > A_3 > A_2 > A_5$
A_3C_1	-51	$A_4 > A_1 > A_5 > A_3 > A_2$
A_4C_1	-43	$A_1 > A_4 > A_3 > A_5 > A_2$
A_5C_1	-25	$A_4 > A_1 > A_3 > A_2 > A_5$
A_1C_2	N/F	--
A_2C_2	35	$A_4 > A_1 > A_3 > A_2 > A_5$
A_3C_2	N/F	--
A_4C_2	30	$A_4 > A_1 > A_3 > A_2 > A_5$
A_5C_2	-20	$A_4 > A_1 > A_3 > A_2 > A_5$
A_1C_3	45	$A_4 > A_1 > A_3 > A_2 > A_5$
A_2C_3	47	$A_4 > A_1 > A_3 > A_2 > A_5$
A_3C_3	N/F	--
A_4C_4	88	$A_4 > A_1 > A_3 > A_2 > A_5$
A_5C_3	-23	$A_4 > A_1 > A_3 > A_2 > A_5$
A_1C_4	N/F	--
A_2C_4	63	$A_4 > A_1 > A_3 > A_2 > A_5$
A_3C_4	N/F	--
A_4C_4	N/F	--
A_5C_4	N/F	--
A_1C_5	N/F	--
A_2C_5	70	$A_4 > A_1 > A_3 > A_2 > A_5$
A_3C_5	N/F	--
A_4C_5	42	$A_4 > A_1 > A_3 > A_2 > A_5$
A_5C_5	-22	$A_4 > A_1 > A_3 > A_2 > A_5$
A_1C_6	N/F	--
A_2C_6	N/F	--
A_3C_6	N/F	--
A_4C_6	83	$A_4 > A_1 > A_3 > A_2 = A_5$
A_5C_6	-51	$A_4 > A_1 > A_3 > A_2 > A_5$

The most critical performance measure in this example using PROMETHEE II was (A_3C_1) which represented the score of Atlanta with respect to Financial Consideration criterion signified by the smallest value (bold number) in Table 5. This value represented the minimum percentage change required in the value of performance measure (A_3C_1) to change the ranking of alternatives three and five, Atlanta and Portland ($A_5 > A_3$). A 29% decrease in its value preferred Portland to Atlanta.

Table 5: Minimum percentage change in performance measures for Corporate Relocation Decision using PROMETHEE II

Performance measure	Percentage change Ranking	New Ranking
A_1C_1	-35	$A_4 > A_3 > A_1 > A_5 > A_2$
A_2C_1	40	$A_4 > A_1 > A_5 > A_3 > A_2$
A_3C_1	**-29**	$A_4 > A_1 > A_5 > A_3 > A_2$
A_4C_1	-56	$A_1 > A_4 > A_3 > A_5 > A_2$
A_5C_1	N/F	--
A_1C_2	N/F	--
A_2C_2	N/F	--
A_3C_2	-58	$A_4 > A_1 > A_5 > A_3 > A_2$
A_4C_2	N/F	--
A_5C_2	-60	$A_4 > A_1 > A_3 > A_2 > A_5$
A_1C_3	-61	$A_4 > A_3 > A_5 > A_1 > A_2$
A_2C_3	N/F	--
A_3C_3	N/F	--
A_4C_4	N/F	--
A_5C_3	N/F	--
A_1C_4	N/F	--
A_2C_4	N/F	--
A_3C_4	N/F	--
A_4C_4	N/F	--
A_5C_4	N/F	--
A_1C_5	N/F	--
A_2C_5	N/F	--
A_3C_5	N/F	--
A_4C_5	N/F	--
A_5C_5	N/F	--
A_1C_6	N/F	--
A_2C_6	N/F	--
A_3C_6	N/F	--
A_4C_6	N/F	--
A_5C_6	N/F	--

This relocation problem provided examples of the three States listed in Section 4 and actions were considered to address them:

STATE ONE: AHP required a 10.514% increase to the value of the most critical criterion weight to alter the ranking of the cities, while PROMETHEE II required a 25,234% decrease to the value of the most critical criterion weight (Financial Consideration) to alter the ranking of the cities. Both methods delivered the same outcomes. PROMETHEE II was 2.4 times less sensitive to changes in the value of the most critical criterion weight than AHP. Decision makers often prefer a method that is resilient to changes in criteria weights and often apply MCDM methods to aid them in delivering strategic decisions and long term planning [14]. A robust method provides more stable outcomes with less sensitivity to risk and uncertainties. PROMETHEE II would be recommended for this relocation problem when decision makers were uncertain of criteria weights or anticipated a risk factor of high severity that could affect criteria weights.

STATE TWO: AHP required a 10% increase to the value of the most critical performance measure score (the score of Washington D.C. with respect to Financial Consideration criterion) to alter the ranking of the cities, while PROMETHEE II required a 29% decrease to the value of the most critical performance measure score (the score of Atlanta with respect to Financial Consideration criterion) to alter the ranking of the cities. PROMETHEE II was 2.9 times less sensitive to changes in the value of the most critical performance measure than AHP. Decision makers often prefer a method that is less sensitive to changes in the values of the performance measures and often apply MCDM methods to aid them in delivering strategic decisions and long-term planning [14]. A robust method provides more stable outcomes with less sensitivity to risk and uncertainties. PROMETHEE II would also be recommended for this relocation problem when decision makers were uncertain of performance measures or anticipated a risk factor of high severity that could affect performance measures.

STATE THREE: The number of the most critical criteria and the most critical performance measures a method has for a certain relocation problem provides guidance about the number of risk factors the method is vulnerable. The higher the number of the most critical criteria and the most critical performance measures, the higher the number of risk factors a method is sensitive that might change the final outcome of the method. Moreover, the lower the minimum percentage change required in the most critical criteria and the most critical performance measure, the higher the sensitivity of the final outcome of a method to changes in the inputs (i.e. risk and uncertainty). PROMETHEE II was less sensitive than AHP to changes in the values of both criteria weights and performance measures. Recommending PROMETHEE II for this relocation problem would provide a more robust outcome with less vulnerability to risk and uncertainty.

In all three states, PROMETHEE II would be recommended for this problem.

DISCUSSION

Huffman [73] identified risk in corporate relocation decisions and categorized them to three categories: financial, physical and regulatory risks. While Rasila and Nenonen [74] identified five categories of relocation risks: financial risks, functional risks, corporate culture risk, interest group risk and future risk. This paper was concerned with the uncertainties associated with decision makers' preferences and judgments that caused these risks.

Corporate relocation decisions are considered to be long term strategic decision impact the success and profitability of organizations. Relocation covers two separate parts: what was planned and what actually happened [2].

Rothe and Heywood [11] identified the first two steps of corporate relocation as: relocation decision process and the application of the relocation decision. Due to the complexity of this decision, where long term planning is considered, a large number of alternative locations were assessed. The assessment was based on a set of often conflicting criteria and where uncertainty in human judgment was present. MCDM methods could provide reliable and stable decisions and could be considered as quantitative corporate relocation techniques.

Uncertainty is inevitable in real world problems, especially in long term planning decisions, using MCDM methods for corporate relocation decisions and conducting sensitivity analysis could help decision makers in capturing and analyzing uncertainties due to human judgments and other sources of uncertainty.

This paper modelled uncertainty as percentage change in criteria weights and performance measures. Uncertainty could be modelled using different approaches and for example for example: probability functions or fuzzy number. Applying sensitivity analysis to one input factor at a time may not be enough and Monte-Carlo simulation might model the uncertainty of more than one input factor at a time.

Glatte [3] claimed that there was no perfect method for making a corporate relocation decision. He recommended applying more than one method to check for suitability and stability of the methods. He stressed the need to use reliable and verifiable input data to achieve reliable decisions. Understanding the level of uncertainty associated with a decision could help decision makers in achieving stable and reliable decisions.

In the work presented in this paper, two MCDM methods were applied to a corporate relocation decision, to provide assurance for decision makers that they had a reliable decision. Sensitivity analysis was applied to the outcomes of both methods, the minimum percentage change required in all criteria and all performance measures were calculated, and critical criteria and critical performance measures were identified.

PROMETHEE II Indifference, Preference and Veto thresholds could be used to provide a more robust outcome and enhance the stability of the outcome of PROMETHEE II method.

Different methods might provide different outputs when applied to the same problem, this was because methods deal differently with performance measures, and criteria weights often have different impact from one method to another, moreover in MCDM problems a "correct" result does not exist [75]. If two methods delivered significantly different results then, at least one method was invalid [66; 76]. MCDM methods deliver a best compromise solution.

Analysing the results of the corporate relocation example, and results from other problems, a set of propositions have been suggested.

In each case the following approach was used:

1. Qualitative and quantitative risk analysis should be conducted first.
2. The new MCDM Methods Selection Framework was applied to that problem to provide a subset of candidate methods suitable for that problem.
3. Conduct sensitivity analysis on the subset of candidate methods.
4. Results from sensitivity analysis and risk analysis should be used to recommend a method that is least sensitive to factors highlighted by the risk analysis.
5. A MCDM method might be recommended for a problem even though it was highly sensitive to changes in a certain factor, but that factor might not be highlighted during the risk analysis. Also a MCDM method might be excluded from the subset of candidate methods if it was sensitive to factors highlighted by the risk analysis.

Some potential scenarios were presented in this paper. From these scenarios a new set of propositions can be stated:

PROPOSITION ONE – Uncertainty in Criteria Weights: If decision makers were uncertain of criteria weights and / or anticipate a risk factor of high severity that could affect criteria weights, for example the weights of: Financial Considerations, Employee Availability, Support Services, Cultural Opportunities, Leisure Activities or Climate, then a method that is least sensitive to changes to these factors should be recommended for the relocation problem. If methods had the same sensitivity to uncertainty in criteria weights, then the method that had fewer critical criteria should be recommended for the relocation problem.

PROPOSITION TWO - Uncertainty in Performance Measures: If decision makers were uncertain of performance measures and / or anticipate a risk factor of high severity that could affect performance measures, for example the scores of the cities with respect to: Financial Considerations, Employee Availability, Support Services, Cultural Opportunities, Leisure Activities and Climate, then a method that is least sensitive to changes in performance measures should be recommended for the relocation problem. If methods had the same sensitivity to uncertainty in performance measures, then the method that had fewer critical performance measures should be recommended for the relocation problem.

PROPOSITION THREE – Uncertainty in Inputs: If decision makers were uncertain and / or anticipate a risk factor of high severity that could affect both criteria weights and performance measures, then a method that is least sensitive to changes in criteria weights and performance measures should be recommended for the relocation problem. If methods had the same sensitivity to uncertainty in criteria weights and / or performance measures, then the method that had fewer critical criteria weights and /or performance measures should be recommended for the relocation problem and a best compromise between these factors would be recommended.

CONCLUSIONS

PROMETHEE II would be recommended for this corporate relocation decision so that the corporate could have a justifiable decision resilient to risk and uncertainty and could relocate to Los Angeles, California.

The long term effect of strategic decisions make it difficult for decision makers to claim responsibility for their decisions, moreover, the ambiguousness and uncertainty associated with these decisions and the large number of stakeholders involved with different preferences (often conflicting) make it even more difficult [37]. Ferrera *et al* [77] claimed that often a small perturbation in input data might lead to infeasible and unreliable results.

A corporate relocation decision is an important strategic decision crucial to the survival of organizations [1] and it has a direct effect on an organization's competitiveness and performance [12]. These decisions were often based on assessing a set of buildings, locations and cities to find the best fit alternatives that fulfilled the desired goals of organizations [11]. Due to the complexity of these decisions, where large numbers of predictable and unpredictable factors were considered, MCDM methods could be recommended as convenient methods for these type of decisions [12].

PROMETHEE methods generally consist of a preference function representing each criterion and weights describing their relative importance. Brans [78] identified six types of preference functions could be used in PROMETHEE methods. This paper applied PROMETHEE II method with type 1 preference function "usual criterion", other types of preference functions might show different behaviour and could enhance the stability of the method.

The large number of existing MCDM methods can confuse potential decision makers, resulting in inappropriate pairing of methods and problems. The authors are not suggesting that one MCDM method was better than another, but that one MCDM method could deliver a more stable and reliable outcome than another for a specific relocation decision. To recommend an appropriate method for a relocation decision, risk and uncertainty factors needed to be considered. Both performance measures and criteria weights were studied, and sensitivity analysis applied to performance measures and criteria weights to give a recommendation.

Other factors might be considered when selecting a MCDM method, for example criteria interaction, where criteria could be independent, cooperative, or conflicting. Interaction among criteria could be addressed by analyzing the level of compensation allowed between good and poor performances of alternatives with respect to criteria [79]. PROMETHEE II Indifference, Preference and Veto thresholds could be used to provide a more robust outcome [80].

This paper presented a new framework and methods to recommend a MCDM method that delivered the most robust corporate relocation decision from a variety of existing MCDM methods, each having its own advantages, disadvantages and limitations. Considering a number of potential scenarios for relocation problems, a new set of propositions were created and were presented.

FUTURE WORK

Decision making is being applied to other areas [80; 81]. After that the authors are now applying the Weighted Sum Model (WSM), the Weighted Product Model (WPM), the Weighted Aggregated Sum Product ASsessment (WASPAS) method, Additive Ratio ASessment method (ARAS), Complex PRoportional ASsessment (COPRAS) method, the Multiplicative Exponent Weighting (MEW) method, Simple Additive Weighting (SAW) method, AHP and PROMETHEE II using different values of λ for WASPAS and different types of preference functions: U-shaped criterion, V-shaped criterion, Level criterion, V-shape with indifference criterion, and Gaussian criterion for PROMETHEE II to different corporate relocation decisions.

Perfect consistency in real life problems is often hard to achieve. To investigate this, the authors intend to apply different MCDM methods to other corporate relocation decisions with inconsistent pairwise comparisons in various uncertain, fuzzy and risky environments.

Future work will consider applying different MCDM methods to corporate relocation decisions such as PROMETHEE VI (a representation of the Human Mind), Elimination Et Choix Traduisant la REalite, (ELECTRE) family methods, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and other Multi Attribute Value (MAVT) methods.

Future work will consider more problems with larger number of alternatives (cities) and evaluation criteria. AHP, PROMETHEE II, PROMETHE, and other MCDM methods will be applied to these problems and the stability of the outcome of these methods will be analyzed in certain and uncertain environments. Monte Carlo simulation and other approaches will be used to model uncertainty in more than one input factor at the same time.

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