Hybrid solutions for international marketing decision-making: mathematical description, computational modelling, knowledge automation and software examples

Li, Shuliang and Li, J.Z.

This is a pre-publication version of a paper published in Proceedings of the 5th WSEAS International Conference on Management Marketing and Finances (MMF '11), 24 - 26 Mar 2011, Meloneras, Gran Canaria, Spain, WSEAS. pp. 174-180.

Li, Shuliang and Li, J.Z. (2011) Hybrid solutions for international marketing decision-making: mathematical description, computational modelling, knowledge automation and software examples. In: Recent researches in sociology, financing, environment and health sciences (Proceedings of the 5th WSEAS International Conference on Management Marketing and Finances (MMF '11)), 24 - 26 Mar 2011, Meloneras, Gran Canaria, Spain. MMF, pp. 174-180. ISBN 9789604742875

Hybrid Solutions for International Marketing Decision-Making: Mathematical Description, Computational Modelling, Knowledge Automation and Software Examples

SHULIANG LI
Westminster Business School, University of Westminster,
35 Marylebone Road, London NW1 5LS
UNITED KINGDOM
E-mail: lish@wmin.ac.uk

JIM ZHENG LI
Department of Computing, Imperial College London,
180 Queen's Gate, South Kensington campus, London SW7 2AZ
UNITED KINGDOM

Abstract: Aiming at supporting the international marketing decision-making process and improving its outcomes, the authors develop and put forward a novel hybrid mathematical, computational and knowledge automation framework for integrating and hybridising the strengths of Web-enabled Monte Carlo simulation algorithms, fuzzy logic, knowledge automation expert system, and online relational data algebraic operations. The value of the framework is illustrated using software examples.

Key-words: International marketing planning; computational modelling; hybrid knowledge automation; simulation; fuzzy logic; expert system; decision support

1 Introduction

Over the past decades, computer-based systems that assist with strategic marketing planning have obtained attention from both researchers and practitioners [9, 10]. Studies have also been conducted to investigate the use of computers in support of different facets of the international marketing decision making process for entering and competing in the global markets using various techniques and technologies including expert systems [1, 2, 14], fuzzy logic [8], software agents [12, 15], and hybrid systems [10, 11, 12, 13].

Previous studies, nonetheless, are mainly concerned with software systems development and evaluation. In contract, as the first attempt, we propose and develop a hybrid mathematical, computational and knowledge automation framework for the process of international marketing decision-making. We will also show and discuss relevant software examples created by the authors.

2 Mathematical Description, Computational Modelling and Knowledge Automation Framework

A hybrid system [4, 5] is an effective solution to many complex problems. Our framework aims at assisting the key stages of international marketing planning: 1) "go versus no go" decision; 2) "how to go" decision, and 3) marketing strategy formulation. Diverse decision support and artificial intelligence techniques and technologies are integrated into one framework, and their specific advantages are utilised to deal with the particular aspects of the planning problem. The following elements will be used in our mathematical description and computational formulation:

Li, Shuliang and Li, J.Z. (2011) Hybrid solutions for international marketing decision-making: mathematical description, computational modelling, knowledge automation and software examples. In: Recent researches in sociology, financing, environment and health sciences (Proceedings of the 5th WSEAS International Conference on Management Marketing and Finances (MMF '11)), 24 - 26 Mar 2011, Meloneras, Gran Canaria, Spain. MMF, pp. 174-180. ISBN 9789604742875

- The simplified international marketing decision making process, I, which focuses on the following three key stages: go versus no go decision (G), how to go decision (entry mode selection) (H), and marketing strategy formulation (S).
- Human judgement, personal vision, intuition and creativity, J.
- Decision support and artificial intelligence techniques and technologies, T, such as analytic hierarchy process (AHP), Internet-enabled intelligent software agents (IA), Monte Carlo simulation (MCS), fuzzy logic (FL), Web-based knowledge automation expert systems (KAES), on-line databases (DB), and other techniques (OT).

The key stages of the international marketing decision making process may be formulated as: I = (G, H, S). The supporting techniques and technologies can be defined as: T = (AHP, IA, MCS, FL, KAES, DB, OT, Web). Managerial judgement can be described as: J = (Judgement, Intuition, Creativity).

The outcome of the international marketing decision making process can be represented as the following equation:

$$\text{OUTCOME} = f_{\text{I}}\,(\text{G, H, S}) + f_{\text{T}}\,(\text{AHP, IA, MCS, FL, KAES, DB, OT, Web}) + f_{\text{J}}\,(\text{Judgement, Intuition, Creativity})$$

where f_{I} , f_{T} and f_{J} are implicit functions for the decision-making process, supporting techniques and human judgement, respectively. Here, symbol "+" indicates logical join, union, integration or hybridisation with associated interaction.

Within this mathematical framework, the Web-based hybrid intelligent decision support system, WHS, is expressed as

WHS = AHP ¤ MCS ¤ FL ¤ KAES ¤ DB ¤ OT ¤ Web

in which the symbol ¤ is intercommunicating hybridisation and integration operator and OT denotes other techniques and associated sub-systems.

2.1 The analytic hierarchy process

The analytic hierarchy process (AHP) [17, 18] can be used to structure the decision making problem in a hierarchical form and incorporate human judgement and preferences [20]. It enables the user to build pair-wise comparison matrices and sum up the weights or relative importance of decision variables or factors to gain an overall ranking [7]. AHP can be applied to estimate the weights for the factors or criteria influencing international marketing planning.

2.2 Web-based Monte Carlo simulation

Monte Carlo simulation utilises probability and random numbers to model and deal with uncertainty and stochastic permutation [16]. The algorithm for Monte Carlo simulation employs uniformly distributed random numbers and the inverse function of a symmetric or asymmetric cumulative distribution of the triangular probability distribution. It is a revised and extended version of the algorithm published by Brighton Webs Ltd. http://www.brighton-webs.co.uk/distributions/triangular.asp (Accessed on 01/12/2008).

2.3 Fuzzy logic and the space of strategic variables

According to page 338 of Zadeh [24], "a fuzzy set is a class of objects with a continuum of grades of membership". Let U be a universe of discourse, a collection of objects $\{u\}$. A fuzzy set A in U is symbolized by a compatibility or membership function μ_A taking values in the range [0, 1]. A in U is denoted as [6, 25]: $A = \{ (u, \mu_A(u)) \,|\, u \in U \}$

When U is continuous $A = \int_U \mu_A(u)/u$

When U is discrete $A = \sum_{i=1}^{n} \mu_A(u_i)/u_i$

Li, Shuliang and Li, J.Z. (2011) Hybrid solutions for international marketing decision-making: mathematical description, computational modelling, knowledge automation and software examples. In: Recent researches in sociology, financing, environment and health sciences (Proceedings of the 5th WSEAS International Conference on Management Marketing and Finances (MMF '11)), 24 - 26 Mar 2011, Meloneras, Gran Canaria, Spain. MMF, pp. 174-180. ISBN 9789604742875

where the integral sign indicates the union of fuzzy singletons and the symbol Σ plays the role of the union and means all possible combinations of all elements.

The space of strategic variables or factors is defined below.

For the cases of making "go versus no go" decisions, the set of variables or factors (values ranging from 1 to 10) that influence the choices can be represented as an vector *Z*, on the basis of Fung et al [3]'s work:

$Z = (Z_1, Z_2, \ldots, Z_m)$ in the fuzzy space of *U*

For the input fuzzy vector *Z*, there exist s a real vector *w* that represents the weights or relative importance for the strategic factors or variables, such that $w = (w_1, w_2, \ldots, w_m)$ which can be determined using the AHP method.

We then aggregate the values of *Z* and *w* to compute the value of an object, *u*, using the formula:

$$u = Z_1 \cdot w_1 + Z_2 \cdot w_2 + \ldots + Z_m \cdot w_m$$

Similarly, for the cases of using four-box or nine-box matrix for strategy formulation, a set of criteria or variables (values ranging from 1 to 10) determining any dimension of a strategic grid/matrix can be modelled and calculated in the same way.

2.4 Fuzzification of the variables or factors affecting international marketing decisions

Trapezoidal membership/compatibility functions are employed to fuzzify the aggregated scores for "go versus no go" variables or strategic grid dimensions. For real numbers $a <= b <= c <= d$, the trapezoid $\check{T}(a, b, c, d)$ with amplitude one is defined by Levy and Yoon [8] as:

$\check{T}(u) = 0$ if $u <= a$; $\check{T}(u) = (u - a)/(b - a)$ if $a < u <= b$; $\check{T}(u) = 1$ if $b < u <= c$; $\check{T}(u) = (d - u)/(d - c)$ if $c < u <= d$; $\check{T}(u) = 0$ if $d < u$; $\check{T}(a) = 1$ if $a = b$; $\check{T}(d) = 1$ if $c = d$.

Here, $u \in U$.

If we use *X* to denote the name of the fuzzy variable and *T(X)* is the term set of *X*, that is, the collection of its linguistic values, then we have such examples as *T* (go vs. no go) = (go, no go) with underlying fuzzy sets; *T*(Internet connectivity) = (low, high) with corresponding fuzzy sets; *T*(information content of products) = (low, high) with associated fuzzy sets.

2. 5 Fuzzification of the strategic models

Firstly, inputs for each strategic factor from the AHP and simulation components and human decision-makers are collected and aggregated. An overall score for each dimension of the strategic matrix or grid is then calculated. The calculated scores are then converted into fuzzy memberships or compatibility functions. Fig. 1 illustrates one example where trapezoidal membership functions are used. Other models may be fuzzified using a similar method.

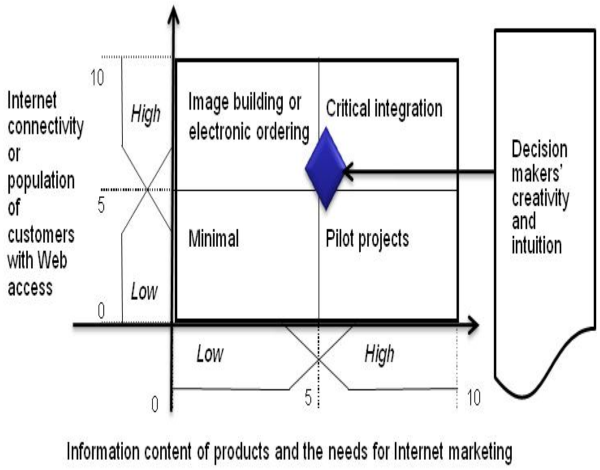

Fig.1. Model fuzzification example using Watson and Zinkhan [23]'s grid (adapted from page 5561 of Li and Li [10])

2.6 Advising "go versus no go" options

Fuzzy variable "go" and "no go" are recommended with levels of confidence simply computed using the above-mentioned trapezoidal membership functions, on the basis of the aggregated scores for pertinent variables or criteria concerned.

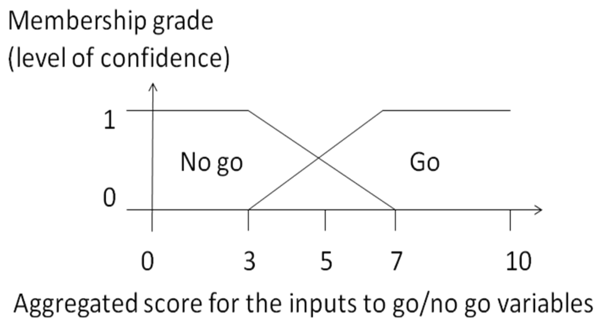

Fig.2. Fuzzy sets for "go versus no go" decisions with membership functions

2.7 Entry mode selection

Entry modes are determined by "if-then" rules on the basis of the user's inputs to the following two criteria: the level of risk the company is wishing to take, and the degree of market control.

2.8 Evaluation of the fuzzy rules for strategic grids or models for advising marketing strategies

Based upon the theory for the management of uncertainty in expert systems pioneered by Zadeh [26], the mechanism for the evaluation fuzzy rules for international marketing strategy recommendation is proposed below. Let D_i denote the dimension (e.g. Internet connectivity or market attractiveness) of a strategic matrix and O_i denote a list of strategic options. For a two-dimensional strategic matrix, the general form of a fuzzy inference rule can be expressed as:

$$R_i: \text{ If } (D_{i1} \text{ is } d_{i1} \text{ and } D_{i2} \text{ is } d_{i2}), \text{ then } O_i \text{ is } o_i$$

where d_{i1} and d_{i2} are the linguistic variables corresponding to the specific values (e.g. low, or high) of the two-dimensions in a strategic grid and o_i is the linguistic variable corresponding to a particular strategic option.

2.9 Evaluating the premise of a fuzzy rule for international marketing strategy development

The level of confidence or grade of certainty of the predicates in the premise (condition part) of the rule R_i is given by:

The level of confidence of 'D_{i1} is d_{i1}' is l_{i1}
The level of confidence of 'D_{i2} is d_{i2}' is l_{i2}

The overall grade of certainty in the premise of R_i can be expressed in the form of conjunctive rule:

$$l_i = (l_{i1}) \wedge (l_{i2}) = \min(l_{i1}, l_{i2})$$

In real-world decision-making situations, to avoid same levels of confidence for different strategic options caused by the above expression, we can apply Bayes theorem to a fuzzy extension [22]. Because the two dimensions of a strategic grid are independent to each other, the overall degree of confidence or certainty factor in the premise of R_i may also be denoted as a joint fuzzy probability:

$$l_i = (l_{i1})(\bullet)(l_{i2})$$

2.10 Determining the degree of confidence for the consequent of the rule

For fuzzy rule R_i, the level of confidence of its consequent will be the same as the overall degree of confidence of its premise. The grade of certainty of the consequent 'O_i is o_i' is also equal to l_i.

2.11 Strategic recommendations

After execution of the fuzzy rules, the automated system produces one or more strategic alternatives in the form of:

O_j is o_{j1}: l_{j1}
O_j is o_{j2}: l_{j2}
… …
O_j is o_{jk}: l_{jk} where *k* <= 4 for a four-cell or nine-cell strategic grid/matrix.

The outputs are not aggregated because we hope to give a list of strategic options/alternatives with corresponding grades of certainty or degrees of confidence. The decision-makers then re-examine the system's outputs and evaluate which alternative is preferred and choose a particular one.

Li, Shuliang and Li, J.Z. (2011) Hybrid solutions for international marketing decision-making: mathematical description, computational modelling, knowledge automation and software examples. In: Recent researches in sociology, financing, environment and health sciences (Proceedings of the 5th WSEAS International Conference on Management Marketing and Finances (MMF '11)), 24 - 26 Mar 2011, Meloneras, Gran Canaria, Spain. MMF, pp. 174-180. ISBN 9789604742875

2.12 Online databases

Following Silberschatz, Korth and Sudarshan [19]'s mathematical notations and representation for manipulative operations on the relations of databases, our target hybrid system mainly include Web-enabled insertion, deletion and updating data.

Insertion into a Web-based relation, r, can be represented in the following relational algebra form:

$r \leftarrow r \cup E$ where $\cup$ is the union of sets and E is an expression.

A deletion manipulation can be stated as:
$r \leftarrow r - E$

Choosing tuples from relation r and modify them when necessary:

$$r \leftarrow \prod_{F1, F2, \ldots, Fn} (\sigma_P (r)) \cup (r - \sigma_P (r))$$

in which each F_i is the ith data field of r while P symbolizes the condition that looks up which tuples to alter. Here, $\prod$ is the projection operator on Web-based database server via the Internet.

Selecting tuples and displaying data:

$\sigma_{selection\ predicate} (r)$ in which σ stands for selection manipulation.

2.13 Roles of managerial intuition, judgement and creativity

The decision makers are required to provide their judgemental inputs to the variables or factors influencing such decision as go versus no go, how to go and marketing strategy formulation. They should also apply their intuition, judgement and creativity when making a final choice on the basis of the system-generated go/no go advice, entry modes, strategic alternatives, considering various degrees of confidence.

3 Examples

3.1 The AgentsInternantional system

The main objective of this system is to aid the following key stages of international marketing decision making discussed in Section 2. Following the mathematical, computational and knowledge automation framework proposed in the previous sections, AgentsInternational [12] was developed by the authors using WIN-Prolog packages and Chimera Agents Toolkits.

The system consists of various multiple agents-enabled components: a chief coordination agent created to manage interaction and communication between the user and connected intelligent agents; a "go vs. no go" agent designed to make ''go" or ''no go" recommendations by helping review the variables or criteria in different categories and at different hierarchies; a Monte Carlo simulation element programmed to model the market changes and uncertainties; an entry mode selection agent developed to advise "how to go" options in line with the levels of risk and control; and strategy formulation agents developed to represent diverse analytical models, domain expertise and guidelines, and conduct fuzzy reasoning for generating and advising marketing strategies, global marketing strategies, Internet strategies, Sun Tze's Art of War guidelines, and Porter's generic competitive strategies, with calculated grades of certainty.

The multi-agent system was tested by carrying out evaluation work in October and November of 2008 with three company directors and managers, and five university course leaders. The participants were asked to apply the AgentsInternational system to take international marketing decisions for their own cases. They then were requested to answer an evaluation questionnaire that contained both closed and open-ended questions.

The system was assessed as very effective in terms of helping understand relevant factors, offering marketing expertise, handling uncertainty, and improving the quality of decision making. In particular, it was described as: ''reinforcing my confidence and consideration in decision making", ''providing useful ideas/suggestions", and ‘‘expanding thinking of areas and issues to be considered".

3.2 The WebInternational system

On the basis of the computational and knowledge automation framework, the WebInternational system [13] was created by the authors to aid the process of international marketing decision-making. It was programmed by the authors using PHP (Hypertext Preprocessor), Ajax, JavaScript and MySQL and is based on server-side implementation architecture.

The elements of WebInternational include: a Web-based database component for saving and retrieving data entries to different types and different levels of decision-making variables and their choices; a knowledge base for containing rules and fuzzy rules which represent the domain expertise for go/no go choices, entry mode decisions, recommendations and advice on strategies; a Web-based inference function for reasoning and producing intelligent outputs; and an user interface for user-system communications.

The efficiency and effectiveness of WebInternational were evaluated with five company directors and managers, and five university course leaders in 2008, 2009 and 2010, employing case-based questionnaire survey method. The system was seen to significantly enhance decision-making efficiency in terms of easy access, speed and saving effort. It was also considered as highly effective in combining analysis with judgement and creativity, improving quality of decision-making outcomes, confidence and satisfaction. In addition, it was evaluated as "more user friendly and easier to access", and ‘‘reviewing the issues, providing focus on key questions, encouraging different thinking".

4 Conclusions

This is the first study that seeks to establish a hybrid mathematical, computational and knowledge automation framework for international marketing planning. We have developed a systematic method for modelling and automating the process of international marketing decision-making, through combining the powers of online databases, Monte Carlo simulation, expert systems, fuzzy rules and approximate reasoning under uncertainty to complement human intuition and creativity, and support the key stages of the planning process. Software examples have been presented to demonstrate the usefulness of such a framework.

Our research work and evaluation findings show that the international marketing planning process can be described mathematically and supported effectively. The application of Web-based hybrid intelligent framework and relevant software systems to the international marketing cases unveil that it is possible for using this type of hybrid solutions to improve the decision-making procedure and its output.

Acknowledgements

Jim Zheng Li and Dr. Shuliang Li designed, developed and tested the AgentsInternational system and the WebInternational system. They therefore own the full copyrights for these software products.

The authors wish to thank the following people for their participation in evaluating the AgentsInternational and WebInternational systems in 2008, 2009 and 2010: Dr Edward Qu, Director of AntiGrav Media Limited, UK; Mr. Rav Ubhi, Systems Manager, WSP group, London, UK; Mr. Clive Spenser, Marketing Director, LPA Ltd., London, UK; Mr. Grozdyu Evgeniev Grozdev, Director, GSATV Ltd.; Mr. Gabriel Wanschelbaum, Business Analyst, CIT International Ltd., London, UK; Ms. Jean Dong, Managing Director, China Factor Ltd., London, UK; Ms. Rachel Lander, Mr. Haik Richards, joint course leader of MSc Digital Enterprise Management, University of Westminster, UK; Mr. Mark Pilkington, course leader of MSc International Finance, the University of Westminster, UK; Ms. Rachel Lander, joint course leader/manager of MSc Digital Enterprise

Management, the University of Westminster, UK; Keith Patrick, course leader of MSc Information Management and Finance, the University of Westminster, UK; Mr. Brian Heagney, course leader of MA Management Studies, the University of Westminster, UK.

References

[1] S. Cavusgil, M. Mitri & T. Evirgen, A decision support system for doing business with Eastern bloc countries, *European Business Review*, Vol.92, No.4, 1992, pp.24–34.

[2] S. Cavusgil & T. Evirgen, Use of expert systems in international marketing: an application for co-operative venture partner selection, *European Journal of Marketing*, Vol.31, No.1, 1997, pp.73–86.

[3] R.Y. K. Fung, K. Popplewell & J. Xie, An intelligent hybrid system for customer requirements analysis and product attribute targets determination, *International Journal of Production Research*, Vol.36, No.1, 1998, pp.13 – 34.

[4] S. Goonatilake & S. Khebbal, Intelligent hybrid systems: Issues, classifications and future directions, In S. Goonatilake & S. Khebbal (Eds.), *Intelligent hybrid systems*, John Wiley & Sons, Chichester, 1995.

[5] A. A. Hopgood, *Intelligent Systems for Engineers and Scientists*, CRC Press, London, 2001.

[6] C. C. Lee, Fuzzy logic in control systems: fuzzy logic controller – part I, *IEEE Transactions on Systems, Man and Cybernetics*, Vol.20 No.2, 1990, pp.404-418.

[7] A. Lee, W. Chen & C. Chang, A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan, *Expert Systems with Applications*, Vol.34, No.1, 2008, pp.96-107.

[8] J. Levy & E. Yoon, Modeling global market entry decision by fuzzy logic with an application to country risk assessment, *European Journal of Operational Research*, Vol.82, 1995, pp.53–78.

[9] S. Li, R. Kinman, Y. Duan & J. Edwards, Computer-based support for marketing strategy development, *European Journal of Marketing*, Vol.34, No 5/6, 2000, pp.551–575.

[10] S. Li & J. Z. Li, Hybridising human judgement, AHP, simulation, and a fuzzy expert system for strategy formulation under uncertainty, *Expert Systems with Applications*, Vol.36, No.3, 2009, pp.5557–5564.

[11] S. Li & J. Z. Li, A Web-based hybrid system for international marketing planning, *the third WSEAS international symposium: Management, marketing and finance (MMF '09)*, 30th April–2nd May 2009, Houston, USA.

[12] S. Li & J. Z. Li, AgentsInternational: Integration of multiple agents, simulation, knowledge bases and fuzzy logic for international marketing decision making. *Expert Systems with Applications*, Vol.37, No.3, 2010, pp.2580–2587.

[13] S. Li & J. Z. Li, WebInternational: combining Web knowledge automation, fuzzy rules and online databases for international marketing planning, *Expert Systems with Applications*, Vol.37, No.10, 2010, pp.7094-7100.

[14] M. Mitri, G. Karimalis, H. Cannon & A. Yaprak, Mapping market entry in the classroom: the market access planning system (MAPS), *Simulation and Gaming*, Vol.31, No.4, 2000, pp. 464–478.

[15] S. Pinson, J. Louca & P. Moraitis P, A distributed decision support system for strategic planning, *Decision Support Systems* Vol.20, No.1, 1997, pp.35–51.

[16] K. Rezaie, M. Amalnik, A. Gereie, B. Ostadi & M. Shakhseniaee, Using extended Monte Carlo simulation method for the improvement of risk management: Consideration of relationships between uncertainties, *Applied Mathematics and Computation*, Vol.190, 2007, pp.1492–1501.

[17] T. L. Saaty, A scaling method for priorities in hierarchical structures, *Journal of Mathematical Psychology*, Vol.15, No.3, 1977, pp.234–281.

[18] T. L. Saaty, How to make a decision: The analytic hierarchy process, *European Journal of Operational Research*, Vol.48, No.1, 1990, pp. 9–26.

[19] A. Silberschatz, H. Korth & S. Sudarshan, *Database System Concepts*, McGraw Hill, New York, 2006.

[20] S. Tsaur, G. Tzeng & K. Wang, Evaluating tourist risks from fuzzy perspectives, *Annals of*

Tourism Research, Vol.24, No.4, 1997, pp.796-812.

[21] L. Von Bertalanffy, An outline of general system theory, t*he British Journal for the Philosophy of Science* Vol.1, No.2, 1950, pp.134–165.

[22] Z. Xu, T. Khoshgoftaar & E. Allen, Application of fuzzy expert systems in assessing operational risk of software, *Information and Software Technology*, Vol.45, No.7, 2003, pp.373-388.

[23] R. Watson & G. Zinkhan, Electronic commerce strategy: addressing the key questions, *Journal of Strategic Marketing*, Vol.5, No.4, 1997, pp.189-210.

[24] L. A. Zadeh, Fuzzy sets, *Information and Control*, Vol.8, No.3, 1965, pp.338-353.

[25] L. A. Zadeh, Fuzzy logic and approximate reasoning, *Synthese*, Vol.30, No.3/4, 1975, pp.407-428.

[26] L. A. Zadeh, The role of fuzzy logic in the management of uncertainty in expert systems, *Fuzzy Sets and Systems*, Vol.11, 1983, pp.199-227.