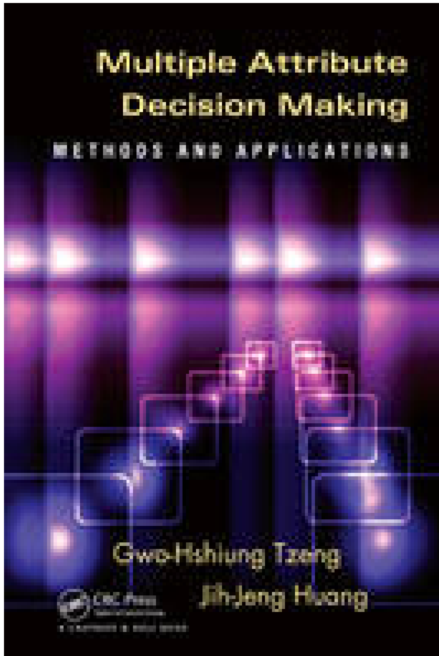
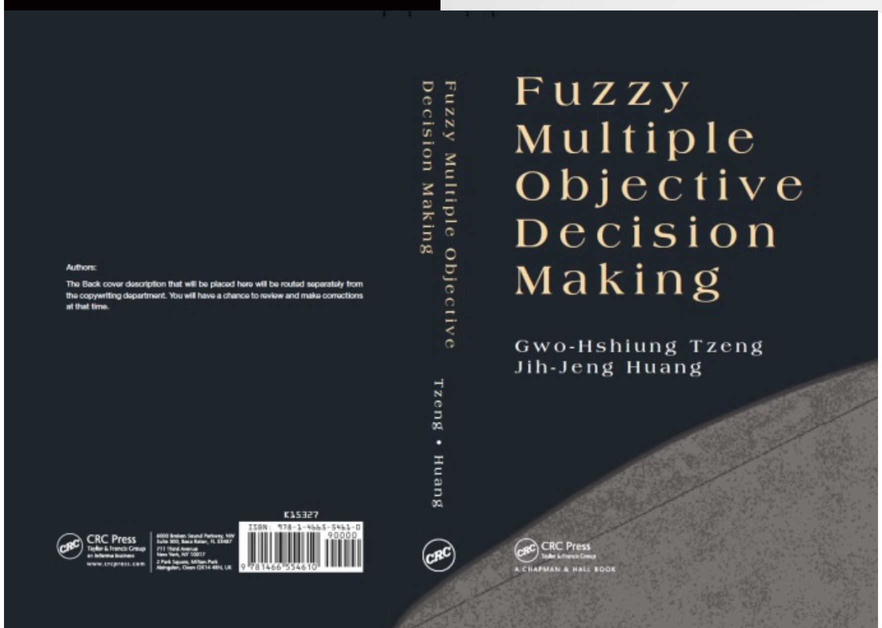


New Concepts and Trends of Hybrid MCDM Model for Tomorrow

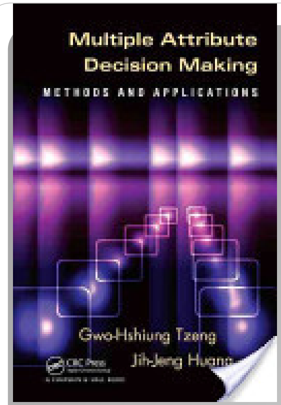
- For Solving Actual Problems – (Summer Camp) - 1 -



Gwo-Hshiung Tzeng
Distinguished Chair Professor

College of Public Affairs
National Taipei University

Talk for Summer Camp, NTPU
Administration Building F4, Room 2
July 15 (TUE) – 17 (THU), 2014

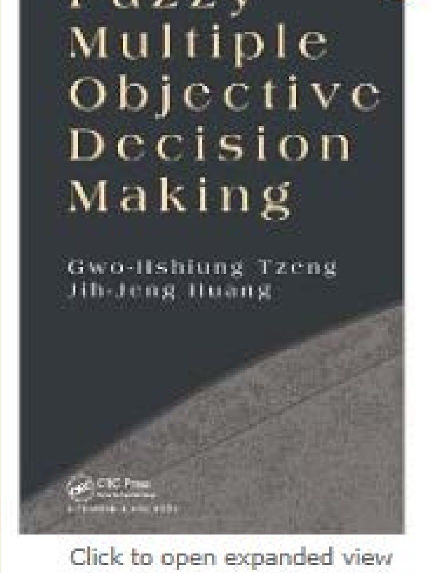


Two New Books (1)

Multiple Attribute Decision Making: Methods and Applications

Gwo-Hshiung Tzeng, Jih-Jeng Huang, CRC Press, Taylor & Francis Group, 2011, 349 pages

- Decision makers are often faced with several conflicting alternatives. How do they evaluate trade-offs when there are more than three criteria? To help people make optimal decisions, scholars in the discipline of multiple criteria decision making (MCDM) continue to develop new methods for structuring preferences and determining the correct relative weights for criteria. A compilation of modern decision-making techniques, Multiple Attribute Decision Making: Methods and Applications focuses on the fuzzy set approach to multiple attribute decision making (MADM). Drawing on their experience, the authors bring together current methods and real-life applications of MADM techniques for decision analysis. **They also propose a novel hybrid MADM model that combines DEMATEL and DEMATEL-based ANP (DANP) with VIKOR procedures**.
- **The first part of the book focuses on the theory of each method and includes examples** that can be calculated without a computer, providing a complete understanding of the procedures. Methods include the analytic hierarchy process (AHP), ANP, simple additive weighting method, ELECTRE, PROMETHEE, the gray relational model, fuzzy integral technique, rough sets, and the structural model. Integrating theory and practice; **the second part of the book illustrates how methods can be used to solve real-world MADM problems**.



Two New Books (2)

Fuzzy Multiple Objective Decision Making

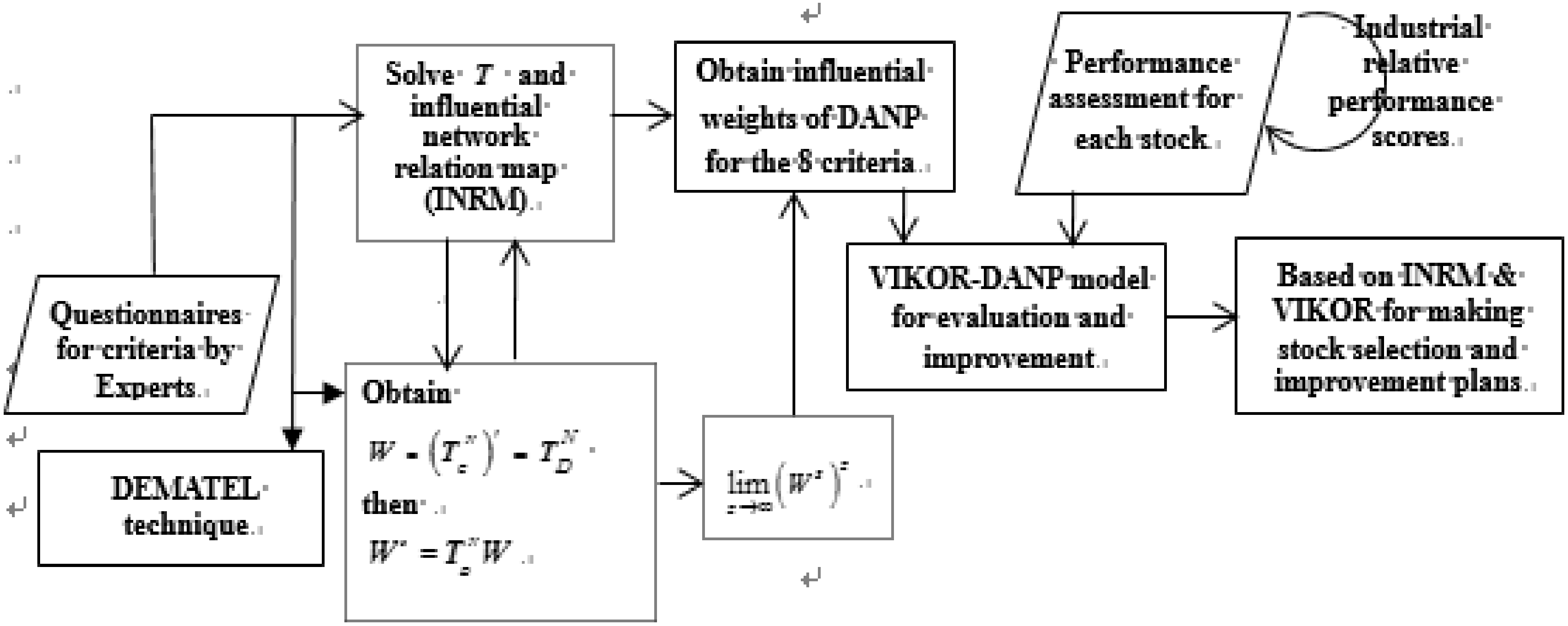
Gwo-Hshiung Tzeng, Jih-Jeng Huang, CRC Press, Taylor & Francis Group, 2013, 313 pages

Multi-objective programming (MOP) can simultaneously optimize multi-objectives in mathematical programming models, but the optimization of multi-objectives triggers the issue of **Pareto solutions** and complicates the derived answers. To address these problems, researchers often incorporate the concepts of fuzzy sets and evolutionary algorithms into MOP models.

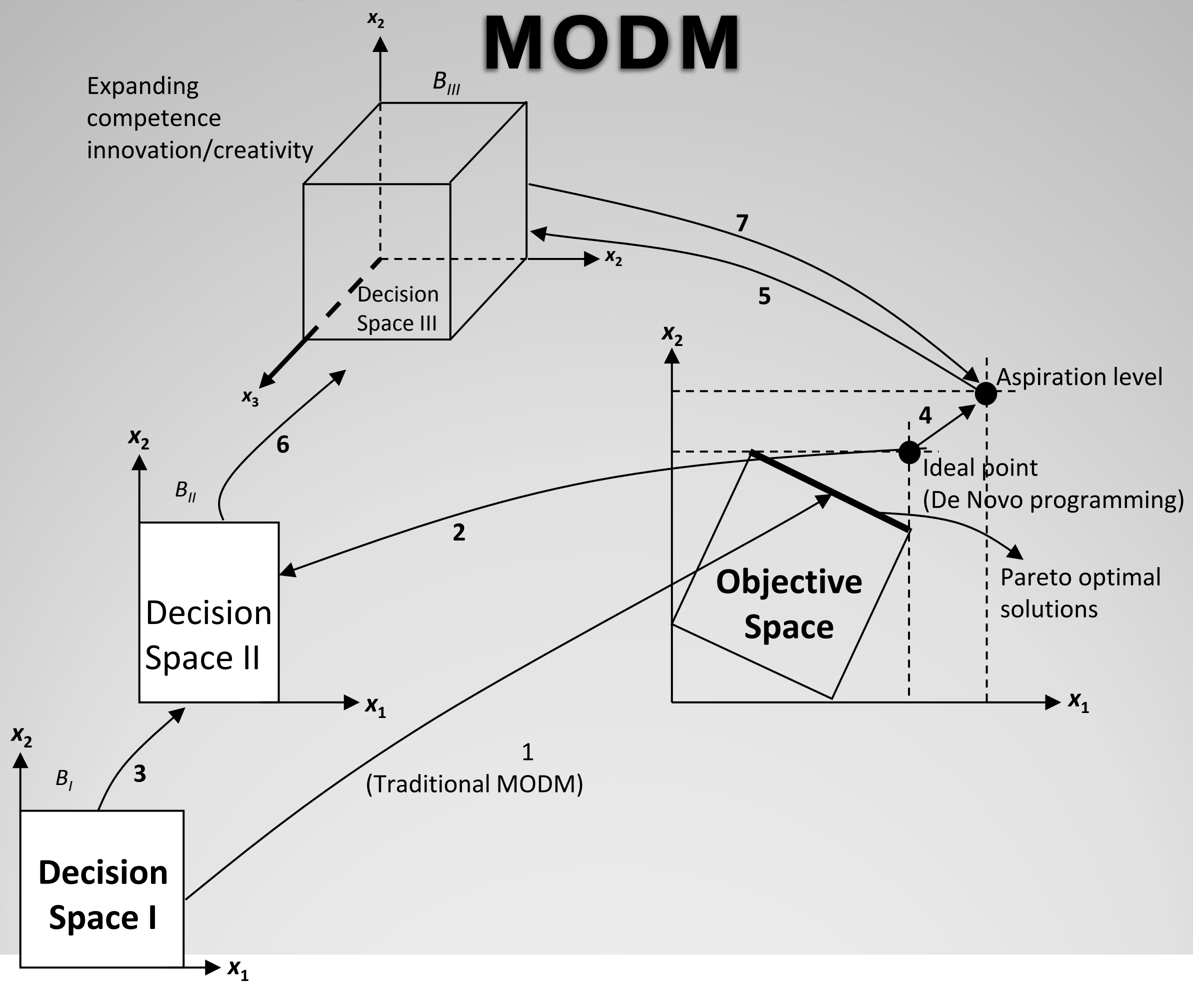
- Focusing on the methodologies and applications of this field, **Fuzzy Multiple Objective Decision Making** presents mathematical tools for complex decision making**. The first part of the book introduces the most popular methods used to calculate the solution of MOP in the field of multiple objective decision making (MODM). The authors describe multi-objective evolutionary algorithms; expand de novo programming to changeable spaces**, **such as decision and objective spaces**; and cover network data envelopment analysis. **The second part focuses on various applications**, giving readers a practical, in-depth understanding of MODM.
- A follow-up to the authors' *Multiple Attribute Decision Making: Methods and Applications*, this book guides practitioners in using MODM methods to make effective decisions. It also extends students' knowledge of the methods and provides researchers with the foundation to publish papers in operations research and management science journals.

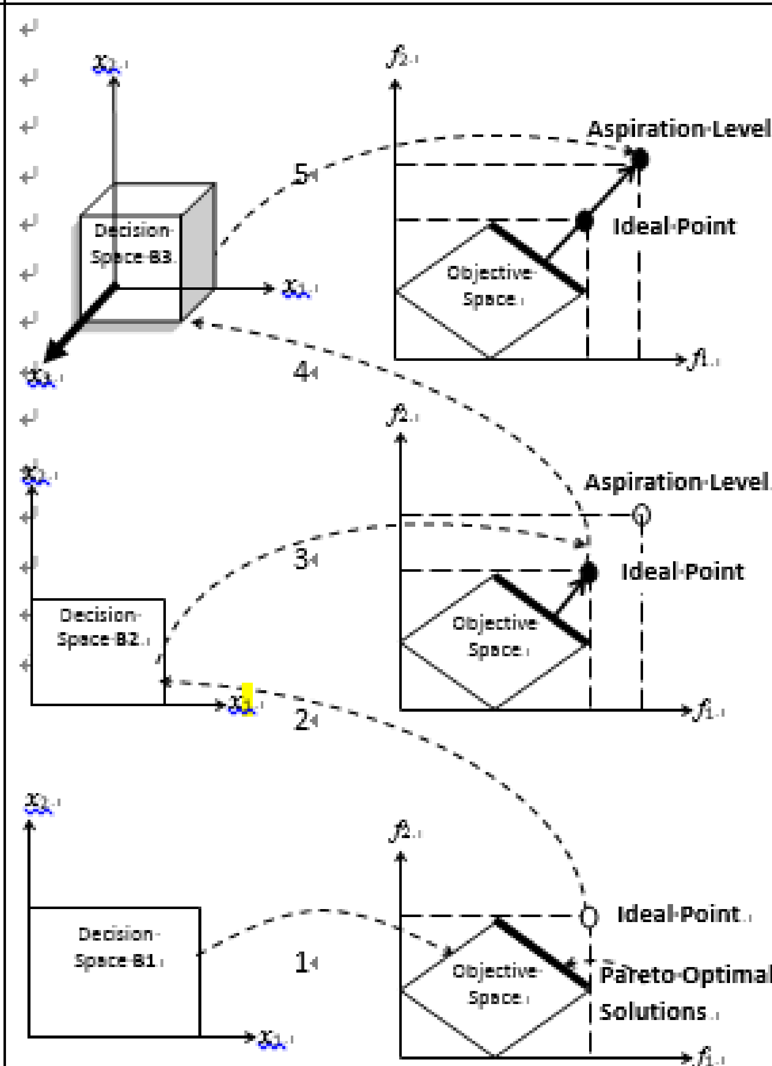
The Basic Concepts of New Hybrid MADM Model in the Real World

- Case of making stock selection and improvement plans -



The new concepts and Trends of changeable spaces and aspiration level in MODM



Concept	Graphical Representation	Approach
Value (Win-Win)		making aspired decisions by expanding competence sets through innovation.
		Making Ideal decisions through re-allocating limited resources.
Price (Win-Lose)		Making Pareto optimal decisions through traditional MOP methods

Changeable Spaces Programming by Stages in New Thinking of MODM

New Publications
(Important papers)

- **Liou, James J.H. and Tzeng, G.H. (Corresponding author)** (**2012**), Comments on "Multiple criteria decision making (MCDM) methods in economics: An overview", ***Technological and Economic Development of Economy***, **18(4)**, 672-695 **(SSCI, IF: 5.605, 2011; IF: 3.235, 2012).** Z Turskis, EK Zavadskas (VGTU)
- **Kua-Hsin Peng, Gwo-Hshiung Tzeng** (**Corresponding author**) (**2013**), A hybrid dynamic MADM model for problems-improvement in economics and business, ***Technological and Economic Development of Economy***, **19(4)**, 638–660 (**SSCI, IF: 5.605, 2011; IF: 3.235, 2012).**
- **James J.H. Liou, Yen-Ching Chuang, Gwo-Hshiung Tzeng** (**Corresponding author**) **(2013),** “A fuzzy integral-based model for supplier evaluation and improvement, ***Information Sciences*, 266**, 199–217 (Impact factor: **3.643** (5-Year) Impact Factor: **3.676 (2012), IPP: 4.686 (2013)**).
- **Jih-Jeng Huang, Gwo-Hshiung Tzeng** (**2014**), New thinking of multi-objective programming with changeable space - In search of excellence, ***Technological and Economic Development of Economy***, **20(2), 254-273 (SSCI, IF: 5.605, 2011; IF: 3.235, 2012).**
- **James J.H. Liou (2013),** New concepts and trends of MCDM for tomorrow – in honor of Professor Gwo-Hshiung Tzeng on the occasion of his 70th birthday, ***Technological and Economic Development of Economy***, **19(2)**, 367–375 (**SSCI, IF: 5.605, 2011; IF: 3.235, 2012).**

New Journal Papers

- **2014**
- Shu-Kung Hu, Ming-Tsang Lu, **Gwo-Hshiung Tzeng** (**Corresponding author**) **(2014)** Exploring smart phone improvements based on a hybrid MCDM model, **Expert Systems With Applications, *Volume 41, Issue 9*, *July 2014*, *Pages 4401-4413* (SCI**, **IF: 1.854**, 2.339 (5-years**, 2012**).
- Chih-Hung Wu*, Yi-Lin Tzeng, Bor-Chen Kuo, **Gwo-Hshiung Tzeng** (2014), **Affective Computing Techniques for Developing a Human Affective Norm Recognition System for U-learning Systems**, **International Journal of Mobile Learning and Organisation (IJMLO), 8(1): 50-66.**
- **Jih-Jeng Huang, Gwo-Hshiung Tzeng** (**2014**), New thinking of multi-objective programming with changeable spaces - In search of excellence, ***Technological and Economic Development of Economy*, 20(2),** 254-273 **(SSCI, IF: 5.605, 2011; IF: 3.235, 2012).**
- Kao-Yi Shen, Min-Ren Yan, and **Gwo-Hshiung Tzeng** (**Corresponding author**) **(2014), Combining VIKOR-DANP model for glamor stock selection and stock performance improvement**, ***Knowledge-Based Systems***, *Volume 58*, *March 2014*, *Pages 86-97* **(SCI**, **IF: 4.104**, 3.371 (5-years**, 2012**).
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- **Yu-Chien Ko, Hamido Fujita, Gwo-Hshiung Tzeng** (**2014**), **A simple utility function with the rules-verified weights for analyzing the top competitiveness of WCY 2012**, ***Knowledge-Based Systems***, *Volume 58*, *March 2014*, *Pages 58-65* (SCI, IF: **4.104**, 3.371 (5-years, 2012).
- Wan-Yu Chiu, **Gwo-Hshiung Tzeng**, Han-Lin Li (**2014**). Developing e-store marketing strategies to satisfy customers' needs using a new hybrid grey relational model, ***International Journal of Information Technology & Decision Making,*** Vol. 13, No. 2 (2014) 231–261.
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10.1007/s11628-014-0239-9

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- Ming-Tsang Lu, **Gwo- Hshiung Tzeng**, Hilary Cheng, Chih-Cheng Hsu **(2014).** Exploring Mobile Banking Services for User Behavior in Intention Adoption: Using New Hybrid MADM Model, ***Service Business*** (Accepted, **SSCI**, **IF: 0.571, 2012**) DOI:10.1007/s11628-014-0239-9

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- Kao-Yi Shen and **Gwo-Hshiung Tzeng** (**Corresponding author**) (2014). A decision rule-based soft computing model for diagnosing financial performance-improvement of commercial banks, Soft Computing, Accepted (**SCI,** 2012 Impact Factor; **1.124**; 5-Year Impact Factor: **2.526**).

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Talk: New Concepts and Trends of Hybrid MCDM Model for Tomorrow

- New concepts and trends of hybrid MCDM model for Tomorrow

- How consider for solving the real world

- Basic concepts of ideas and thinking in trends

- Some examples for the real cases: New hybrid MCDM model
  - Dominance-based rough set approach (DRSA) MCDM
  - MADM: DEMATEL, DANP (DEMATEL-based ANP), Integration (Additive: SAW, VIKOR, Grey Relation Analysis, PROMETHEE, ELECTRE; Non-additive: Fuzzy Integral)
  - MODM: Changeable Spaces Programming

- Conclusions

New concepts and trends of hybrid MCDM model for Tomorrow

Solving Actual Problems

(relieve traditional assumption/hypothesis in unrealistic)

New Concepts and Trends of Hybrid MCDM Model for Tomorrow

- **Which concepts and how trends in future prospects of MCDM field for Tomorrow?**

- **Which problems will be improved for satisfying the users'/customers'/social needs in real (marketing, the whole people, etc.) situations?**

- **How overall considering problems in total, aspects/dimensions, and criteria can be achieved the aspiration levels?**

New Concepts and Trends of hybrid MCDM model for Tomorrow

Solving Actual Problems

- We find that **the traditional MCDM field ignored some important new concepts and trends,** needed some assumptions limit/defects to solve actual real-world problems (how relax or relieve?).
- Therefore, in our researches **some new concepts and trends in the MCDM field for solving actual problems** have been proposed as follows.

New Concepts and Trends of Hybrid MCDM Model for Tomorrow Solving Actual Problems

- **First,** the traditional model (such path analysis, SEM, etc.) assumes that the criteria in value-created are independent and hierarchical in structure;
- However, criteria are often **interdependent** in real-world problems; because "**Statistics and Economics are unrealistic in the real world** (避免統計經計脫離現實)", in reality, problems are often characterized by interdependent criteria/dimensions and may even exhibit feedback-like cause-effects in influential relationship.
- So DEMATEL technique can be used to find the **influential relationship matrix** and build a **influential network relation map (INRM)** for solving the relationship problems in the real world.

New Concepts and Trends of Hybrid MCDM Model for Tomorrow
Solving Actual Problems

- **Second**, the relative good solution (max-min) from the existing alternatives is replaced by the **aspiration levels** to avoid **"Choose the best among inferior choices/alternatives", i.e., avoid "Pick the best apple among a barrel of rotten apples" (避免由「一堆爛蘋果中找出最好的蘋果」)**.
- **HA Simon** - Decision and organization, 1972 - innovbfa.viabloga.com ... **The Scottish word "satisficing" (=satisfying) has been revived to denote problem solving and decision making that sets an aspiration level,** searches until an alternative is found that **is satisfactory by the aspiration level criterion,** and selects that alternative (Simon (1957), Part IV ... (Simon, 1978, Nobel Prize)

New Concepts and Trends of Hybrid MCDM Model for Tomorrow
Solving Actual Problems

- **Third**, the emphasis in the field has shifted from ranking and selection when determining the most preferable approaches to performance **improvement** of existing methods based on INRM, because "**we need a systematic approach to problem-solving; instead of addressing the systems of the problem, we need to identify the sources of the problem, i.e., avoid "stop-gap piecemeal (避免「腳痛醫腳頭痛醫頭」)**".

New Concepts and Trends of Hybrid MCDM Model for Tomorrow
Solving Actual Problems

- **Fourth**, **information fusion / aggregation**, **one plus one is larger than two**, such as fuzzy integrals, basically, a **non-additive / super-additive model**, has been developed to **aggregate the performances**. Therefore, in order to overcome the defects of conventional MADM method, we have focused on developing a series of **new Hybrid Dynamic Multiple Criteria Decision Making (HDMADM) method for solving the complication dynamic problems in suitable real world and applying to improve the real issues in the trends and prospects.** (Kahneman, 2002, Nobel Prize) **D. Kahneman & A. Tversky (1979). Prospect Theory: An Analysis of Decision under Risk, *Econometrica*, Vol. 47, No. 2. (Mar., 1979), pp. 263-292.**
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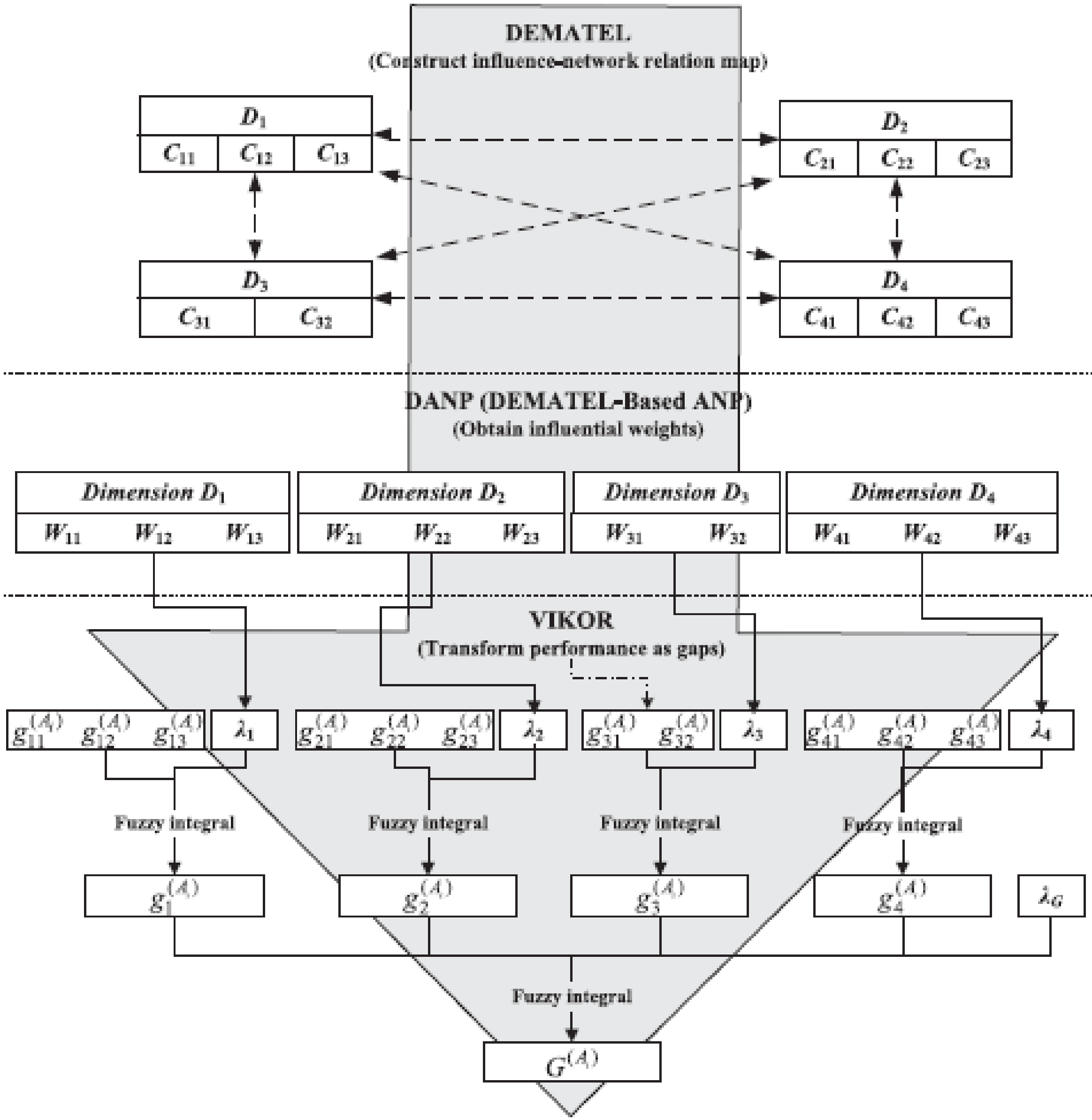

New Concepts and Trends of MADM model in Real World Problem for Tomorrow

DEMATEL for building INRM and finding influential weights of DANP → Modified VIKOR based on INRM by using super-additive (or called non-additive) form for performance improvement.

New Concepts and Trends of hybrid MCDM model for Tomorrow
Solving Actual Problems

Fifth, we proposed a new thinking of MODM models with **changeable spaces** to help the decision-makers for win-win planning/designing to achieve the aspiration level, which is better than to achieve the ideal point or Pareto optimal solutions; i.e., the original fixed resources in multi-objective programming are divided such that both decision and objective spaces are changeable (called **"Changeable Spaces Programming"**) in new thinking of MODM.

Jih-Jeng Huang, Gwo-Hshiung Tzeng (**2014**), New thinking of multi-objective programming with changeable spaces - In search of excellence, ***Technological and Economic Development of Economy***, **20(2),** 242-261 (**SSCI, IF: 5.605, 2011; IF: 3.235, 2012).**

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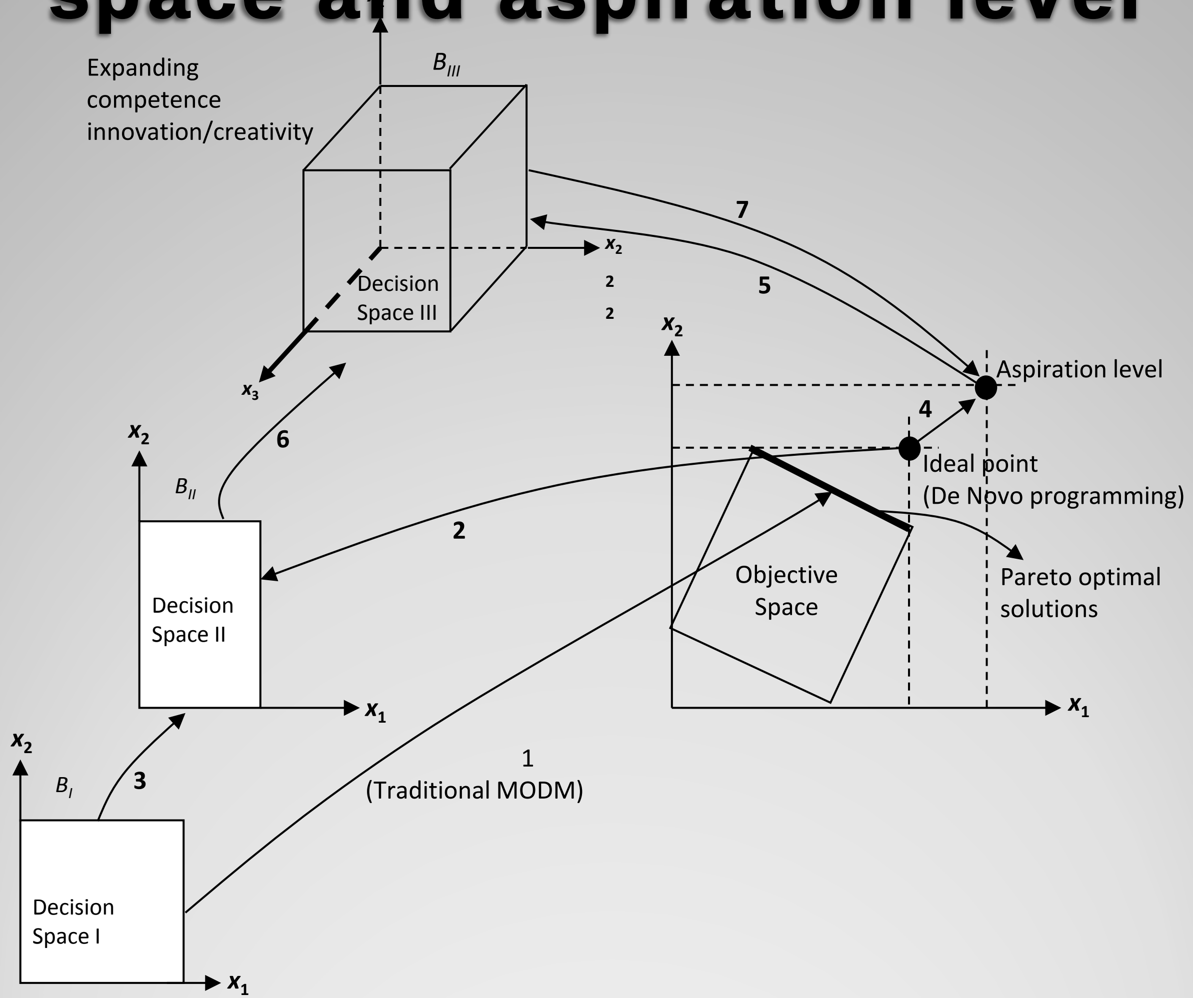
The concepts of changeable decision space and aspiration level

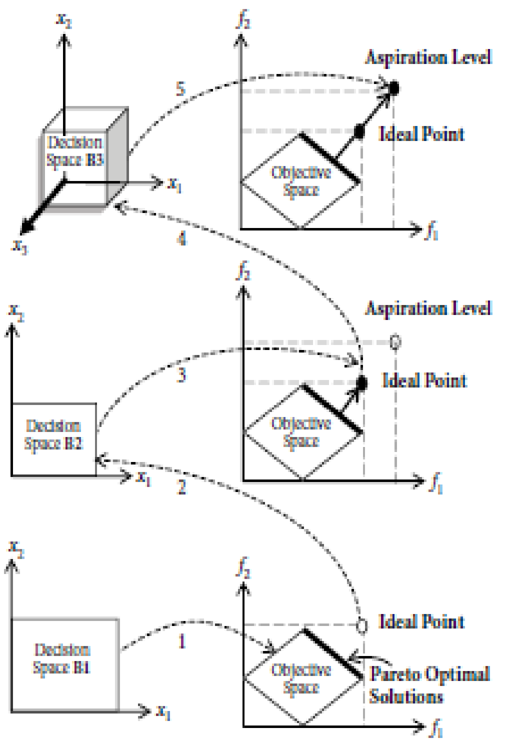


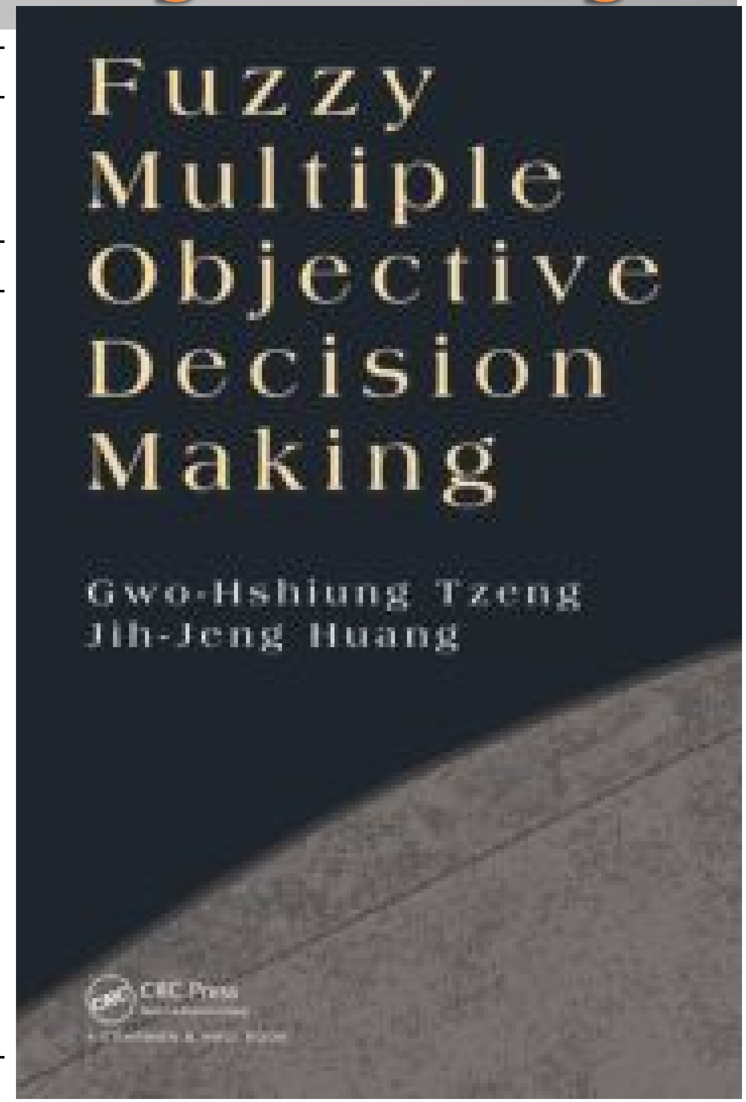
Changeable Space Programming

Toward a MCDM New Era – Professor Tzeng's Roadmap

Philosophy
Taking True Responsibility,
Creating Added Value, and
Making Contribution through MCDM Knowledge to Global Society

concept	Graphical Representation	Approach
Value (Win-Win)		making aspired decisions by expanding competence sets through innovation
		Making Ideal decisions through re-allocating limited resources
Price (Win-Lose)		Making Pareto optimal decisions through traditional MOP methods





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Review

COMMENTS ON "MULTIPLE CRITERIA DECISION MAKING (MCDM) METHODS IN ECONOMICS: AN OVERVIEW"

James J. H. Liou[1], Gwo-Hshiung Tzeng[2]

E-mails: 1jamesjhliou@gmail.com; 2ghtzeng@mail.knu.edu.tw (corresponding author)

Abstract. This paper offers comments on a previously published paper, titled "Multiple criteria decision making (MCDM) methods in economics: an overview," by Zavadskas and Turskis (2011). The paper's authors made great efforts to summarize MCDM methods but may have failed to consider several important new concepts and trends in the MCDM field for solving actual problems. First, the traditional model assumes the criteria are independently and hierarchically structured; however, in reality, problems are often characterized by interdependent criteria and dimensions and may even exhibit feedback-like effects. Second, relatively good solutions from the existing alternatives are replaced by aspiration levels to fit today's competitive markets. Third, the emphasis in the field has shifted from ranking and selection when determining the most preferable approaches to performance improvement of existing methods. Fourth, information fusion techniques, including the fuzzy integral method, have been developed to aggregate the performances. Finally, the original fixed resources in multi-objective programming are divided such that both decision and objective spaces are changeable. In this paper, we add new concepts and provide comments that could be thought of as an attempt to complete the original paper.

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2013 Volume 19(2): 367–375
doi:10.3846/20294913.2013.811037

Invited review

NEW CONCEPTS AND TRENDS OF MCDM FOR TOMORROW – IN HONOR OF PROFESSOR GWO-HSHIUNG TZENG ON THE OCCASION OF HIS 70th BIRTHDAY

James J. H. LIOU

Department of Industrial Engineering and Management, National Taipei University of Technology, No. 1, Section 3, Chung-Hsiao East Road, Taipei, Taiwan

Abstract. This article introduces several new concepts and trends in multiple criteria decision making (MCDM) for solving actual problems, as proposed by Professor Gwo-Hshiung Tzeng. These new concepts are as follows: (1) interdependency in real-world problems; (2) replacing the relative good solution from the existing alternatives using aspiration levels; (3) shifting from ranking and selection to performance improvement; (4) information fusion/aggregation; and (5) changeable decision spaces. To honor Prof. Tzeng's contribution in the MCDM field and to commemorate his 70th birthday, this article also highlights his research career in MCDM and some publication list in the past 10 years.

Keywords: MCDM, MADM, MODM, DEMATEL, DANP, VIKOR, Changeable space, Aspiration level.

Reference to this paper should be made as follows: Liou, J. J. H. 2013. New concepts and trends of MCDM for tomorrow – in honor of Professor Gwo-Hshiung Tzeng on the occasion of his 70th birthday, *Technological and Economic Development of Economy* 19(2): 367–375.

1. New trends and concepts in MCDM

Over the past two decades, the development of information technology (IT) has been characterized by a series of positive, but temporary, shocks. The alternate perspective is that IT in Internet communication has produced a fundamental change in the world, leading to a permanent improvement in fast growth-change prospects such as telephone, telegraph, Internet, smart phone, i-phone, i-pad, cloud computing, business, economy, society, and government. What are the prospects for future trends? Which problems will be solved regarding user/customer/societal needs in marketing situations, and how can overall problems in dimensions and criteria be resolved using aspiration levels? The traditional MCDM field ignored some important new concepts and trends and needed several assumptions to solve real-world problems. Therefore, Prof. Tzeng proposed some new concepts for facing tomorrow's world. First, the traditional model assumes that the criteria in value-creation are independent and hierarchical in structure; however, criteria are often interdependent in real-world problems because 'Some statistics and economics assumptions are unrealistic in the real world'. The Decision Making Trial and Evaluation Laboratory (DEMATEL) technique is an effective tool to find the interrelationship matrix and building an influential network relation map (INRM) for solving relationship problems in the real world. Second, the relatively good solution from existing alternatives is replaced by aspiration levels to avoid "Choosing the best among inferior options/alternatives", i.e. "Picking the best apple among a barrel of rotten apples". Third, the emphasis in the field has shifted from ranking and selection when determining the most preferable approaches to performance improvement of existing methods based on INRM because "we need a systematic approach to problem-solving; instead of addressing the systems of the problem, we need to identify the sources of the problem". Fourth, Kahneman and Tversky (Kahneman received the Nobel Prize in Economics in 2002) developed the basic concept of the non-additive (or super-additive) value-function aggregation in multi-criteria problems in 1973. Simon incorporated the basic concept of the "aspiration level" in his work, receiving the Nobel Prize in Economics in 1978. The question that arises is "How can we implement these two concepts (non-additive value function and aspiration level) within real-world inter-relationship (dependence and feedback) problems?" Information fusion or aggregation/integration such as fuzzy integrals (basically, a non-additive or super-additive model) has been developed to aggregate/integrate performances. Therefore, to overcome the defects of the conventional Multiple Attributes Decision Making (MADM) method, a new Hybrid Dynamic Multiple Criteria Decision Making (HDMADM) method has been developed for solving complicated and dynamic problems in the real world and application to improve real issues, e.g. Internet communication, government overall policy improvement, etc. Fifth, classical Multiple Objectives Decision Making (MODM) methods are used to pursue an optimal solution in a fixed feasible region (objective space) based on fixed conditions or resources (decision space). A new thinking of MODM models with changeable spaces can help decision-makers reach a win-win for planning/designing and achieve the desired point (aspiration level), which is better than pursuing the ideal point or Pareto optimal solution.

Google Scholar

Gwo-Hshiung Tzeng
Distinguished Chair Professor

Research methods for problems-solving: Data Analysis (crisp sets, fuzzy set theory, rough set theory -> statistics and multivariate analysis, evolutionary computation, soft computing, etc.), multiple criteria decision making (MADM and MODM), and so on for applications in the real world problems

Citation indices

	All	Since 2009
Citations	12441	9714
h-index	59	51
i10-index	172	153

July 10, 2014: 2011 (1531 times), 2012 (2254 times), 2013 (2399times)

Citations to my articles

http://scholar.google.com/citations?user=ZRXOrvQAAAAJ&hl=en

http://scholar.google.com/citations?user=ZRXOrvQAAAAJ&hl=en

Talk

- New concepts and trends of MCDM for Tomorrow: Solving actual problems
- How consider for solving the real world
- Basic concepts of ideas and thinking in trends
- Some examples for the real cases: New hybrid MCDM model
  - MADM: DEMATEL, DANP (DEMATEL-based ANP), Integration (Additive: SAW, VIKOR, Grey Relation Analysis, PROMETHEE, ELECTRE; Non-additive: Fuzzy Integral)
  - MODM: Changeable Spaces Programming
- Conclusions

How consider for solving the real world problems

⇓

How consider for solving the real world problems

"Story (Objects)" in Real Case Problems
(Case Study in Experience) for Real World

+

Research Methods for Problems-Solving
(Which methods? New concepts and trends of New hybrid MCDM model?)

Expressions in Results

⇩

(Writing Skills and Speech Skills in Logic)

Problems-Solving in a real world

How Do Logic Thinking and Reasoning?

Define

- Understand the addressed real world problems
- From conceptual ideas to symbolic notations based on logic reasoning in real world problems

Model

- Find and define relevant features/structures (variables/factors/aspects/dimensions/criteria/attributes by literature review, brain storming with Delphi, pre-testing)
- Propose an initial model for addressed on solving the real world problems (new concepts and trends of new hybrid of MCDM model for solving real world problems)
- Apply suitable methods/techniques to form the real world model in real world case

Goal

- Description (e.g. linear, non-linear, logical, etc.)
- Evaluation (Selection/outranking and improvement) and Plan/Design (Changeable spaces (decision space and objective space) programming in improvement for achieving aspiration level
- Optimization or called the best (including improvement toward aspiration level)
- Classification/improvement
- Forecast/Prediction

Understanding

- Observation (experience)
- Intuition/feeling
- Knowledge
- Theory

Symbolic notation

- Conceptualize
  - Multiple dimensions
  - Multiple criteria
  - Single or multiple goals
- Define data sets
  - Crisp data sets
  - Fuzzy sets
  - Rough sets
  - Grey Hazy sets

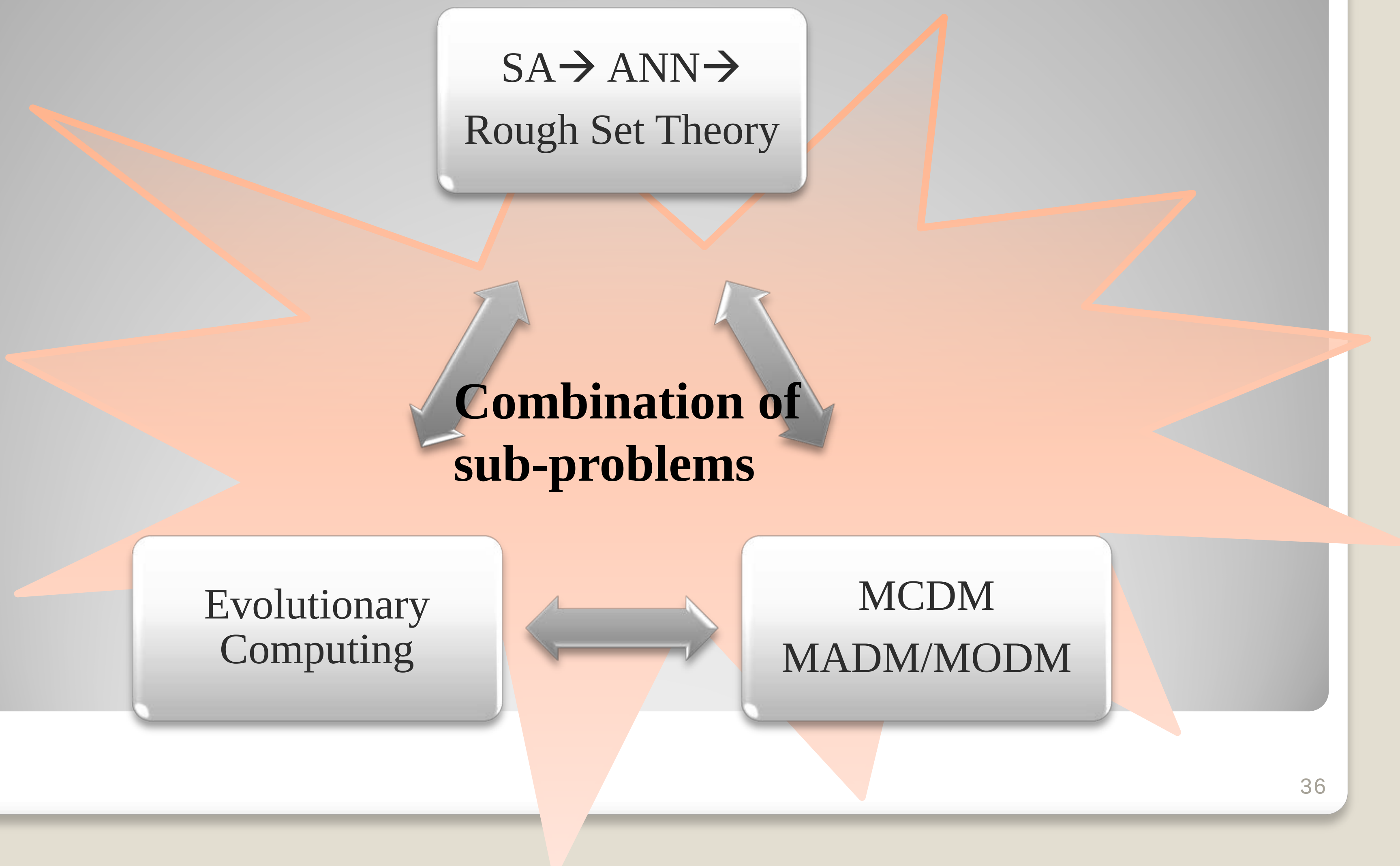
- **Data** sets →**Information** Systems → **Knowledge** Discovery → **Intelligence**/**Wisdom** (→ **enlightenme**nt for making the best decision)

Define a problem

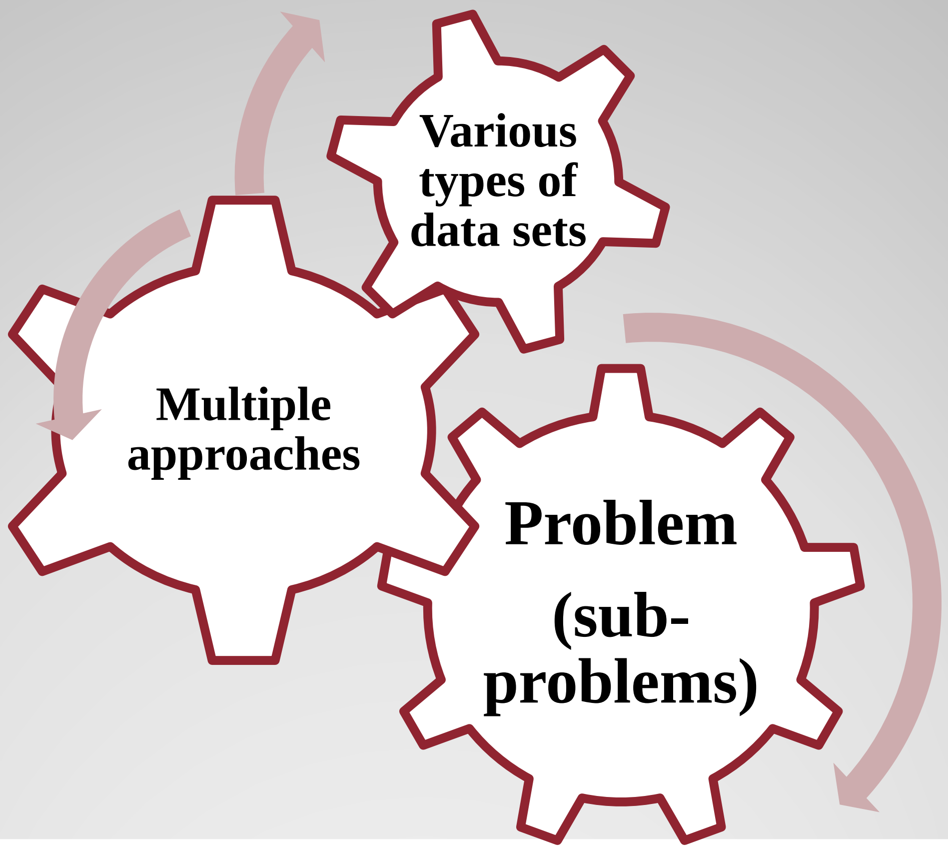
Multi-paths to reach the end

Statistical Analysis (SA) (Conventional approach)	Data sets (nominal, ordinal, scale, numerical)	Find/Shape the relations (classification, regression…etc.)
Evolutionary Computation	Data sets (similar to SA, plus Fuzzy/Rough/Grey..)	Find/Shape the relations (classification, regression, etc.)
MCDM MADM/MODM approach	Data sets (similar to SA, plus Fuzzy/Rough/Grey..)	Find/Shape the relations (classification, regression, etc.)

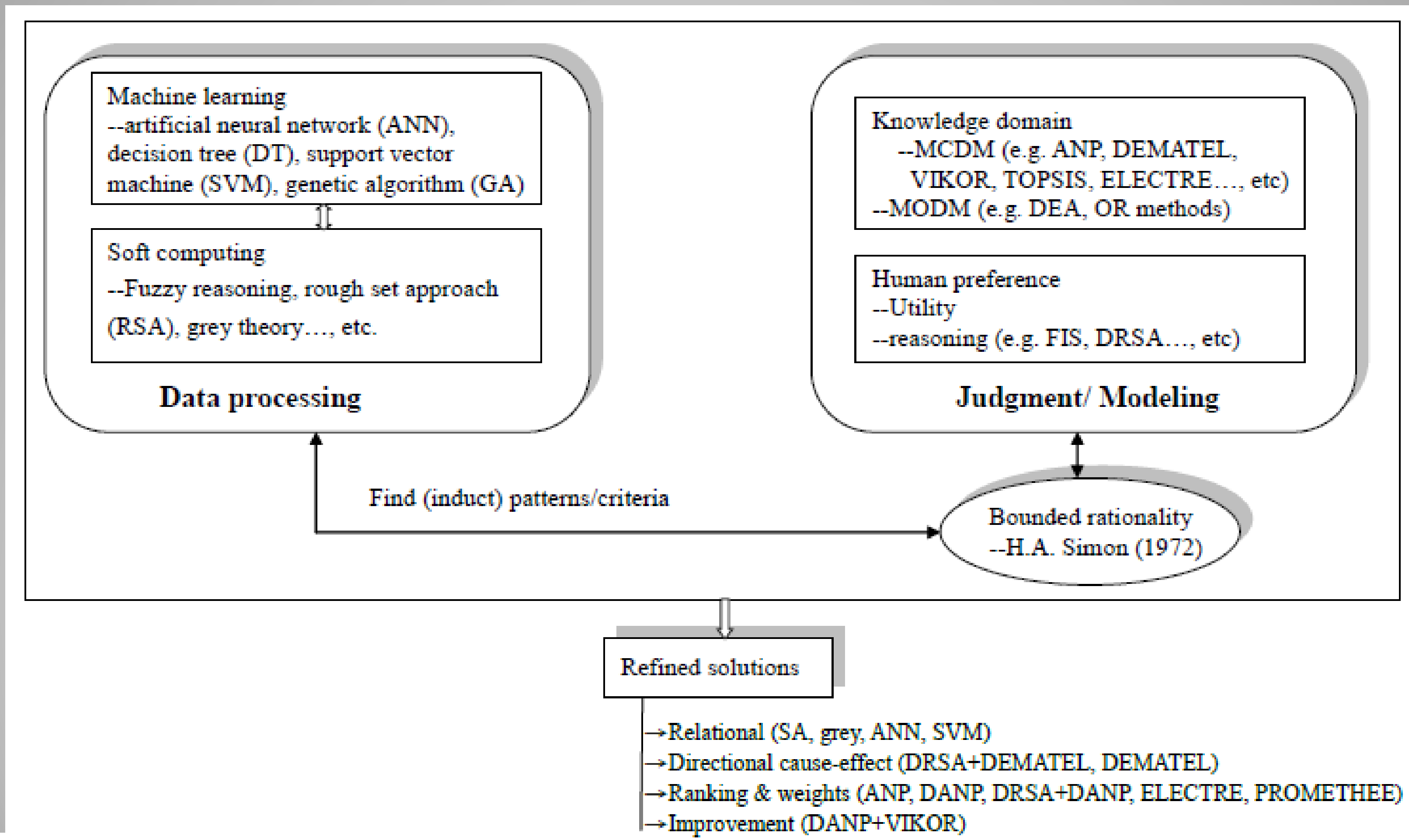
A new combined/hybrid approach



Infusion (Big Data)



Basic Concepts of Recent developments



Talk

- New concepts and trends of hybrid MCDM model for Tomorrow: Solving actual problems
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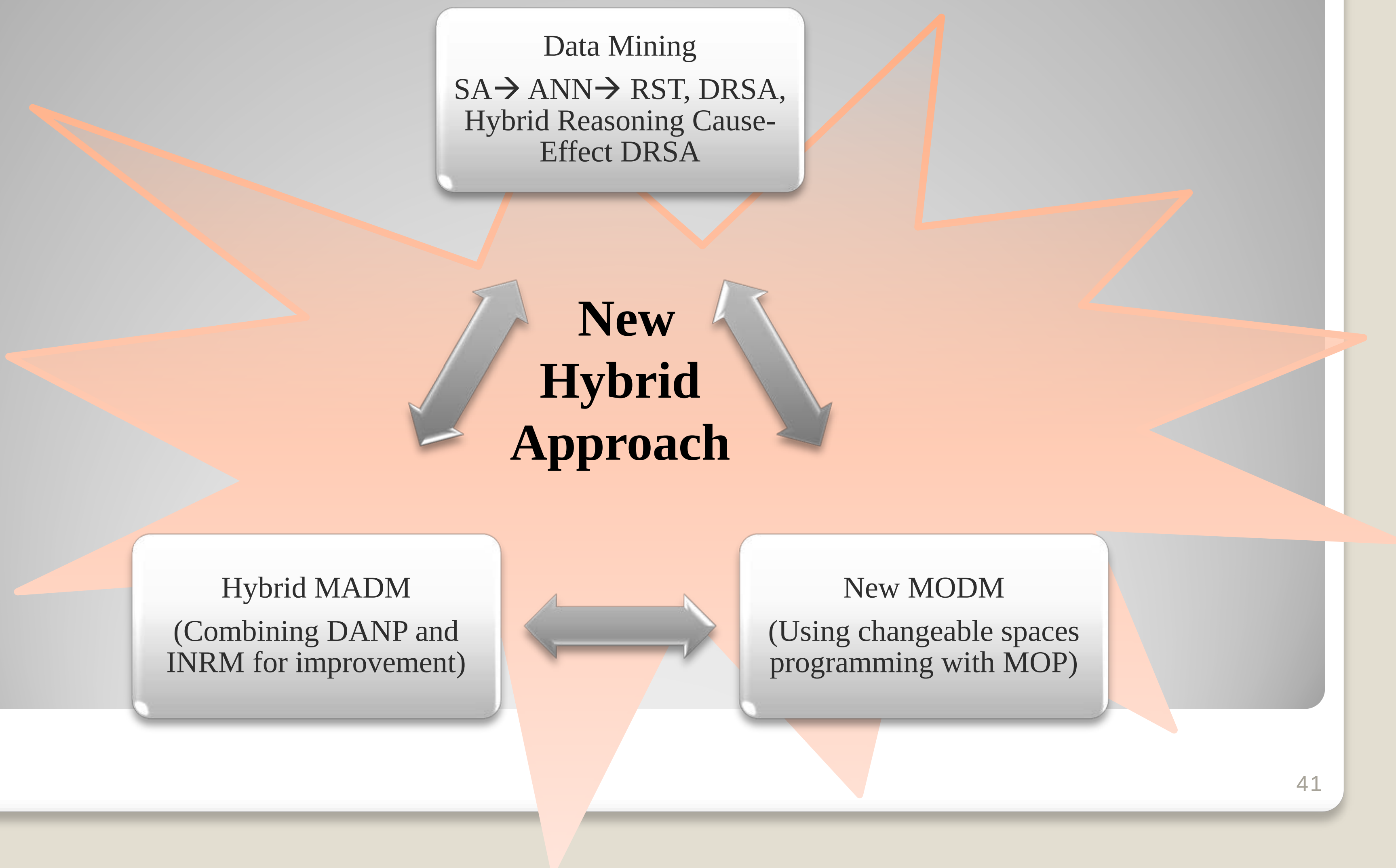
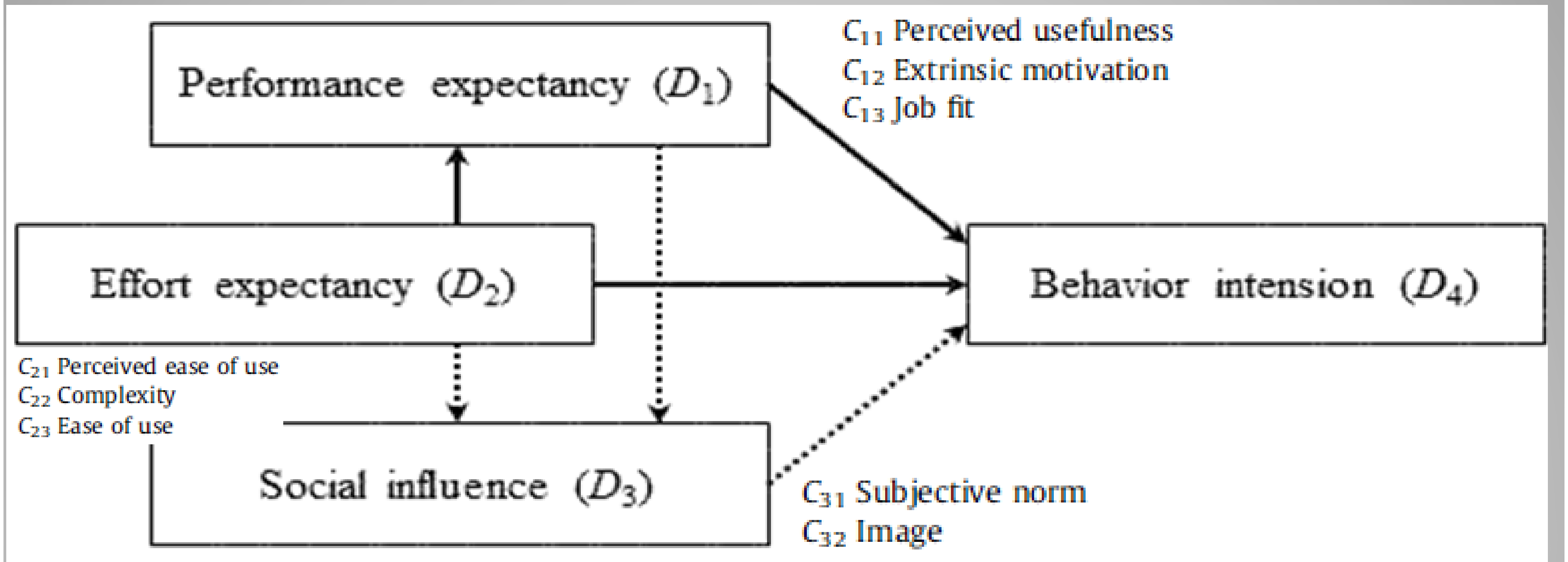
  - MODM: Changeable Spaces Programming
- Conclusions

Basic concepts of ideas and thinking in trends

A new combined/hybrid approach for improving performance gaps

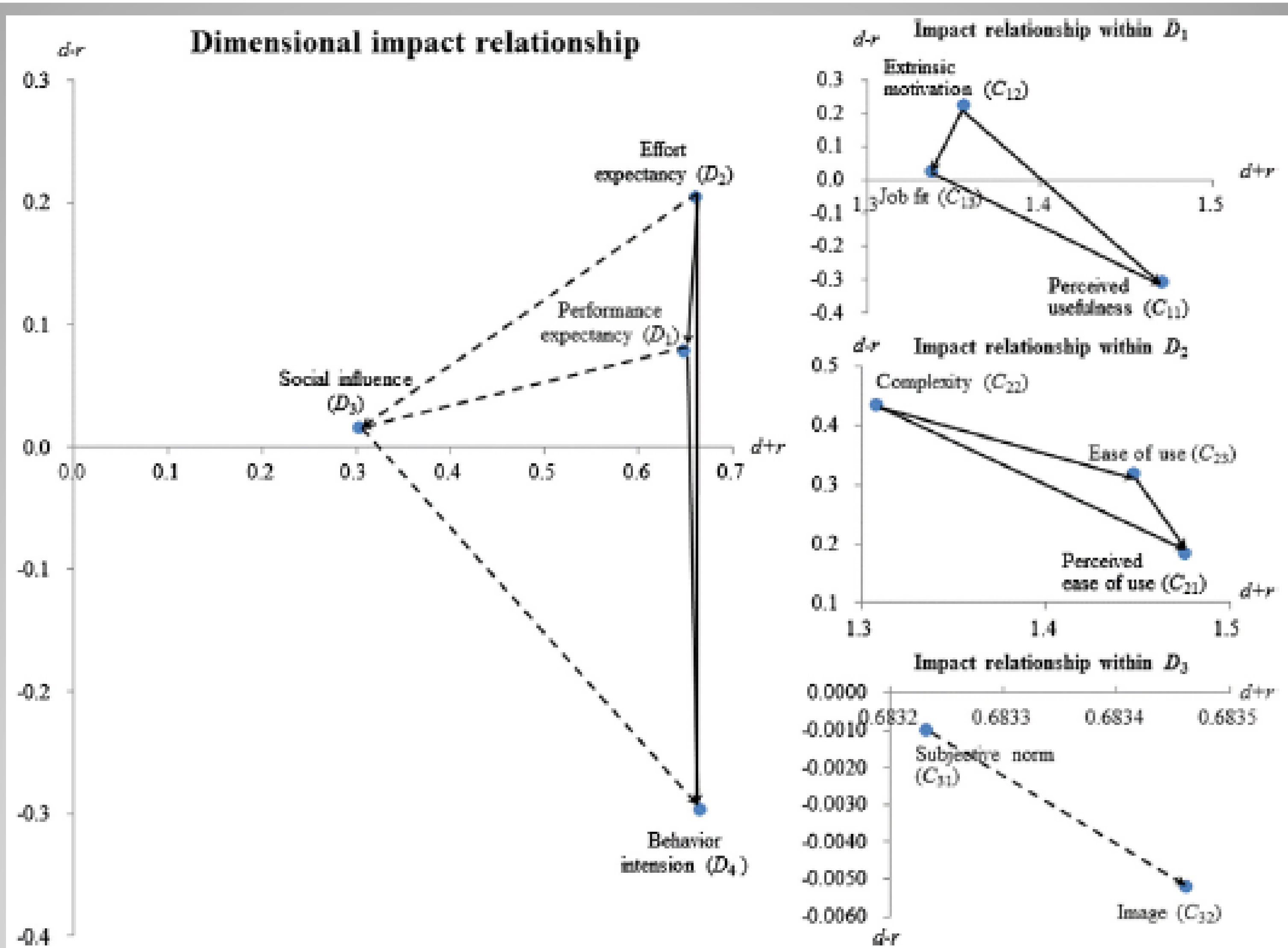


Basic concept of SEM (Structure Equation Modelling) combining DEMATEL technique



The causal relation map (SEM based on DEMATEL technique → DRSA → MCDM)

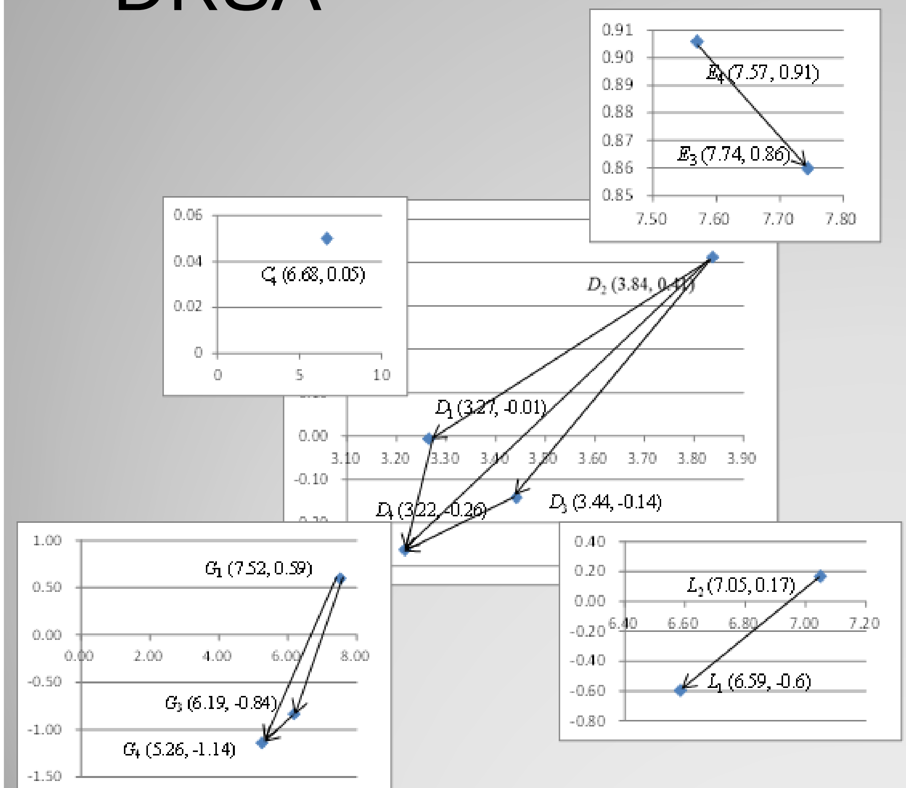
Jeng, D. J.F. and Tzeng, G.H. (2012). Social influence on the use of Clinical Decision Support Systems: Revisiting the Unified Theory of Acceptance and Use of Technology by the fuzzy DEMATEL technique, Computers & Industrial Engineering, 62(3), 819-828.



Influential network relation map (INRM) by DEMATEL technique

DRSA-based Neuro-Fuzzy Inference Systems for the Financial Performance Prediction of Commercial Bank

- DRSA



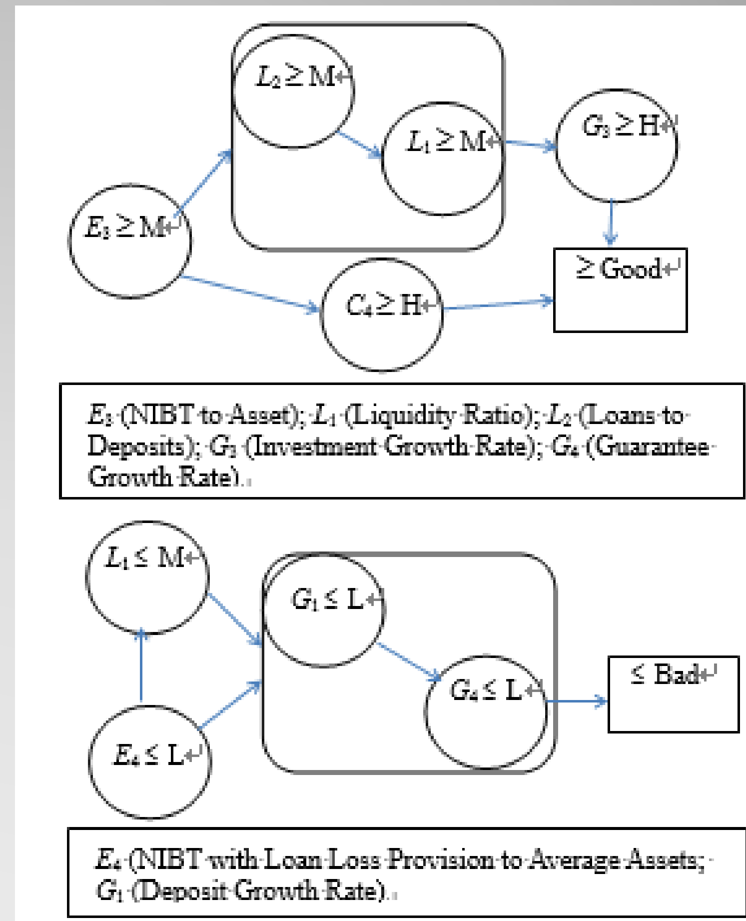
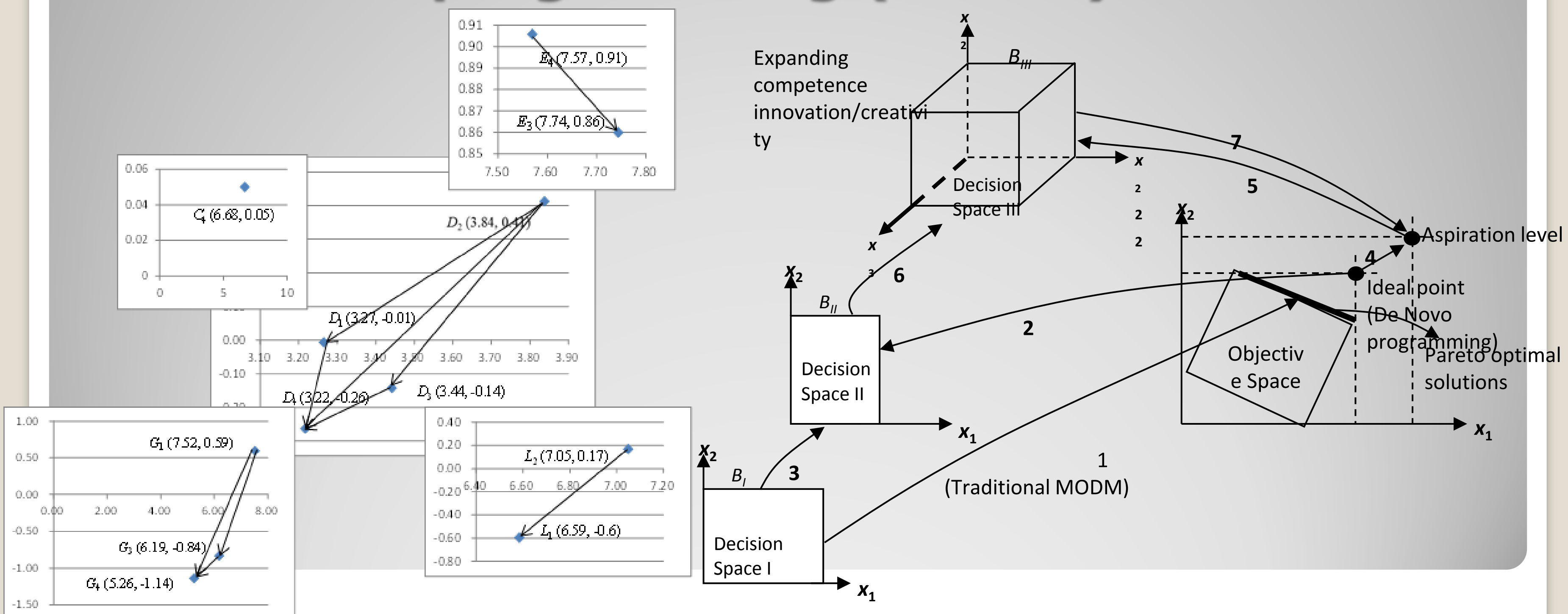


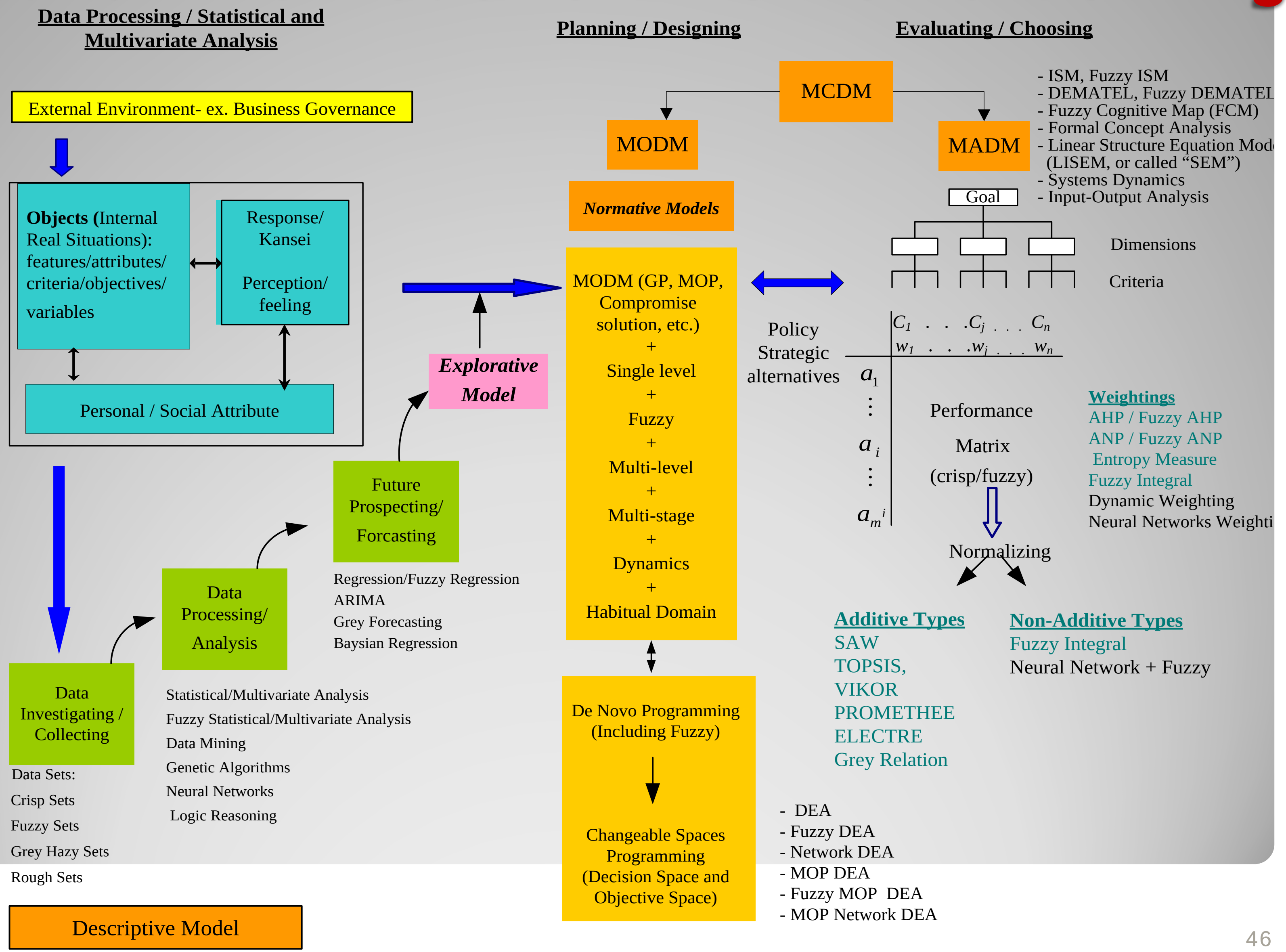
Figure 3. Directional Flow Graph

Kao-Yi Shen, and **Gwo-Hshiung Tzeng (2014).** DRSA-based Neuro-Fuzzy Inference Systems for the Financial Performance Prediction of Commercial Bank, *International Journal of Fuzzy Systems* (Inpress, **SCI, IF: 1.506, 2012).**

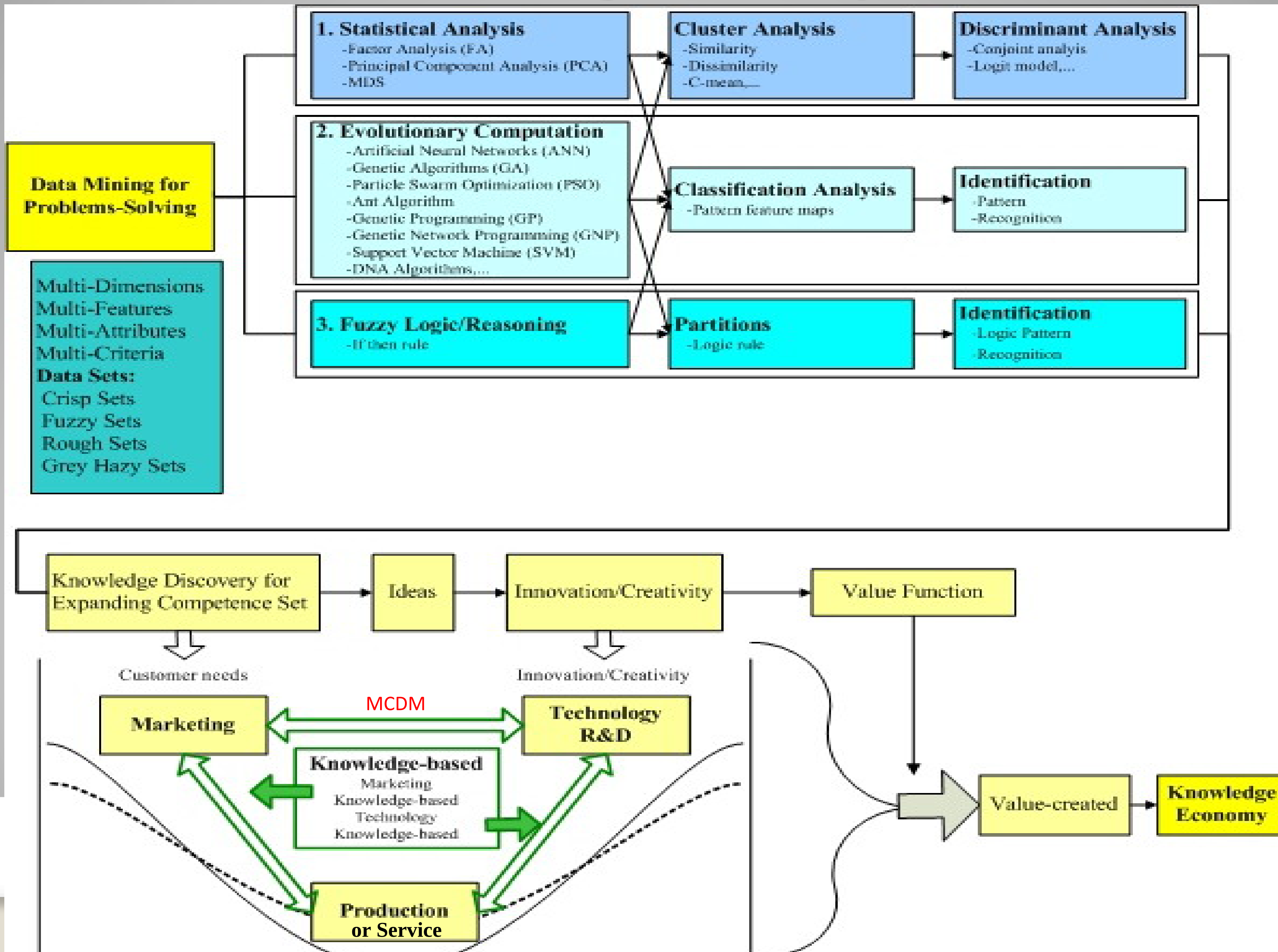
How resource allocation to improve the gaps of performance values in each criterion for achieving aspiration level (MADM) through the basic concepts of changeable spaces (decision space and objective space) programming (MODM)



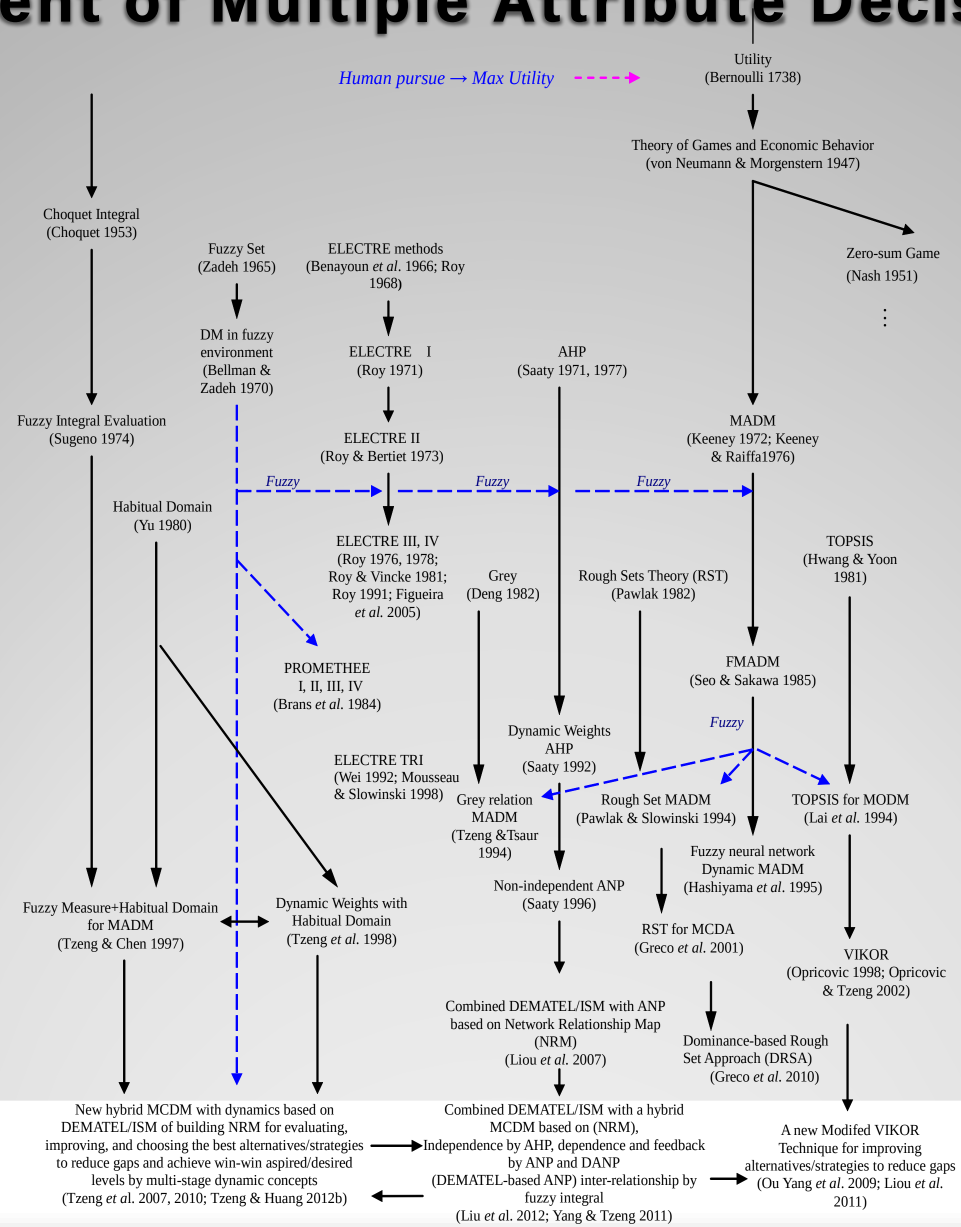
Research Methods for Problems-Solving



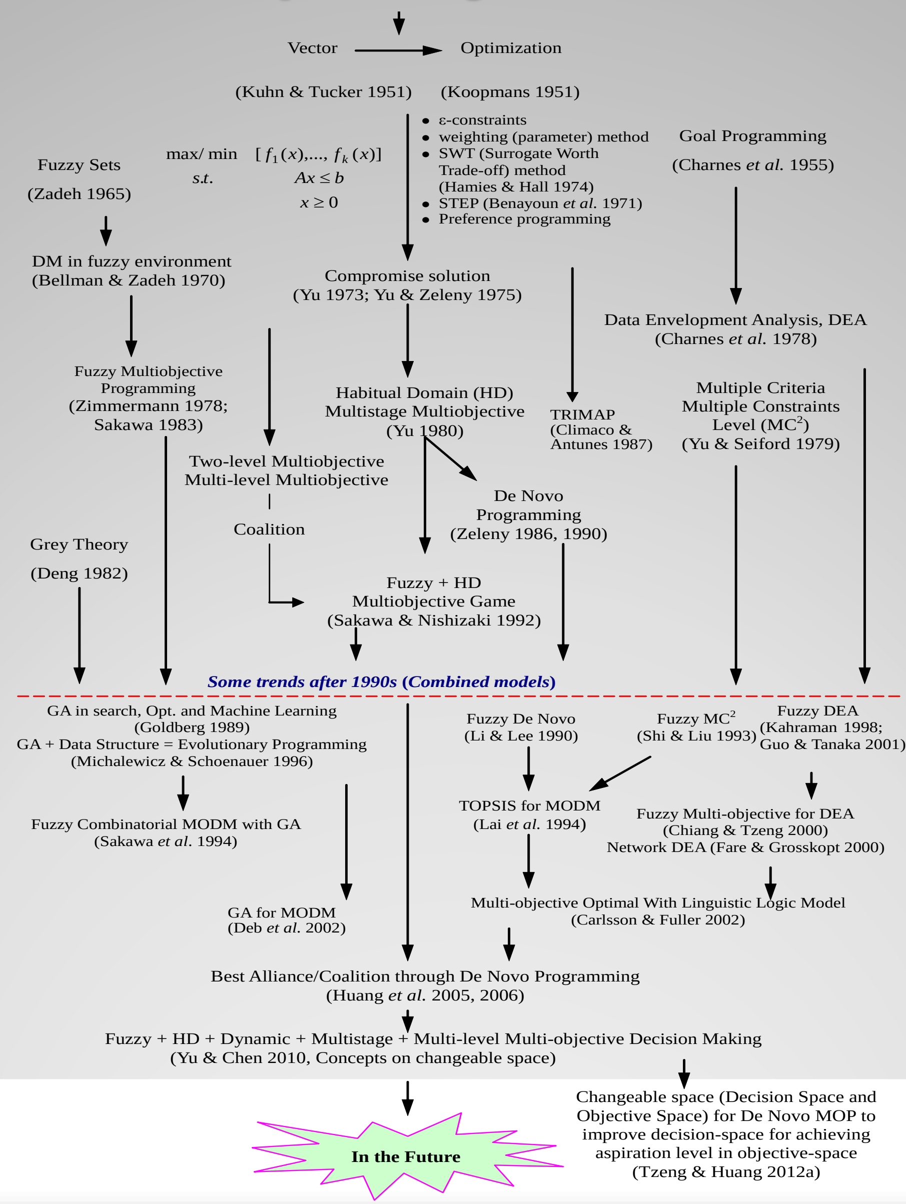
Data Mining Concepts of Intelligent Computation in Knowledge Economy



Development of Multiple Attribute Decision Making



Development of Multiple Objective Decision Making



Talk

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Some examples for the real cases: New hybrid MCDM model

Some examples for the real cases: New hybrid MCDM model

basic concepts

Hwang and Yoon (1981) classified **MCDM problems** into two main categories: **multiple attribute decision making (MADM**) and **multiple objective decision making (MODM)** (**Fig. 2)** based on the different purposes and the different data types**. MADM** applied in the **evaluation/improvement/selection**, which usually associated with a limited number of predetermined alternatives and the discrete preference ratings in **interdependent problems**. **MODM** is especially **suitable for the design/planning**, which is to achieve the **optimal or aspired goals** by considering the various interactions within the given constrains, so **that both decision and objective spaces are changeable in new concepts of our research.**

Some examples for the real cases: New hybrid MCDM model

Basic concepts

- A typical **MADM** is a scientific analytical method for evaluating a set of **criteria/attributes** and **alternatives** based on considering a set of **multiple,** i.e., data set of information systems as, $IS = (U, A, V, f)$.
- However, we find that the traditional MADM ignored **some important new concepts** and **have some assumptions/ hypothesis limit/defects for solving real-world** problems; for example, many traditional **Economics and Statistics are unrealistic of assumption in the real world**, such as assuming independent problem, using coefficients of correlation (not measuring influential relationship among criteria, etc.

Some examples for the real cases: New hybrid MCDM model
Basic concepts

MADM

- **First**, the traditional model assumes criteria are **independent** with hierarchical structure; but the **relationships** between criteria or dimensions are usually **interdependent** and sometimes even exit **feedback** effects in the real-world.
- **Second,** the relative good solution from the existing alternatives is replaced by the **aspiration levels** to fit today's competitive markets.
- **Third,** the trends have shifted from how can be "ranking" or "selection" the most preferable alternatives to how can be **"improvement**" their performances.
- **Fourth**, information fusion/aggregation such as fuzzy integral, a **non-additive/super-additive model**, has been developed to aggregate the performances.

Some examples for the real cases: New hybrid MCDM model

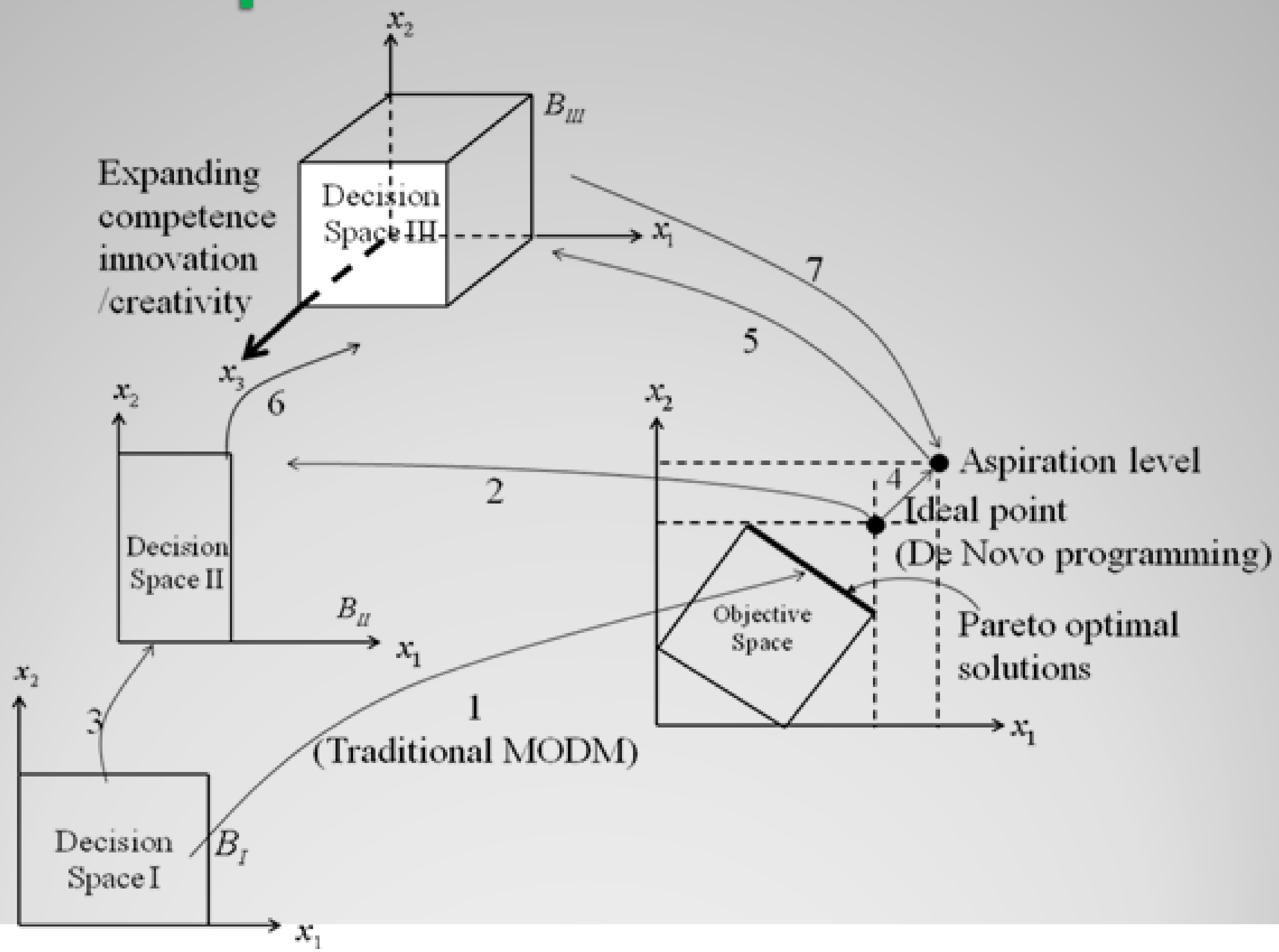
Basic concepts

- **Why we don't use "traditional Statistics and Economics" approaches:** Traditional Statistics and Economics are unrealistic in the real world.
- **Setting aspiration level**: For avoiding "Choose the best among inferior choices", i.e., for avoiding "Pick the best apple among a barrel of rotten apples".
- **Constructing influential network relation map (INRM) for systematic improvement**: We need to find a cure to the problem instead of just treating its symptoms; i.e., we need a systematic approach to problem-solving. Instead of addressing the symptoms of the problem, we need to identify the sources of the problem.

Some examples for the real cases: New hybrid MCDM model

Basic concepts

MODM



The concept of changeable decision space and aspiration level

Some examples for the real cases: New hybrid MCDM model

Basic concepts

- **James J.H. Liou, Gwo-Hshiung Tzeng** (**Corresponding author**) (**2012**), Comments on "Multiple criteria decision making (MCDM) methods in economics: An overview", ***Technological and Economic Development of Economy***, **18(4)**, 672-695 **(SSCI, IF: 5.605, 2011; IF: 3.235, 2012). MCDM**

- **Kua-Hsin Peng, Gwo-Hshiung Tzeng** (**Corresponding author**) (**2013**), A hybrid dynamic MADM model for problems-improvement in economics and business, ***Technological and Economic Development of Economy***, **19(4)**, 638–660 (**SSCI, IF: 5.605, 2011; IF: 3.235, 2012). MADM**

- **James J.H. Liou, Yen-Ching Chuang, Gwo-Hshiung Tzeng** (**Corresponding author**) **(2013)** "A fuzzy integral-based model for supplier evaluation and improvement, **Information Sciences, 266**, 199–217 (Impact factor: **3.643**, 5-Year Impact Factor: **3.676, 2012**). **MADM**

- **Jih-Jeng Huang, Gwo-Hshiung Tzeng** (**2013**), New thinking of multi-objective programming with changeable space - In search of excellence, ***Technological and Economic Development of Economy,*** **20(2): 242-261, SSCI, IF: 5.605, 2011; IF: 3.235, 2012). MODM**

Purposes of new hybrid MADM methods

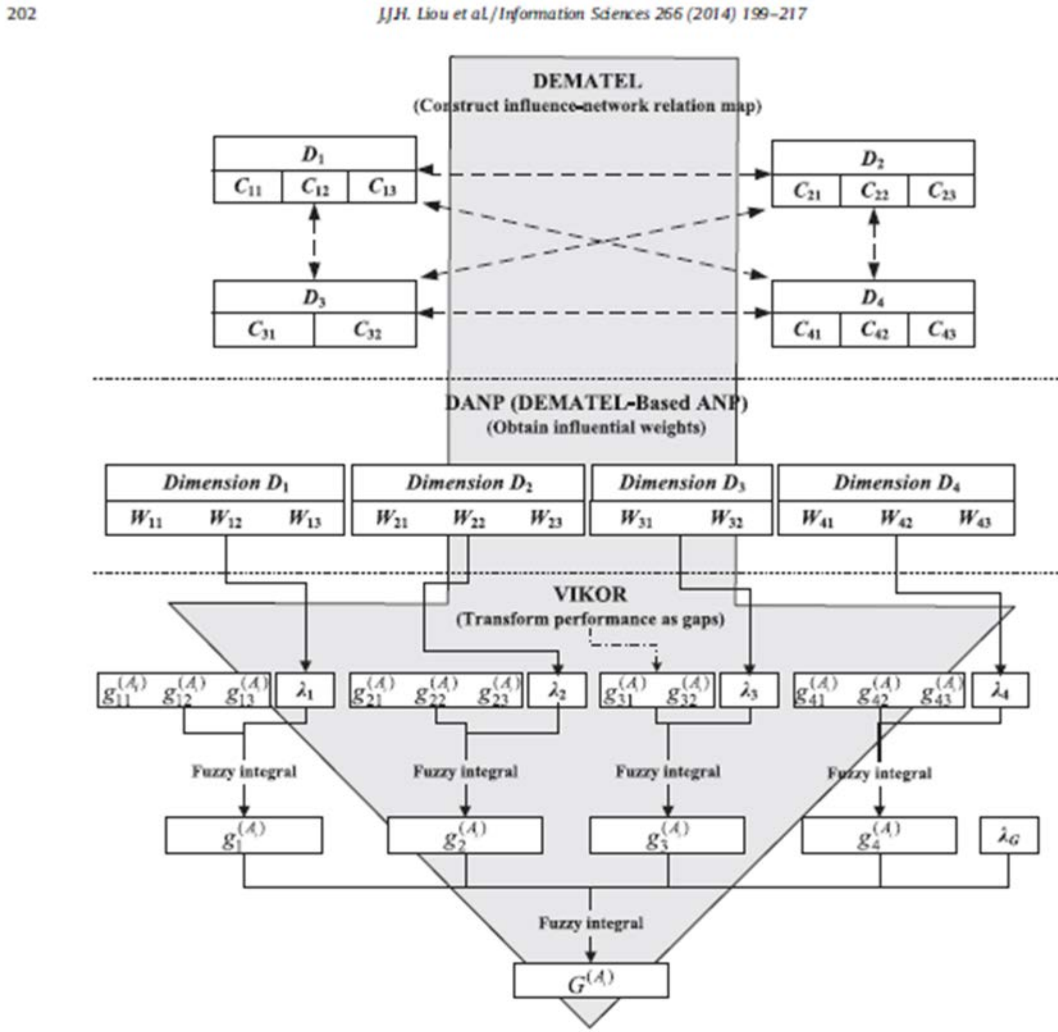
The purposes of our proposed these new hybrid MADM methods:

- Not only in order to overcome the defects of conventional MADM method, we have focused on developing **a series of new Hybrid Dynamic Multiple Attribute Decision Making** (HDMADM) method for solving the complication dynamic problem in real world and applying to various fields.
- But also in order **to: (1) avoid "Statistics and economics are unrealistic in the real world"**; **(2) avoid** "**choose the best among inferior choices/ options/alternatives**, i.e., **avoid "Pick the best apple among a barrel of rotten apples"; (3) deal with super-additive/non-additive problems in the real world; (4)** "**we need a systematic improvement, we need to identify the sources of the problem, i.e., avoid "stop-gap piecemeal (腳痛醫腳頭痛醫頭)" for achieving aspiration level** in each criterion**.** Finally empirical real cases are illustrated to **and effectiveness** of the proposed **new hybrid MADM methods for solving the real world problems**.

Concept of Methods

- **DEMATEL** technique is used to construct the cause-effects of interactions/interrelationship between criteria (called influence matrix) and build an influential network relation map (INRM).
- **DANP** (DEMATEL-based ANP) for deriving global influential weights (for solving interdependence and feedback dynamic problems)
- **VIKOR** uses the class distance function (Yu, 1973), based on the concept how can be closest to positive-ideal (the Aspiration level) solution and furthest away from the negative-ideal (the Worst level) solution for improvement the gaps of each criterion (different from max-min approach in tradition in order).
- **Fuzzy integral** for integrating the performance value (fusing information in performance matrix) of value function (non-additive/super-additive approach), i.e., one plus one is larger than two (1+1 > 2).

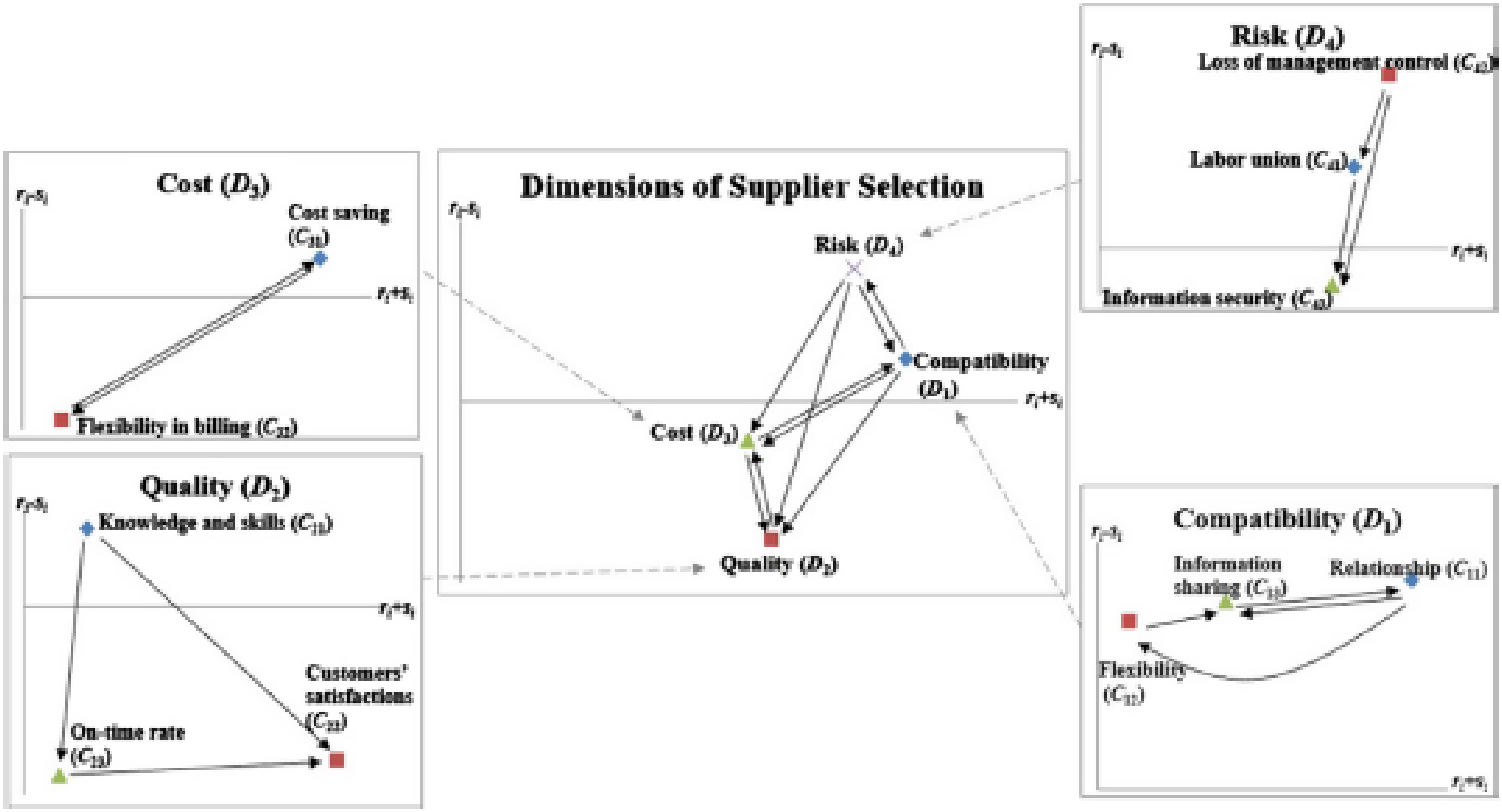
Basic Concepts of New Hybrid MADM Model



Improvement

James J.H. Liou, Yen-Ching Chuang, Gwo-Hshiung Tzeng (Corresponding author) (2013) "A fuzzy integral-based model for supplier evaluation and improvement, **Information Sciences, 266**, 199–217 (Impact factor: **3.643**, 5-Year Impact Factor: **3.676, 2012**).

Example in the real world



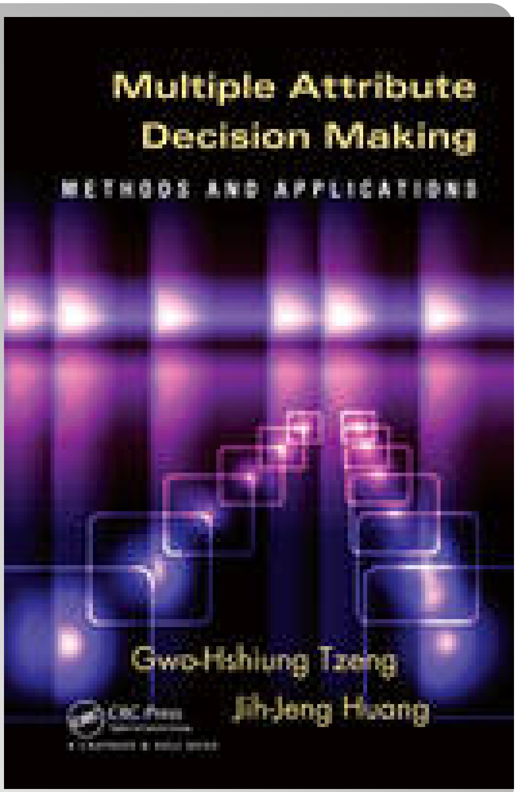
James J.H. Liou, Yen-Ching Chuang, Gwo-Hshiung Tzeng (Corresponding author) (2013) "A fuzzy integral-based model for supplier evaluation and improvement, Information Sciences, 266, 199–217 (Impact factor: 3.643, 5-Year Impact Factor: 3.676, 2012).

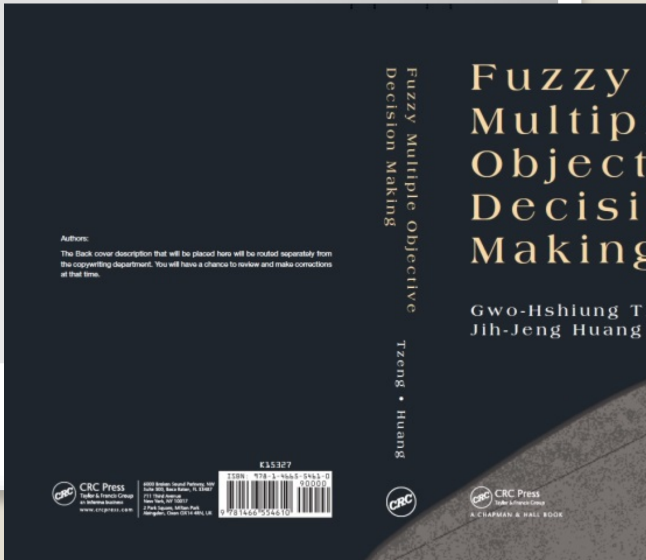
Research Methods for Problems-Solving

- Rough sets (DRSA), DEMATEL
- ANP
- DANP (DEMATEL-based ANP)
- VIKOR, Grey Relation Analysis, PROMETHEE, etc.
- Fuzzy Integral (Non-additive/ Super-additive)
- Improvement by changeable spaces MOP programming

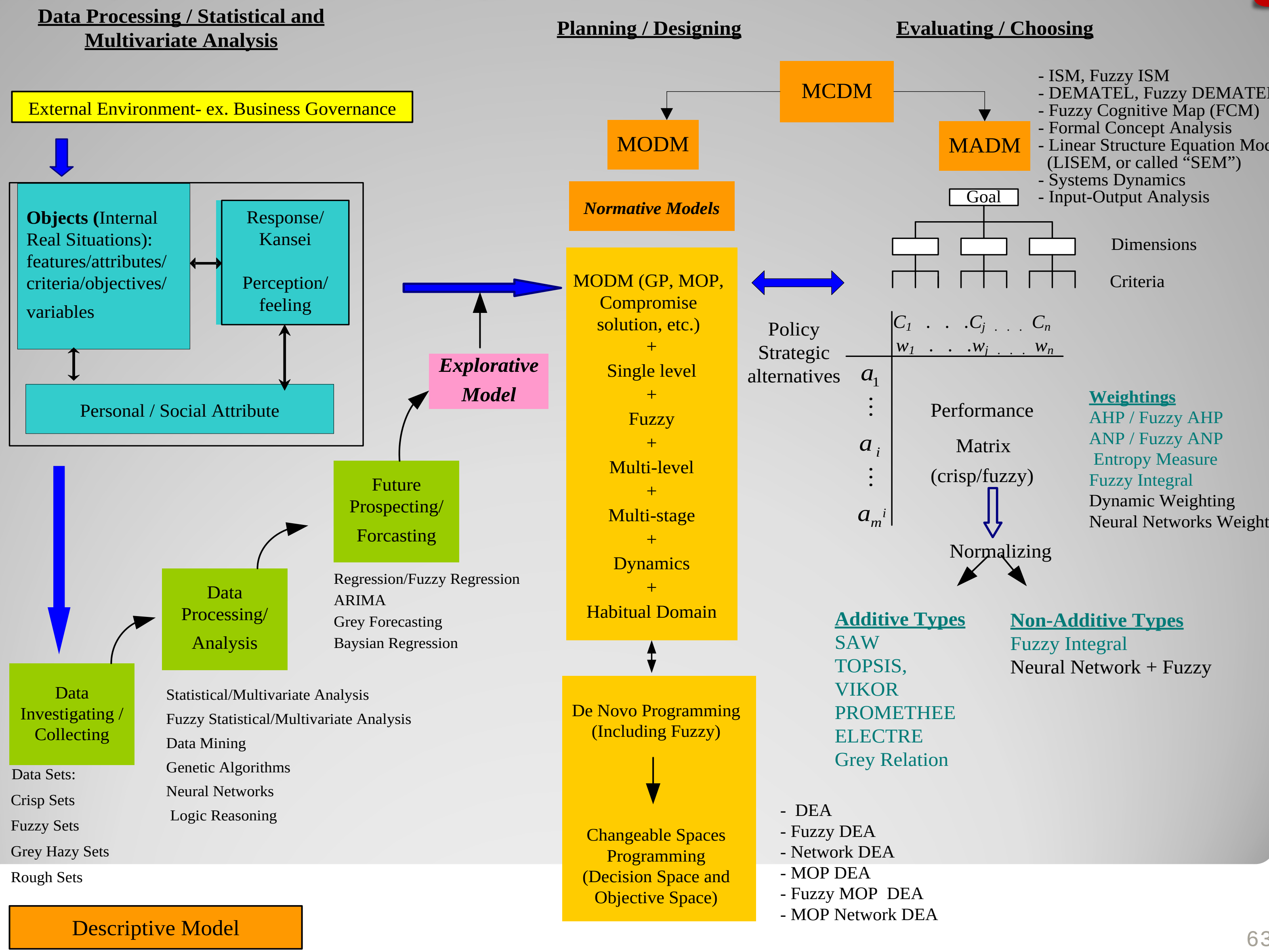
→ Hybrid MCDM Methods

For Problems-solving - Improvement

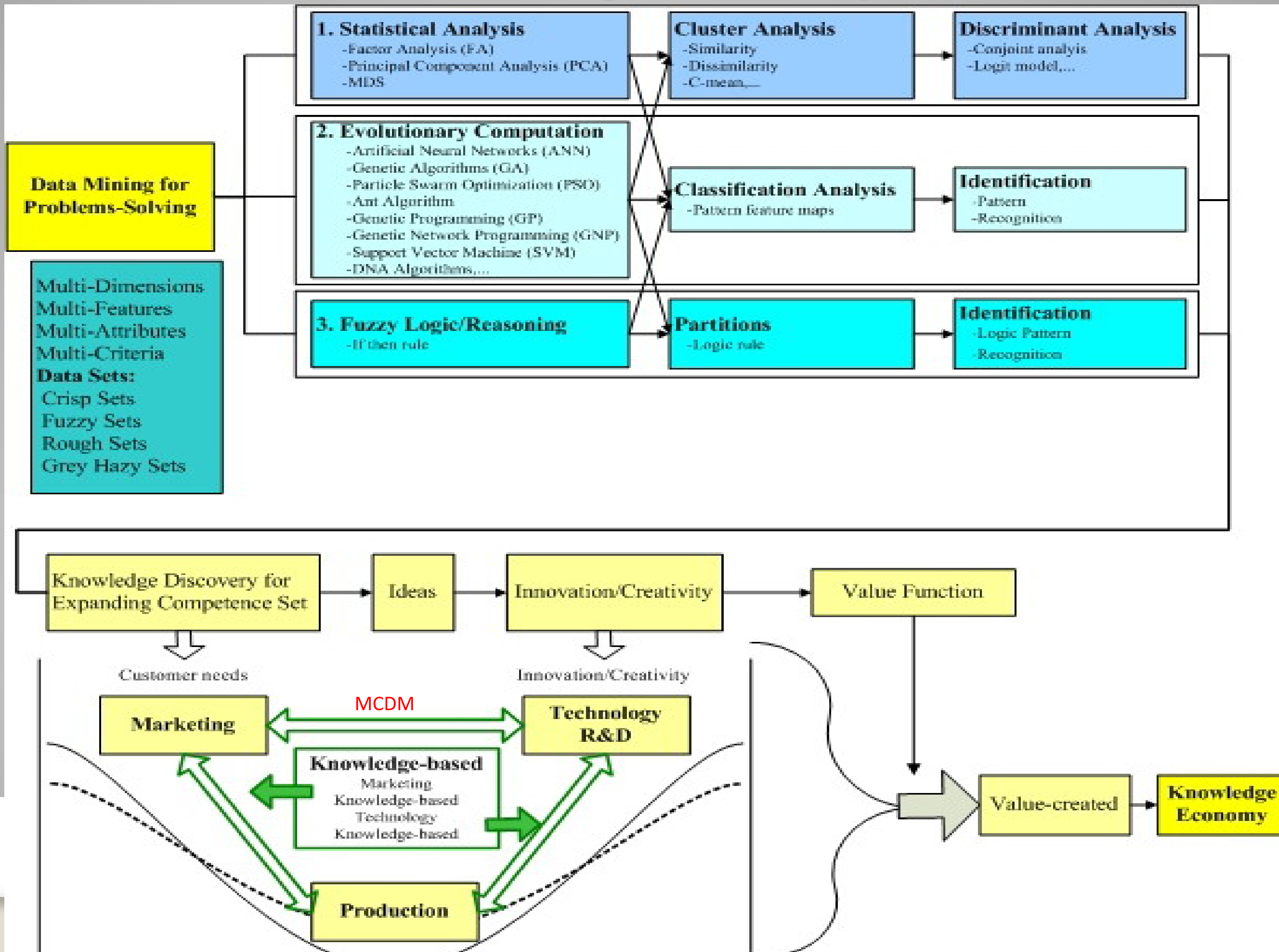




Research Methods for Problems-Solving



Data Mining Concepts of Intelligent Computation in Knowledge Economy



Background -A Quick Overview of Traditional MCDM Approaches

- Criteria weight calculations by AHP (assuming criteria independences) or
- ANP based weight derivations by a decision problem structure being derived arbitrarily (based on assumption, Saaty)
- TOPSIS which determines a solution with
  - The shortest distance from the ideal solution and
  - The farthest distance from the negative-ideal solution (cannot be used for **ranking purpose**)

Opricovic, S., Tzeng, G.H. (2004). **Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPISIS**, *European Journal of Operational Research*, *Volume 156, Issue 2*, *16 July 2004*, *Pages 445-455*

(***Essential Science Indicators**^{sm}* to be one of the **most cited papers** in the **field of Economics**).

Background - Problems being Faced by Traditional MCDM Approaches

Alternatives being derived as is

- Wrong assumptions on the **independences** between the determinants (very few exists in the real world)
- Vague correlations between criteria, such as, SEM, etc., improved by using DEMATEL technique (**"Statistics and Economics are unrealistic in the real world**", using independent, additive, and so on problems).
- The lack of improvement of each alternative (improvement is more important, **avoid "stop-gap piecemeal (腳痛醫腳頭痛醫頭)"**..
- Compromise solutions being derived (e.g. by TOPSIS) is not always the closest to the ideal (cannot be used for **ranking purpose**)
- "Rotten (decay, not good) apples versus rotten apples" situation

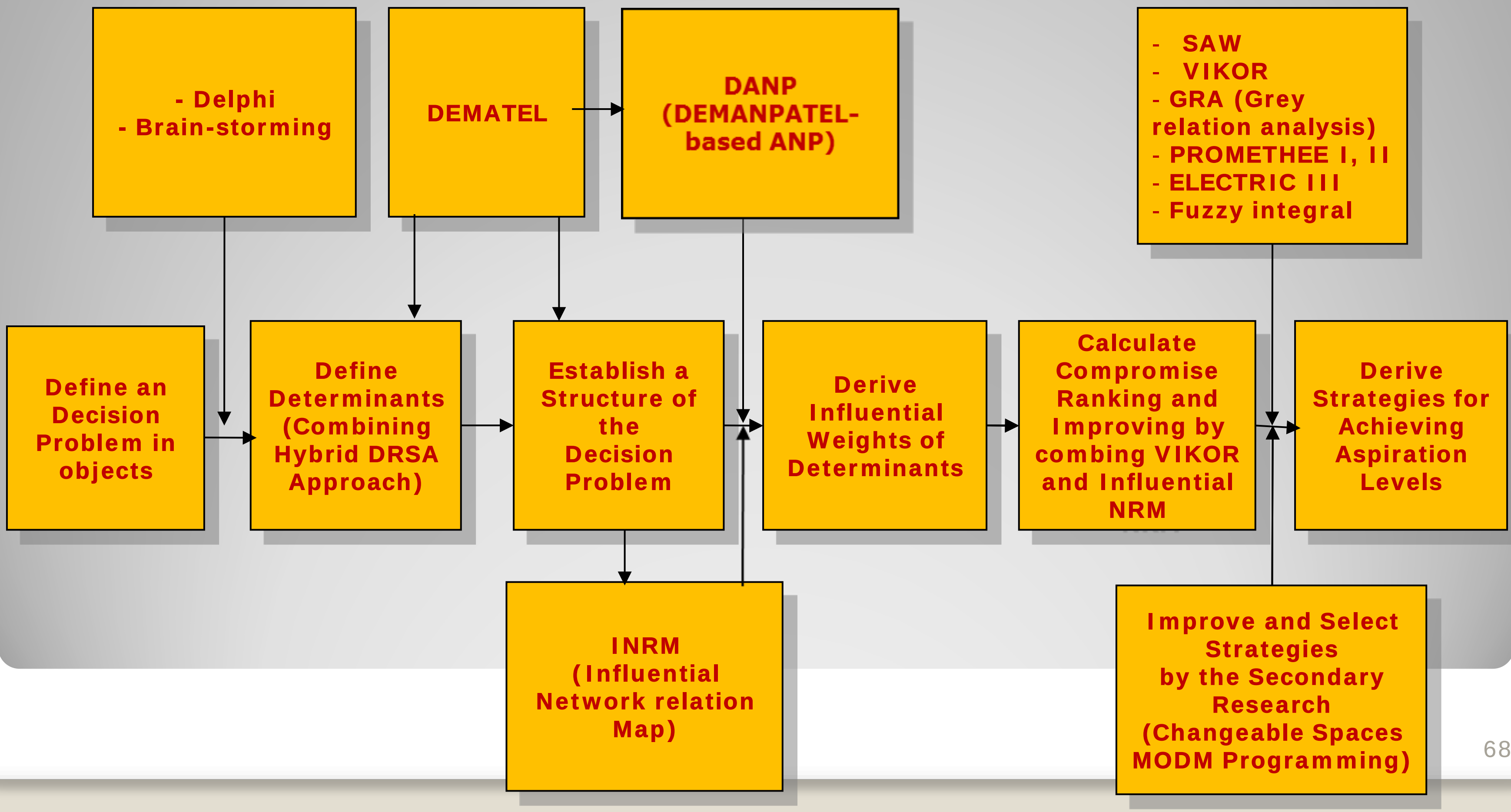
Purpose

- Introduce for solving the suitable real world MCDM problems, and the above mentioned problems should be corrected
  - A proposal of new concepts and trends of novel hybrid MCDM framework is essential in my two new books and in my publication papers of our research group

Appreciate I have an opportunity to talk **“New concepts and trends of hybrid MCDM model for tomorrow”** including my two new books and a series of recent published SSCI/SCI journal papers for sharing with our Colleagues of **National Taipei University** for **solving actual/real world problems in business and economics** by Academic Speaker in this talk..

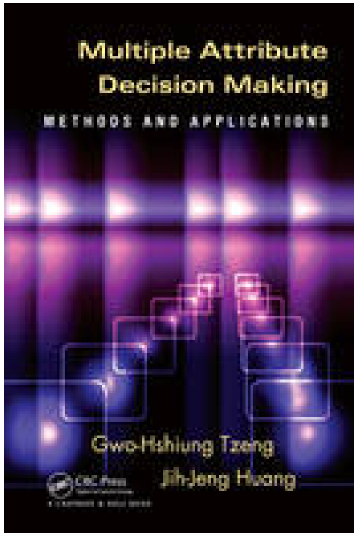
Research Methods

Combined DEMATEL Technique with a Hybrid Novel MCDM Method for applying the real case



DEMATEL -
Decision Making Trial and Evaluation Laboratory

New Methods



Basic Concept (1)

- The DEMATEL method was developed by the Battelle Geneva Institute to
  - Analyze complex “world problems” dealing mainly with interactive man-model techniques in complex social systems (Gabus and Fontela, 1972) for improving traditional “System Dynamics” by Forester” (in 1960-1970s), then we use this basic concepts for using to evaluate qualitative and factor-linked aspects of social problems by natural language.
  - We, also based on these concepts, develop a series of novel hybrid MADM model, such as Liou et al. (2007), Tzeng et al. (2007); Ou Yang, et al. (2008), Liu et al. (2012) and so on.
- **The applicability of the method can be widespread**
  - Industrial planning and improvement
  - Decision-making to transportation planning, urban planning and design
  - Regional environmental assessment
  - Analysis of world problems
  - Social network analysis, and
  - Others

Basic Concept (2)

- The DEMATEL method is based upon graph theory
  - Enabling us to plan and solve complex problems visually
    - We may divide multiple criteria into a cause-and-effects group, in order to better understand causal relationships and build influential network relationship map (INRM) in interdependence and feedback problems for improving the gaps of criteria to achieve **aspiration levels** in **satisfaction**. [Solving and treating the basic concepts proposed by **Herbert Simon**, 1978 Nobel Prize]

Relation Graphs (1)

- Directed, in-directed, and total relation graphs (also called digraphs) are more useful than directionless graphs
  - Digraphs (such as **SEM** model etc.) will demonstrate the directed, in-directed and total relationships of sub-systems, but based on Hypotheses.
- A digraph typically represents a communication network, or a domination relationship between individuals, etc.
- Suppose a system contains a set of elements, $S = \{s_1, s_2, \ldots, s_n\}$, and particular pair-wise relationships are determined for modeling, with respect to a mathematical relationship, **MR**.

Relation Graphs (2)

- Next, portray the influential relationship (RG) as a influence matrix that is indexed equally in both dimensions by elements from the set *S* by directed relation graph. Then, extract the case for which the number 0 (completely no influence) to 4 (extremely or very high influence) appears in the cell (i,j) by directed relation graph, if the entry is a positive integral that has the meaning of:
  - the ordered pair (s_i, s_j) is in the relationship;
  - it has the kind of relationship regarding that element such that s_i causes element s_j.

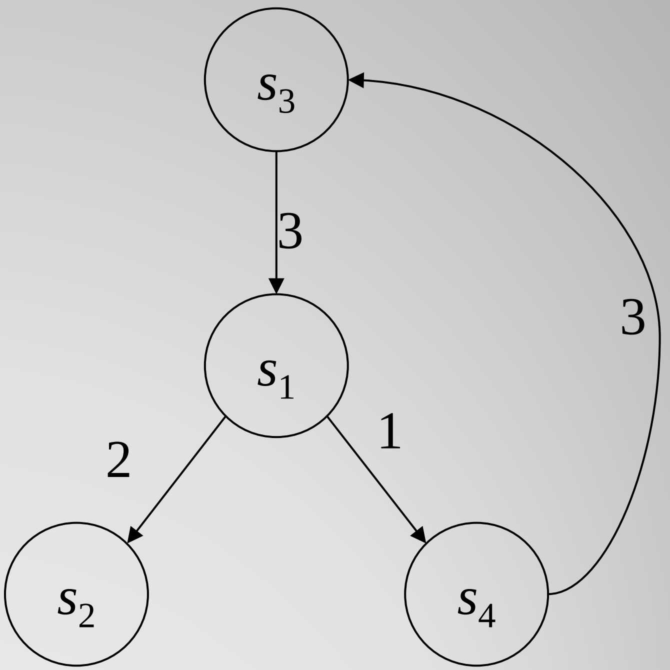
Relation Graphs (3)

- The number between factors is influence or influenced degree.
- The DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system

Relation Graphs (4)

Directed Relation Graph

- The elements, S_1, S_2, S_3 and S_4 represent the factors that have relationships in the digraph.
- The number between factors is influence or influenced degree.
  - For example, an arrow from S_1 to S_2 represents the fact that influences and its influenced degree is two.



Definitions (1)

- Definition 1
  - The pair-wise comparison scale may be designated as eleven levels, where the scores, such as ‘completely no influence (0),’ ‘low influence (1),’ ‘medium influence (2),’ ‘high influence (3),’ and ‘very high influence (4),’ respectively (or 0, 1, 2, 3, 4 or 0, 1, 2,..., 10) represent the range from ‘no influence’ to ‘very high influence’.

Definitions (2)

- Definition 2
  - The initial direct relation/influence matrix $\boldsymbol{A}$ is an $n \times n$ matrix obtained by pair-wise comparisons, in terms of influences and directions between the criteria, in which a_{ij} is denoted as the degree to which the i^{th} criteria affects the j^{th} criteria.

$$\begin{array}{cc} & \begin{array}{cccc} \phantom{a_{11}} & \phantom{a_{12}} & j & \phantom{a_{1n}} \end{array} \\ \boldsymbol{A} = & \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & a_{ij} & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}$$

i

$$i \longrightarrow j$$

Definitions (3)

- Definition 3
  - The normalized direct relation/influence matrix $\boldsymbol{X}$ can be obtained through Equations (1) and (2) by normlization, in which all principal diagonal elements are equal to zero.

$$\boldsymbol{N} = s\boldsymbol{A} \qquad (1)$$

where

$$s = 1 \Big/ \max\left\{ \max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij} \right\} \qquad (2)$$

$$\left(\text{or } s = \min\left\{ 1 \Big/ \max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, 1 \Big/ \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij} \right\} \right)$$

In this case, $\boldsymbol{X}$ is called the normalized matrix.

Since $\lim_{g \to \infty} \boldsymbol{X}^{g} = [0]$

Definitions (4)

- Definition 4
  - Then, the total relationship matrix $\boldsymbol{T}$ can be obtained using Equation (3), where $\boldsymbol{I}$ stands for the identity matrix.
  - $$\boldsymbol{T} = \boldsymbol{X} + \boldsymbol{X}^2 + \ldots + \boldsymbol{X}^g$$
  - $$= \boldsymbol{X}\left(\boldsymbol{I} + \boldsymbol{X} + \ldots + \boldsymbol{X}^{g-1}\right)[(\boldsymbol{I} - \boldsymbol{X})(\boldsymbol{I} - \boldsymbol{X})^{-1}]$$
  - $$= \boldsymbol{X}\left(\boldsymbol{I} - \boldsymbol{X}^g\right)(\boldsymbol{I} - \boldsymbol{X})^{-1}$$
  then, $\boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1}$, $\quad \lim_{g \to \infty} \boldsymbol{X}^g = [0]$ when $g \to \infty$ (3)
  - where $\boldsymbol{X} = [x_{ij}]_{n \times n}$, $0 \le x_{ij} < 1$, $0 < \sum_{j=1}^{n} x_{ij} \le 1$ and $0 < \sum_{i=1}^{n} x_{ij} \le 1$,
  - If at least one row or column of summation, but not all, is equal to 1, then $\lim_{g \to \infty} \boldsymbol{X}^g = [0]$ and $\boldsymbol{T}$ is a total influence-related matrix; matrix $\boldsymbol{X}$ is a direct influence matrix and
  - matrix $\left(\boldsymbol{X} + \boldsymbol{X}^2 + \ldots + \boldsymbol{X}^g\right)$ stands for a indirect influence matrix. The (i,j) element t_{ij} of matrix $\boldsymbol{T}$ denotes the direct and indirect influences of factor i on factor j.

$\boldsymbol{T} = [t_{ij}], \quad i, j \in \{1, 2, \ldots, n\}$

Definition (5)

- Definition 5
  - The row and column sums are separately denoted as vector $\boldsymbol{r}$ and vector $\boldsymbol{c}$ within the total-relation matrix $\boldsymbol{T}$ through Equations (4), (5), and (6).

$$\boldsymbol{T} = [t_{ij}], \quad i, j \in \{1, 2, \ldots, n\} \tag{4}$$

$$\boldsymbol{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = (r_1, \ldots, r_i, \ldots, r_n)' \tag{5}$$

$$\boldsymbol{d} = [d_j]_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = (d_1, \ldots, d_j, \ldots, d_n)' \tag{6}$$

where the vector $\boldsymbol{r}$ and vector $\boldsymbol{d}$ vectors denote the sums of the rows and columns, respectively.

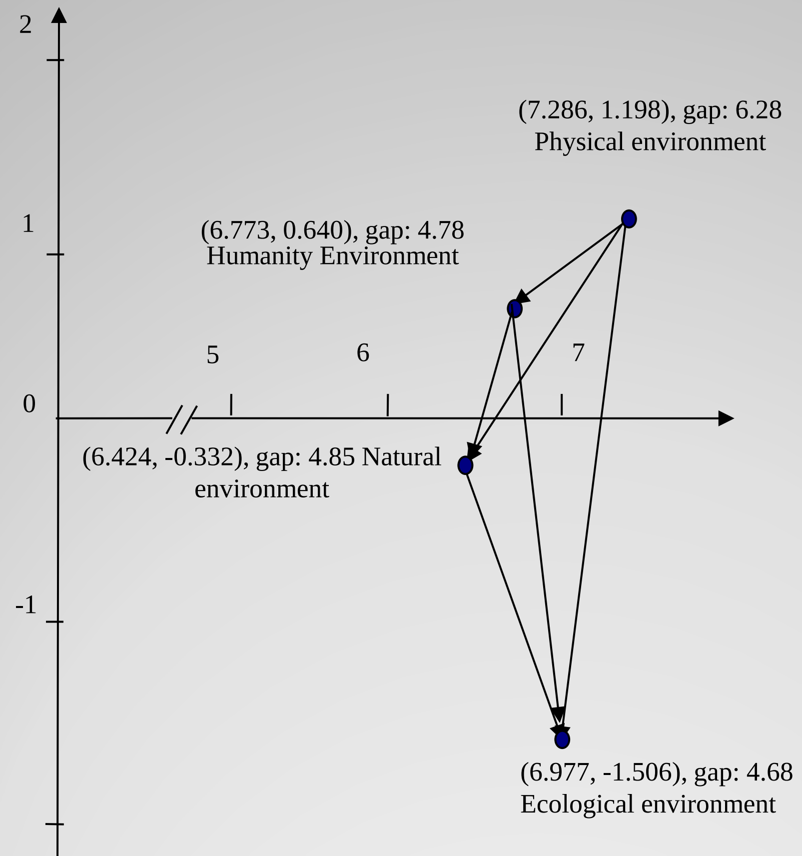
Definition 6

- Definition 6
  - Suppose r_i denotes the row sum of the i^{th} row of matrix $\boldsymbol{T}$. Then, r_i is the sum of the influences dispatching from factor i to the other all factors, both directly and indirectly. Suppose that d_j denotes the j^{th} column sum of the column of matrix $\boldsymbol{T}$. Then, d_j is the sum of the influences that factor j is received from the other all factors.

Definition 6 (Continued)

- Furthermore, when $i=j$ (i.e., the sum of the row sum and the column sum (r_i+d_j) represents the index representing the strength of the influence, both dispatching and received), (r_i+d_j) is the degree of the central role that factor i plays in the problem.
- If (r_i-d_j) is positive, then factor primarily is dispatching influence upon the other factors; and if (r_i-d_j) is negative, then factor primarily is received influence from other factors (Tamura et al., 2002; Tzeng et al., 2007; etc.).

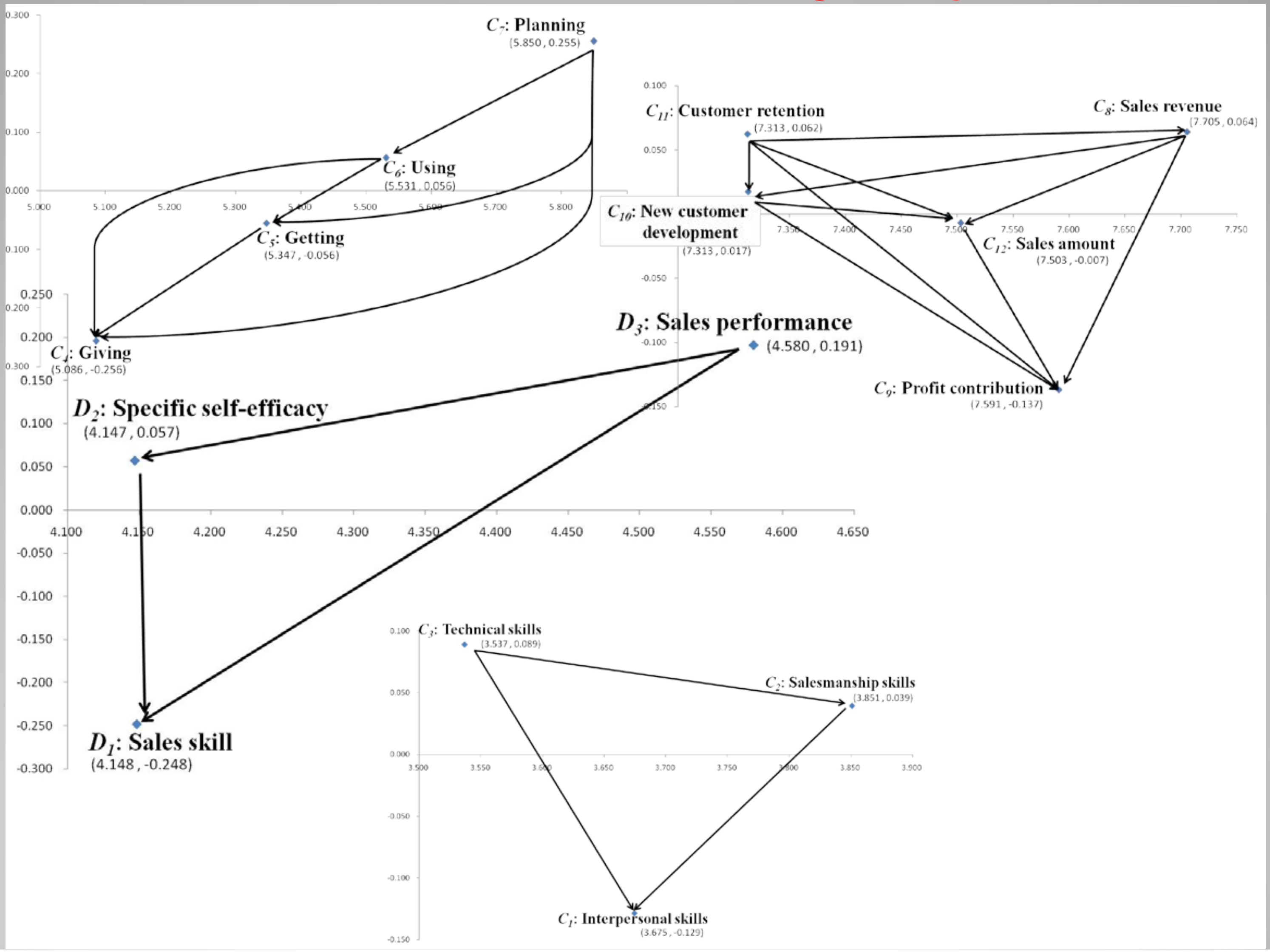
- **Example 1: For improving wetland environments**



The impact-direction map for improving gaps in performance values

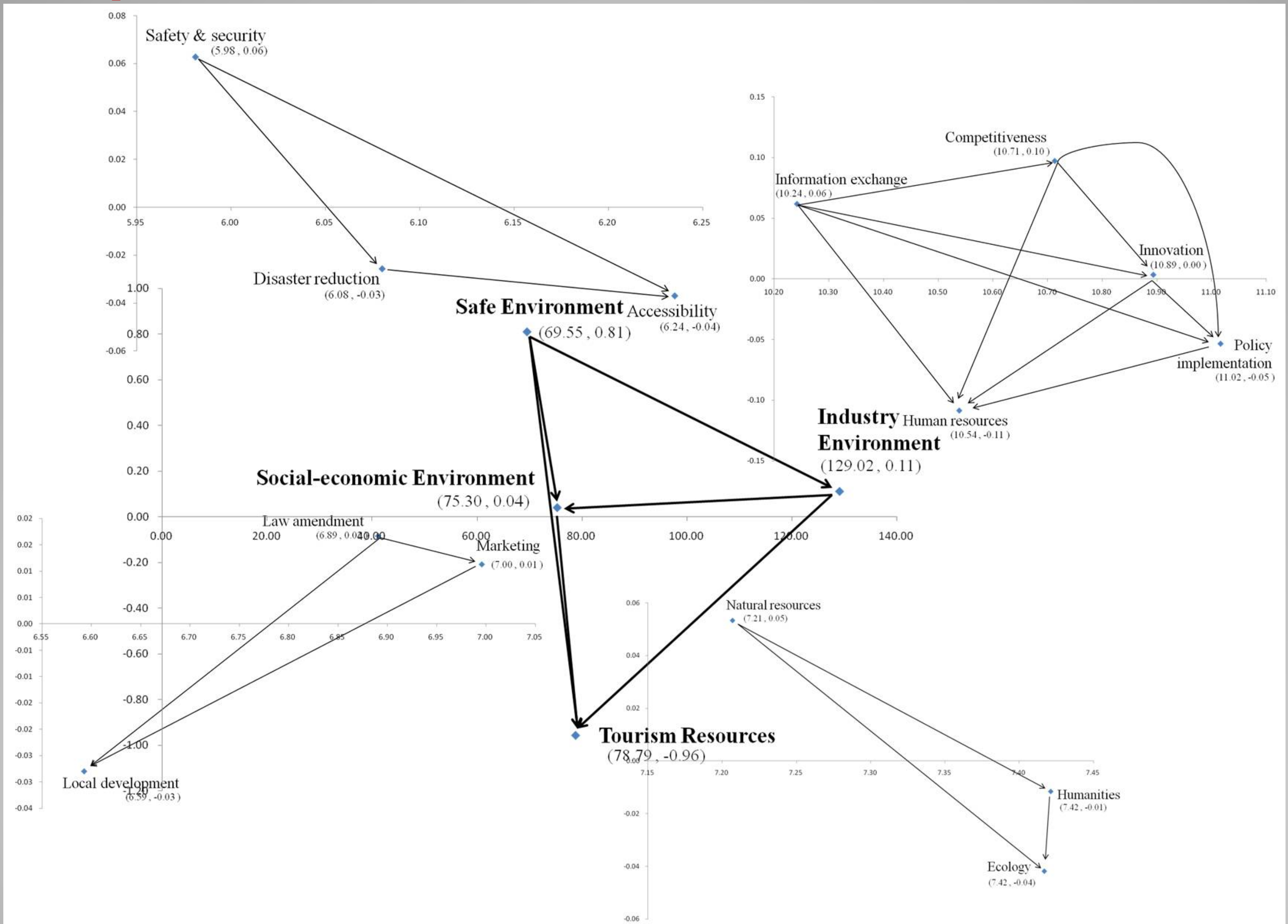
Chen, Y.C., Lien, H. P., Tzeng, G.H. (2010), Measures and evaluation for environment watershed plan using a novel hybrid MCDM model, *Expert Systems with Applications*, 37(2), *926-938*

- **Example 2: Strategies for improving cruise product sales in the travel agency**



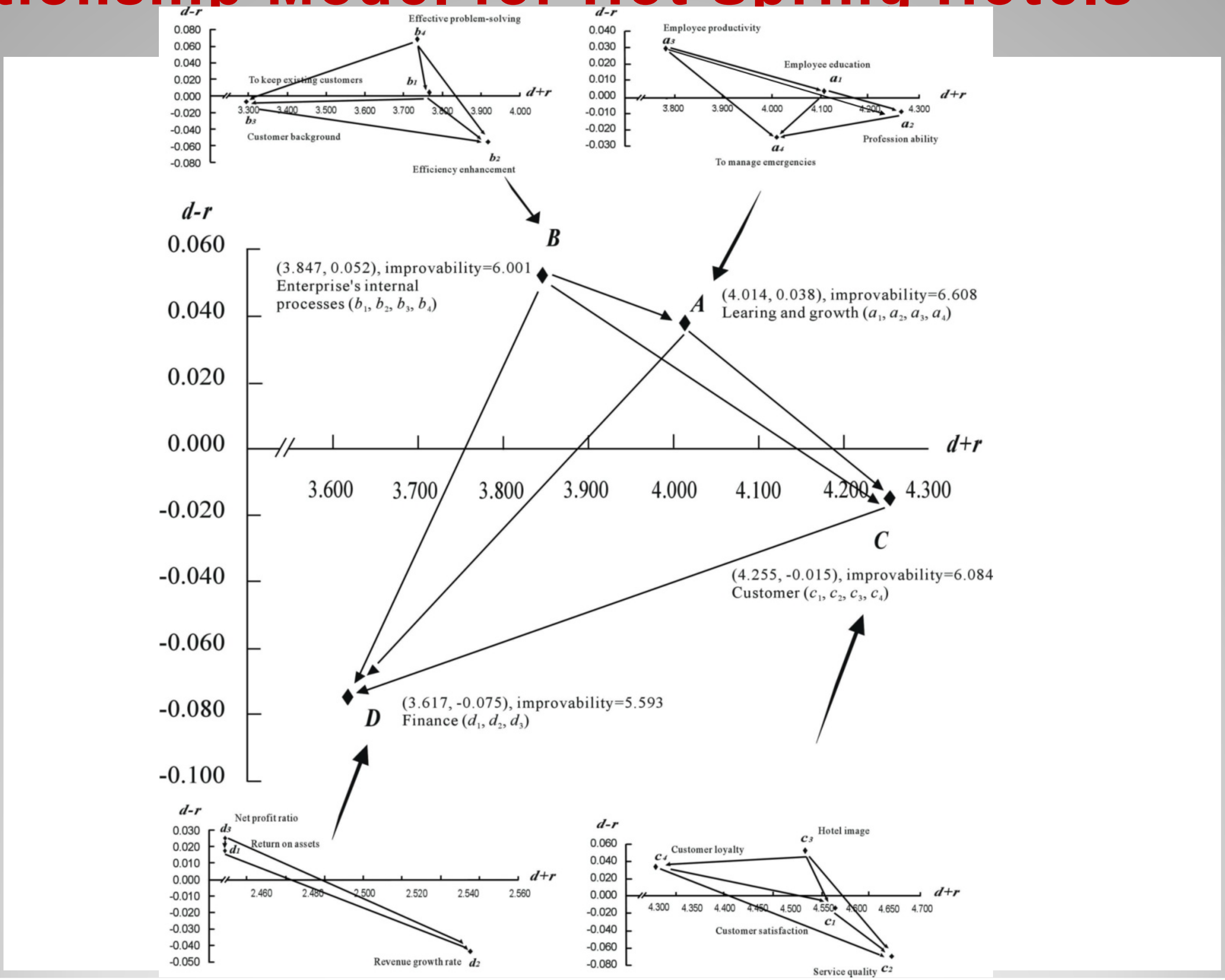
Liu, C. H., Tzeng, G.H., Lee, M.H. (2011), Strategies for improving cruise product sales in the travel agency- using hybrid MCDM models, The Service Industry Journal (Forthcoming).

- **Example 3: For improving tourism policy implementation**



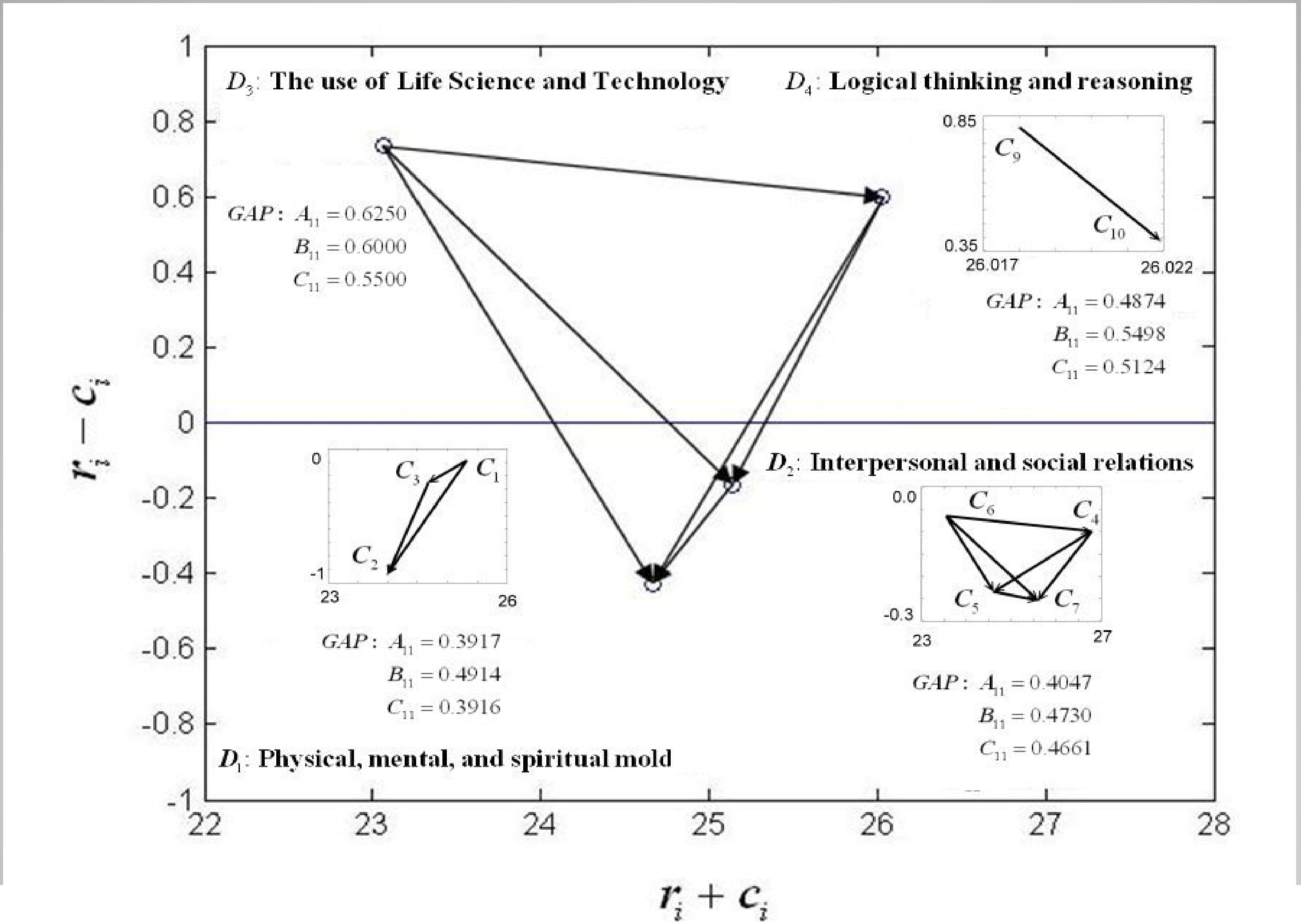
Liu, C.H., Tzeng, G.H., Lee, M.H. (2011), Improving tourism policy implementation - the use of hybrid MCDM models, Tourism Management (Accepted)

Example 4: Balanced Scorecard Approach to Establish a Performance Evaluation and Relationship Model for Hot Spring Hotels



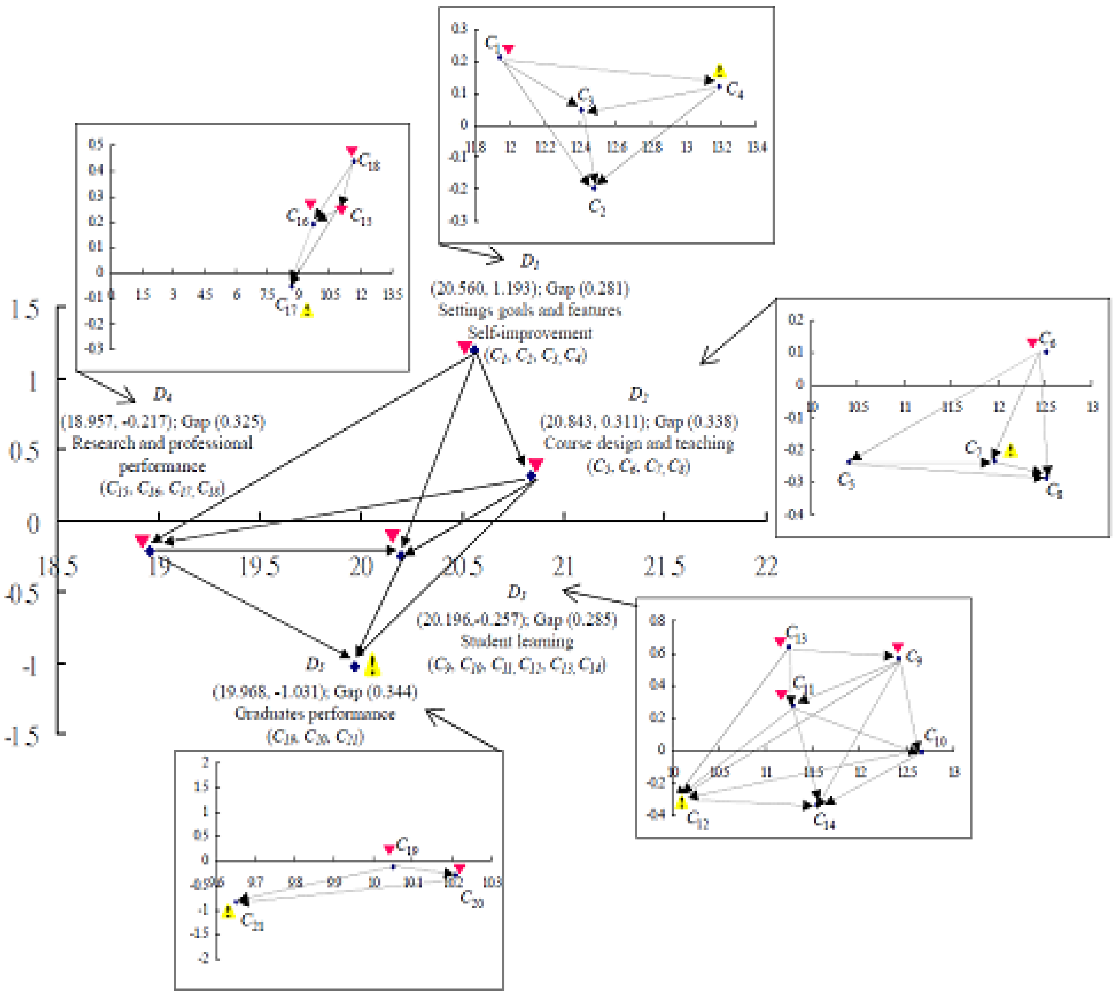
Chen, F.H., Hsu,T.S., Tzeng , G.H. (2011), A Balanced Scorecard Approach to Establish a Performance Evaluation and Relationship Model for Hot Spring Hotels Based on a Hybrid MCDM Model Combining DEMATEL and ANP, International Journal of Hospitality Management, 30(4), 908-932.

Example 5: Creating the Aspired Intelligent Assessment Systems for Teaching Materials: Case of Mandarin Chinese



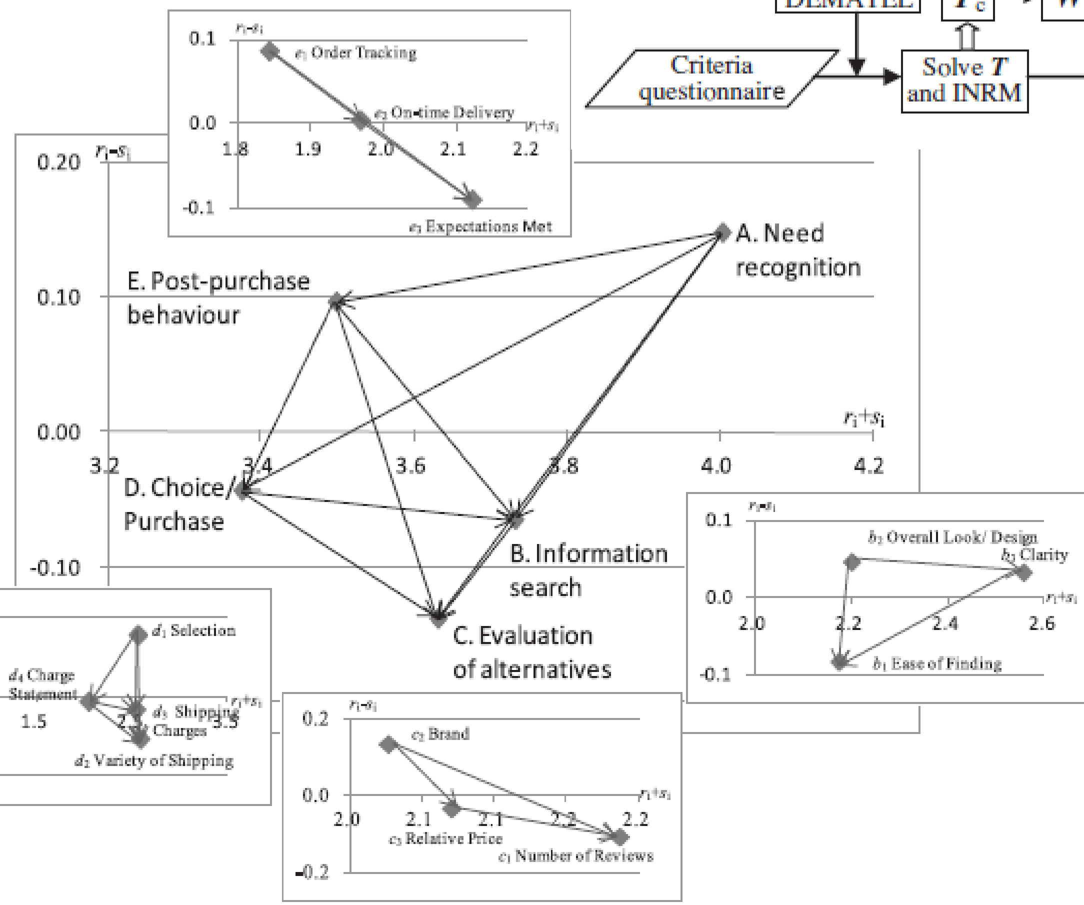
Chen, C.H. and Tzeng, G.H. (2011), Creating the Aspired Intelligent Assessment Systems for Teaching Materials, *Expert Systems with Applications*, 38(10), 12168-12179.

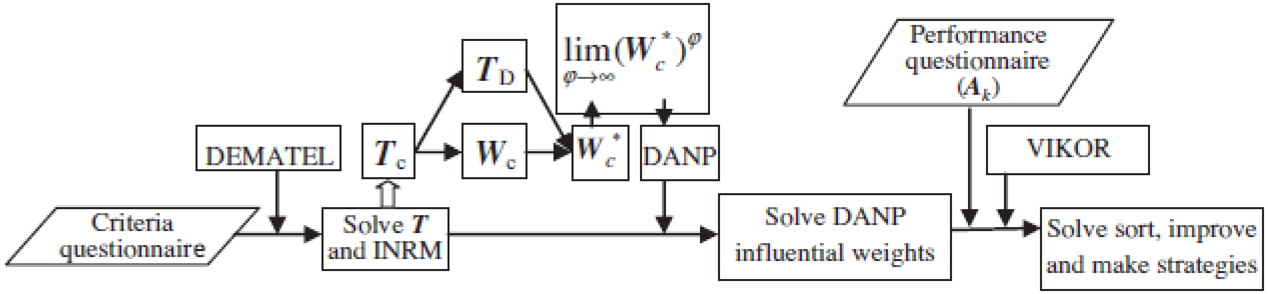
Example 6. For improve accreditation performance in higher education



Kua-Hsin Peng and **Gwo-Hshiung Tzeng**, "Strategies for Improving Accredition Performance in higher education institution, 4th International Conference on Computer Support Education (CSEDU 2012), Porto, Portugal, 16-18 April, 2012.

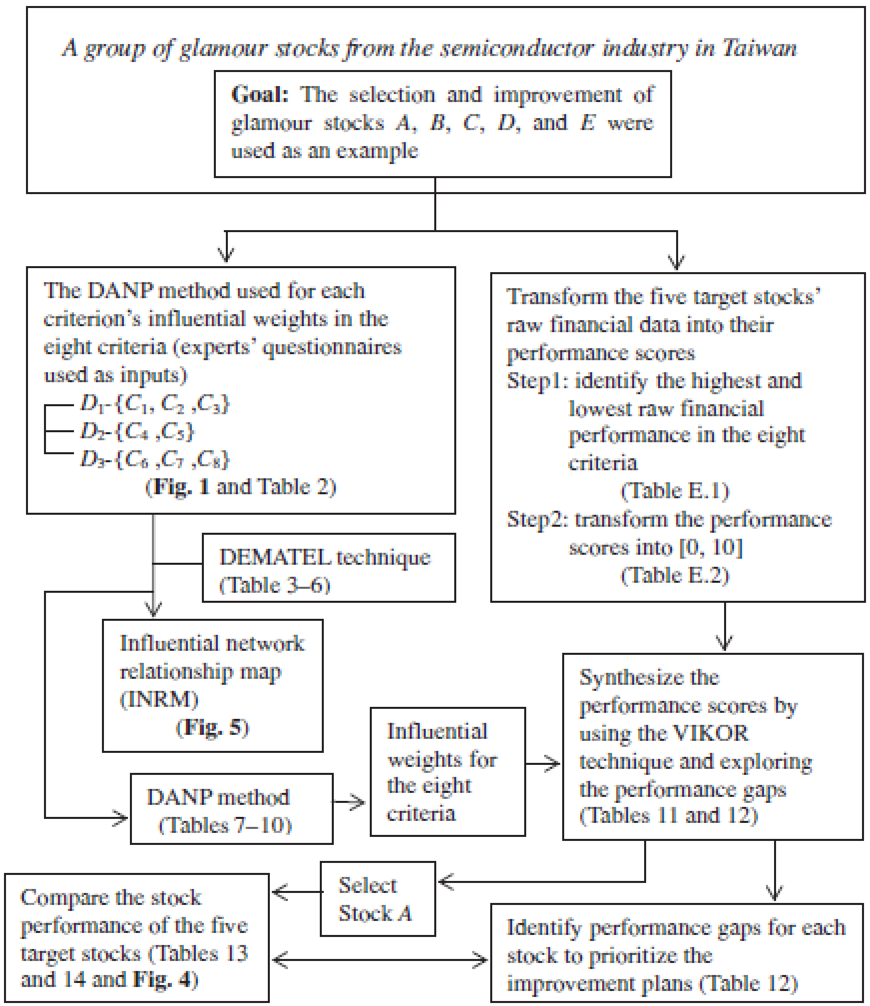
Example 7 Improve e-store business

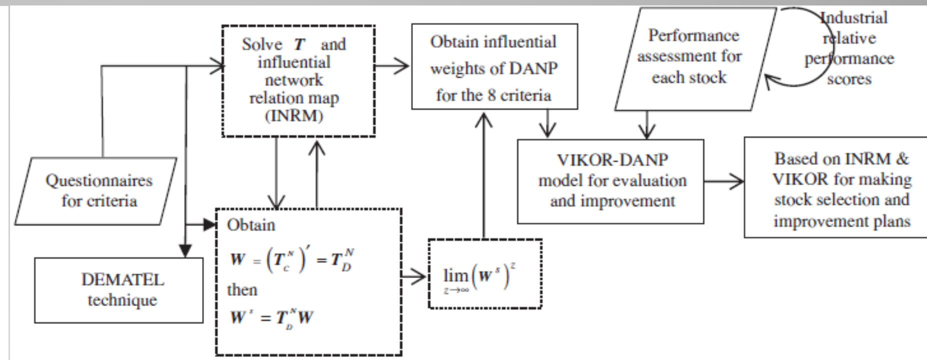




Wan-Yu Chiu, **Gwo-Hshiung Tzeng** (**Corresponding author**), Han-Lin Li (**2013**), **A new hybrid MCDM model combining DANP with VIKOR to improve e-store business**, ***Knowledge-Based Systems***, *Volume 37*, *January 2013*, *Pages 48-61* **(SCI**, **IF: 4.104**, 3.371 (5-years, 2012))

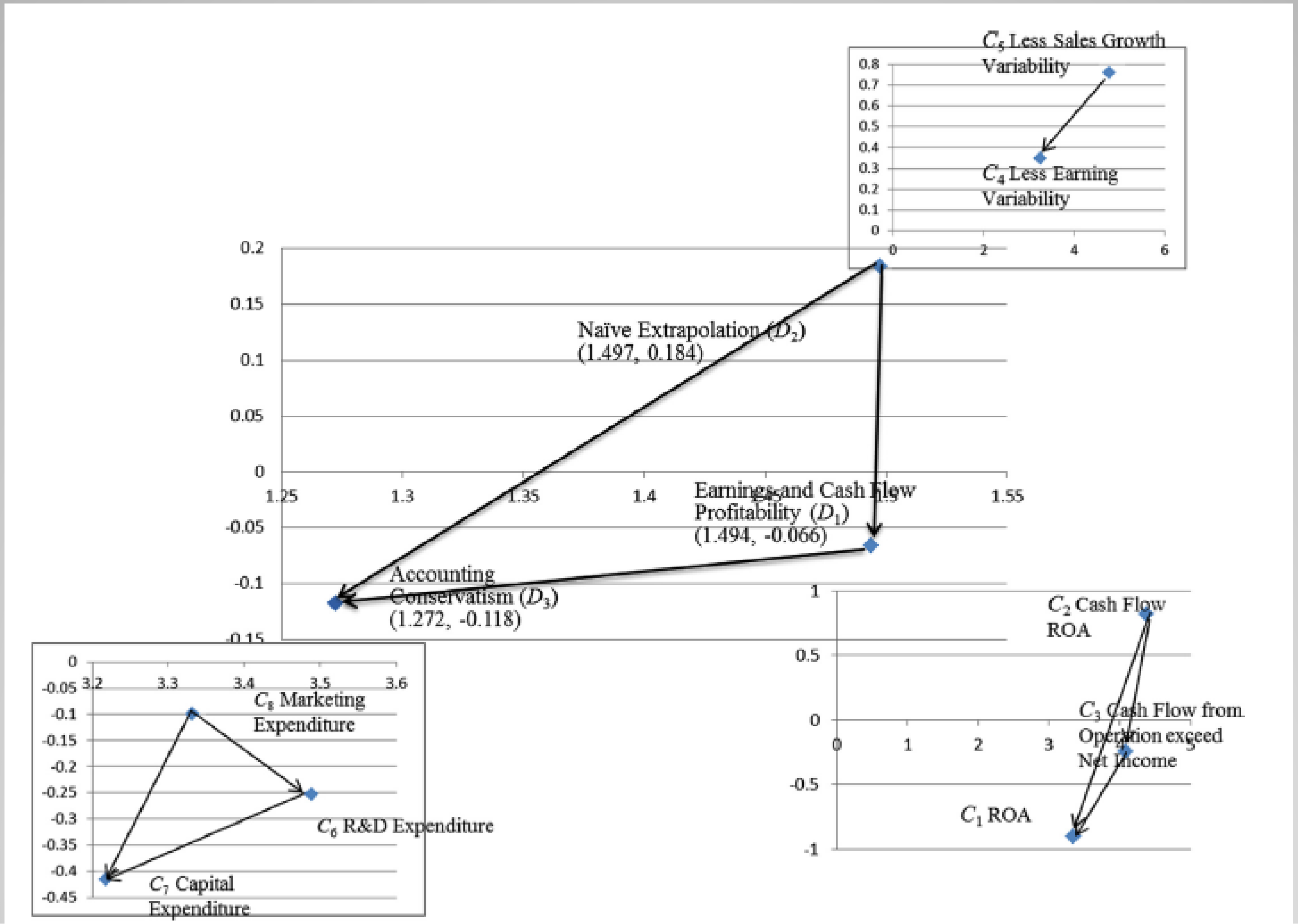
Example 8 Glamor stock selection and stock performance improvement



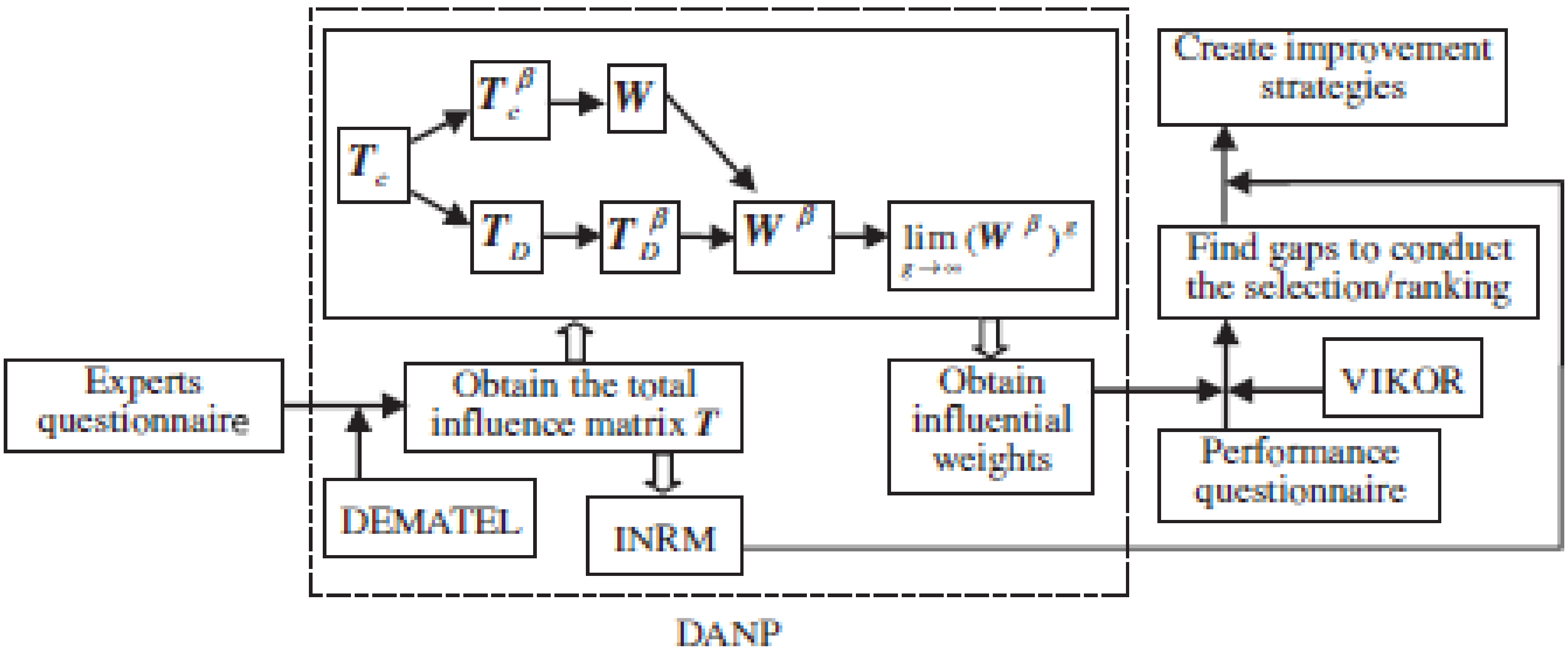


Kao-Yi Shen, Min-Ren Yan, and **Gwo-Hshiung Tzeng** (**Corresponding author**) **(2014)**, [Combining VIKOR-DANP model for glamor stock selection and stock performance improvement], ***Knowledge-Based Systems***, *Volume 58, March 2014, Pages 86-97* **(SCI**, **IF: 4.104**, 3.371 (5-years, **2012**).

Example 8 Glamor stock selection and stock performance improvement

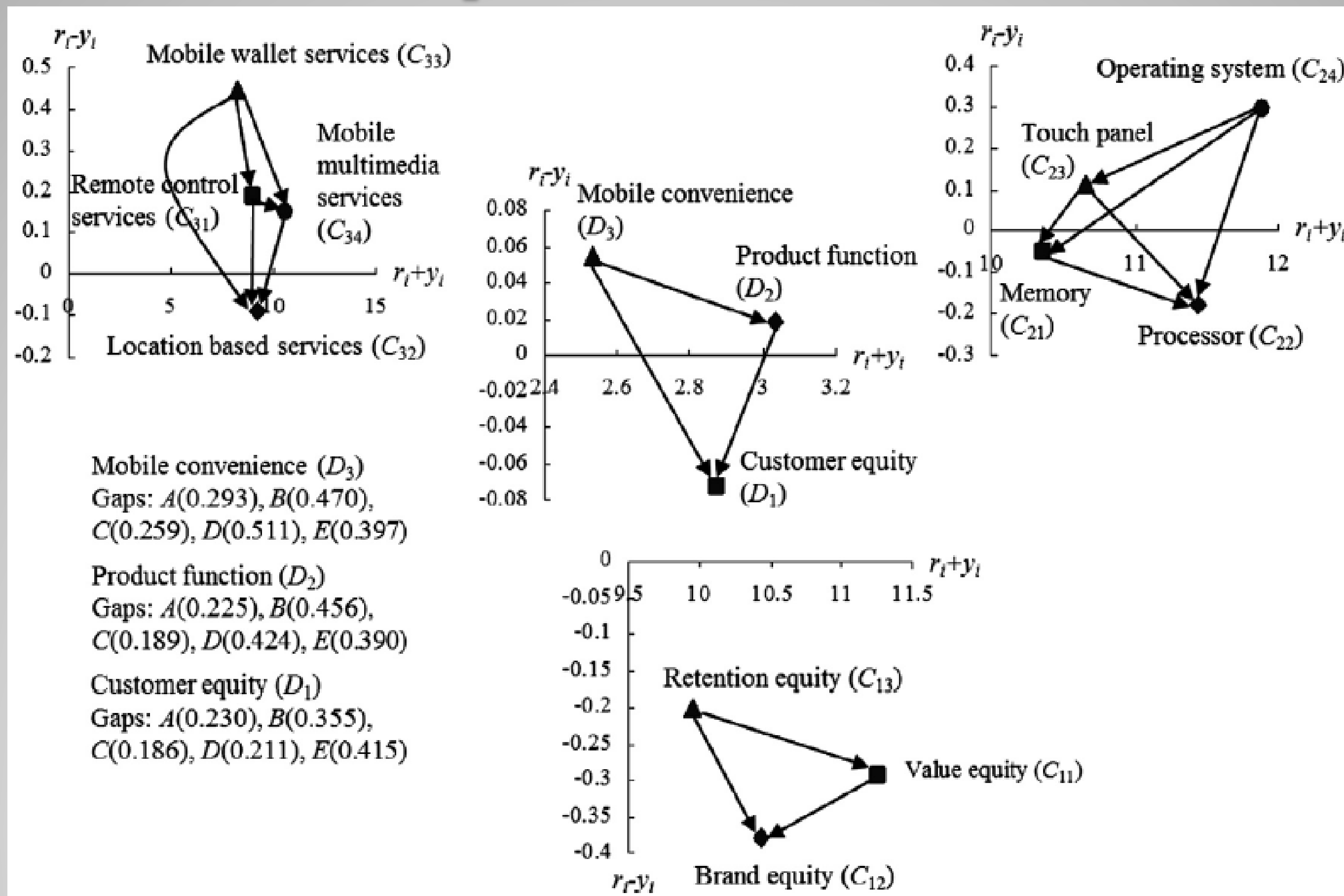


Example 9 Exploring smart phone improvements



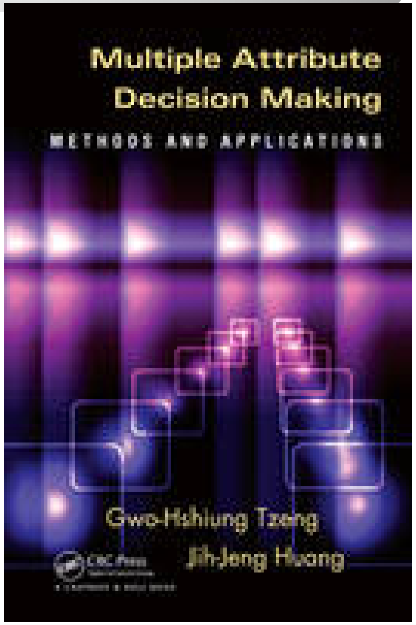
- Shu-Kung Hu, Ming-Tsang Lu, **Gwo-Hshiung Tzeng** (**Corresponding author**) **(2014)** Exploring smart phone improvements based on a hybrid MCDM model, **Expert Systems With Applications**, ***Volume 41, Issue 9***, ***July 2014***, ***Pages 4401-4413*** (**SCI**, **IF: 1.854**, 2.339 (5-years, **2012**).

Example 9 Exploring smart phone improvements



Analytic Network Process (ANP) and DANP (DEMATEL-based ANP)

DANP (DEMATEL-based ANP) based on DEMATEL technique to build network relationship map (NRP) for constructing Super-matrix using the basic concept of ANP to find the influential weights (called DANP)



Source: Tzeng (2006)

Basic concept (1)

- The ANP method
  - A multi-criteria theory of measurement proposed by Saaty (1996).
  - Provides a general framework to deal with
    - Decisions without making assumptions about the independence of higher-level elements from lower level elements
    - About the independence of the elements within a level as in a hierarchy.

  [i.e., between each dimension is dependent, but criteria within dimension are independent]

Basic concept (2)

- Compared with traditional MCDM methods, ANP is a more reasonable tool for dealing with complex MCDM problems in the real world.
  - Traditional MCDM methods usually assume the independence between criteria.
  - ANP extends AHP to deal with dependence in feedback and utilizes the super-matrix approach.

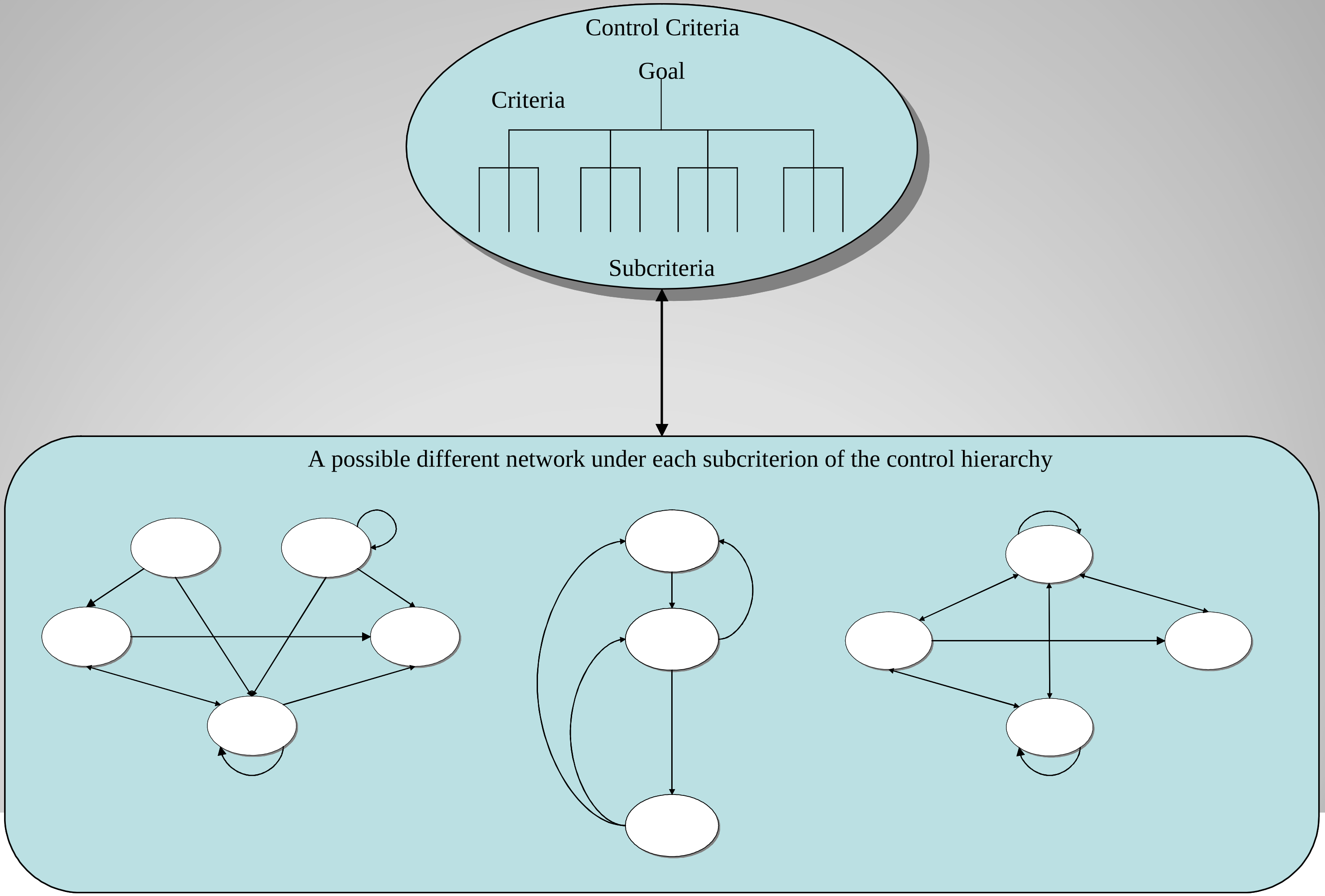
Basic concept (3)

- The ANP is a coupling of two parts.
  - The first consists of a control hierarchy or network of criteria and subcriteria that control the interactions.
  - The second is a network of influences among the elements and clusters.
    - The network varies from criterion to criterion
    - A different supermatrix of limiting influence is computed for each control criterion.
- Each of these super-matrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria.

The Control Hierarchy (1)

- A control hierarchy is a hierarchy of criteria and subcriteria for which priorities are derived in the usual way with respect to the goal of the system being considered.
  - The criteria are used to compare the components of a system, and
  - The subcriteria are used to compare the elements.
  - The criteria with respect to which influence is presented in individual supermatrices are called control criteria.

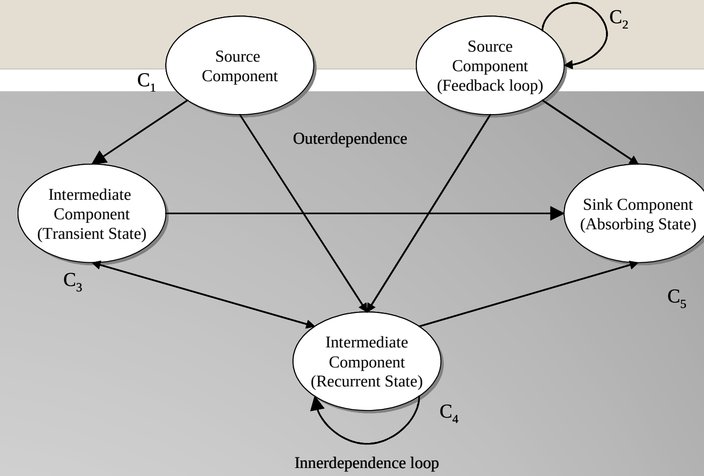
The Control Hierarchy (2)



The Network (1)

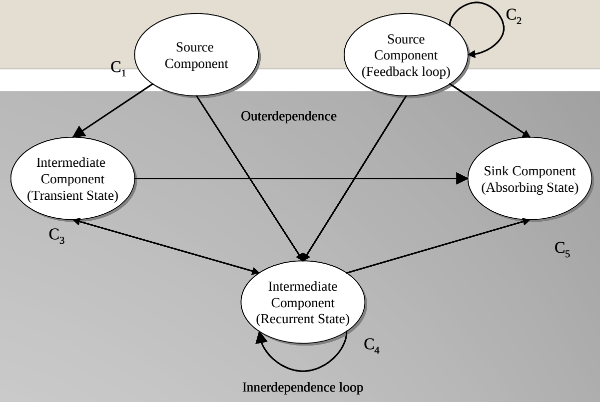
- A network connects the components of a decision system.
- According to size, there will be a system that is made up of subsystems, with each subsystem made up of components, and each component made up of elements.
- The elements in each component interact or have an influence on some or all of the elements of another component with respect to a property governing the interactions of the entire system, such as energy, capital, or political influence.

The Network (2)



- Source component
  - Those components which no arrow enters are known as source components. E.g. C_1 and C_2.
- Sink component
  - Those from which no arrow leaves are known as sink component. E.g. C_5.
- Transient component
  - Those components which arrows both enter and exit leave. E.g. C_3 and C_4.

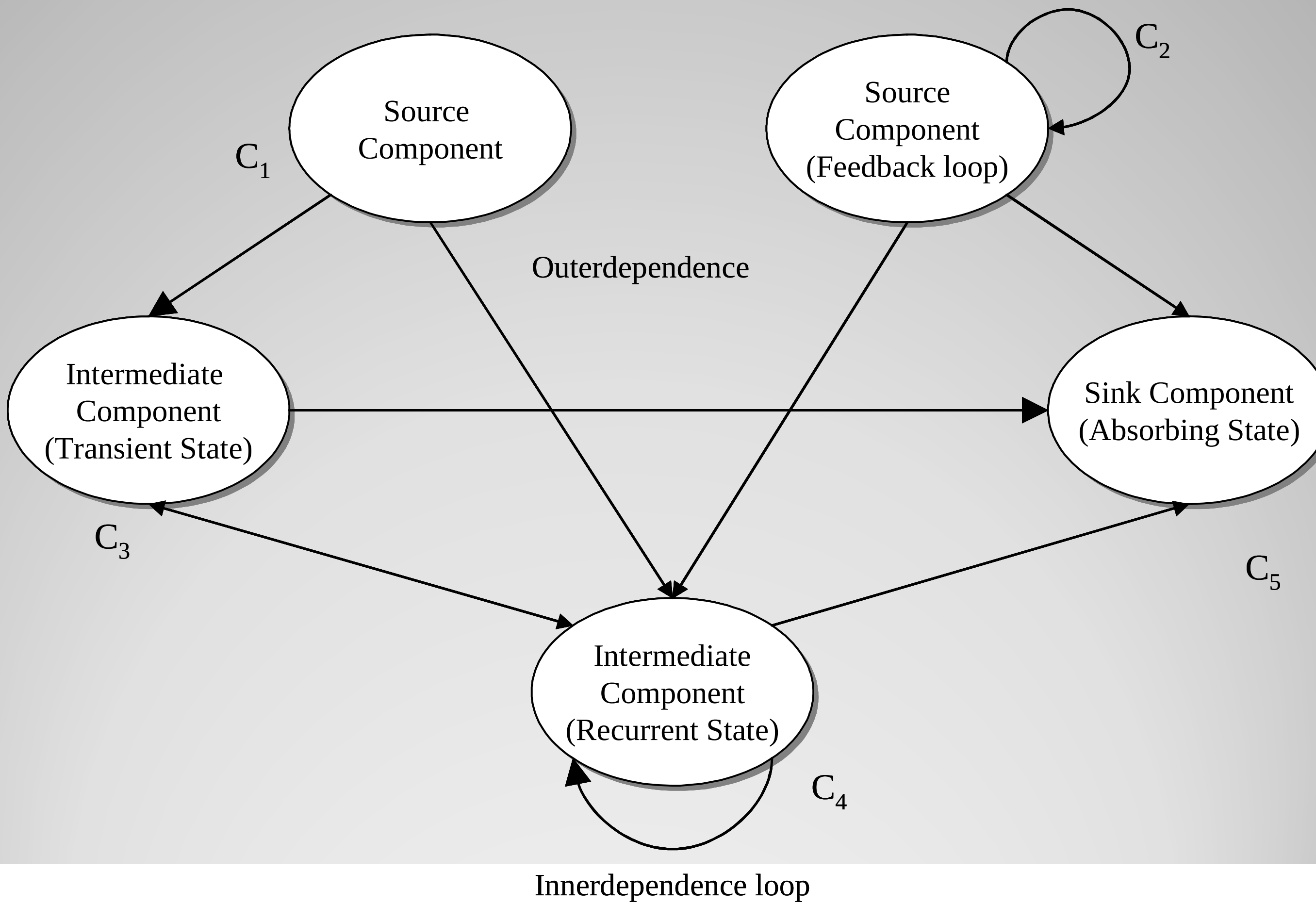
The Network (3)



- Cycle
  - A cycle of components is formed when the components feed back and forth into each other. E.g. C_3 and C_4.
- Loop
  - A loop connect to a component itself and is inner dependent. E.g.. C_2 and C_4 have loops that connect them to themselves and are inner dependent.
- Outer dependent
  - Other connections represent dependence between components which are thus known to be outer dependent.

The Network (4)

A Typical Example



The Super-matrix (1)

- A component of a decision network will be denoted by C_h, $h = 1,2,\ldots,m$, and assume that it has n_h elements, which we denote by e_{h1}, $e_{h2}, \ldots, e_{hm}$.
- The influences of a given set of elements in a component on any element in the decision system are represented by a ratio scale priority vector derived from pair-wise comparisons of the relative importance of one criterion and another criterion with respect to the interests or preferences of the decision-makers.

The Super-matrix (2)

- This relative importance value can be determined using a scale of 1 – 9 to represent equal importance to extreme importance.
- The influence of elements in the network on other elements in that network can be represented in the following supermatrix:

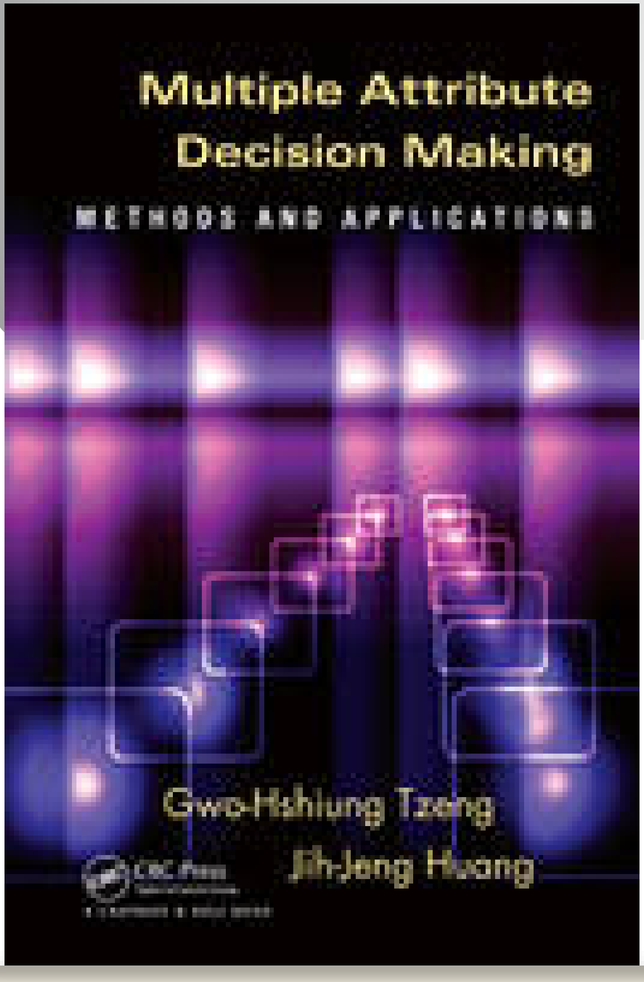
The Super-matrix (3)

- A typical entry W_{ij} in the supermatrix, is called a block of the supermatrix in the following form where each column of W_{ij} is a principal eigenvector of the influence of the elements in the ith component of the network on an element in the jth component. Some of its entries may be zero corresponding to those elements that have no influence.

The Supermatrix (4)

$$
\begin{array}{rc}
 & \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \\ e_{11} \cdots e_{1n_1} & e_{21} \cdots e_{2n_2} & \cdots & e_{m1} \cdots e_{mn_m} \end{array} \\
W = \begin{array}{cc}
C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \end{array} \\
C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{array} \\
\vdots & \vdots \\
C_2 & \begin{array}{c} e_{m1} \\ e_{m2} \\ \vdots \\ e_{mn_m} \end{array}
\end{array}
&
\begin{bmatrix}
W_{11} & W_{12} & \cdots & W_{1m} \\
W_{21} & W_{22} & \cdots & W_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
W_{m1} & W_{m2} & \cdots & W_{mm}
\end{bmatrix}
\end{array}
$$

DEMATEL based Analytic Network Process (DANP)



New method
Hybrid MCDM model

- DEMATEL-based Analytic Network Process (DANP) (1/14)

➢ The DANP is proposed by Pro. Tzeng, which is composed of DEMATEL technique and ANP concept.

DEMATEL-based ANP = DANP

- DEMATEL based Analytic Network Process (DANP) (2/14)

-

➢ The DEMATEL technique was developed by the Battelle Geneva Institute:

(1) to analyze complex "real world problems" dealing mainly with interactive map-model techniques (Gabus & Fontela, 1972).

(2) to evaluate qualitative and factor-linked aspects of societal problems.

DEMATEL-based ANP = DANP

DEMATEL based Analytic Network Process (DANP) (3/14)

- The ANP method, a multi criteria theory of measurement developed by Saaty (Saaty, 1996) provides a general framework to deal with decisions without making assumptions about the independence of higher-level elements from lower level elements and about the independence of the elements within a level as in a hierarchy.

DEMATEL-based ANP = DANP

- DEMATEL based Analytic Network Process (DANP) (4/14) -

- Step1: Calculate the direct-influence matrix by scores. Lead users and experts are asked to indicate the direct effect they believe a factor will have on factor , as indicated by . The matrix D of direct relations can be obtained.

- Step2: Normalize the direct-influence matrix based on the direct-influence matrix D by the equation:

$$N = vD; v = \min\{1/\max_i \sum_{j=1}^{n} d_{ij}, 1/\max_j \sum_{i=1}^{n} d_{ij}\}, i, j \in \{1, 2, ..., n\}$$

DEMATEL-based ANP = DANP

- DEMATEL based Analytic Network Process (DANP) (5/14) -

- Step3: Attaining the total-influence matrix $\boldsymbol{T}$ by calculating this equation: $\boldsymbol{T} = \boldsymbol{N} + \boldsymbol{N}^2 + \ldots + \boldsymbol{N}^h = \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1}, \quad \text{when } h \to \infty$

- Step4: The row and column sums are separately denoted as and within the total-relation matrix through equations:

$$\boldsymbol{T} = [t_{ij}], \quad i, j \in \{1, 2, \ldots, n\}$$

$$\boldsymbol{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \qquad \boldsymbol{c} = [c_j]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n}$$

DEMATEL-based ANP = DANP

DEMATEL based Analytic Network Process (DANP) (6/14)

Total relationship matrix $\boldsymbol{T}$ can be measured by criteria, shown as $\boldsymbol{T}_c$

$$\boldsymbol{T}_c = \begin{array}{cc} & \begin{array}{ccccc} D_1 & & D_j & & D_n \\ c_{11}\cdots c_{1m_1} & \cdots & c_{j1}\cdots c_{jm_j} & \cdots & c_{n1}\cdots c_{nm_n} \end{array} \\ \begin{array}{cc} D_1 & \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \\ \vdots & \vdots \\ D_i & \begin{array}{c} c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \end{array} \\ \vdots & \vdots \\ D_n & \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} & \begin{bmatrix} \boldsymbol{T}_c^{11} & \cdots & \boldsymbol{T}_c^{1j} & \cdots & \boldsymbol{T}_c^{1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{i1} & \cdots & \boldsymbol{T}_c^{ij} & \cdots & \boldsymbol{T}_c^{in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{n1} & \cdots & \boldsymbol{T}_c^{nj} & \cdots & \boldsymbol{T}_c^{nn} \end{bmatrix} \end{array}$$

DEMATEL based Analytic Network Process (DANP) (7/14)

Step 5: Normalize $\boldsymbol{T}_c$ with the total degree of effect and obtain $\boldsymbol{T}_C^{\alpha}$

$$\boldsymbol{T}_C^{\alpha} = \begin{array}{cc} & \begin{array}{ccccc} D_1 & & D_j & & D_n \\ c_{11}\cdots c_{1m_1} & \cdots & c_{j1}\cdots c_{jm_j} & \cdots & c_{n1}\cdots c_{nm_n} \end{array} \\ \begin{array}{cc} D_1 & \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \end{array} \\ \vdots & \vdots \\ D_i & \begin{array}{c} c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \end{array} \\ \vdots & \vdots \\ D_n & \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} & \begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \cdots & \boldsymbol{T}_c^{\alpha 1j} & \cdots & \boldsymbol{T}_c^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha i1} & \cdots & \boldsymbol{T}_c^{\alpha ij} & \cdots & \boldsymbol{T}_c^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha n1} & \cdots & \boldsymbol{T}_c^{\alpha nj} & \cdots & \boldsymbol{T}_c^{\alpha nn} \end{bmatrix} \end{array}$$

- DEMATEL based Analytic Network Process (DANP) (8/14) -

- According to the result of step 4
  - $(r_i + c_i)$ represents the index representing the strength of the influence, both dispatching and receiving, it is the degree of the central role that factor plays in the problem.
  - If $(r_i - c_i)$ is positive, then factor primarily is dispatching influence upon the strength of other factors; and if $(r_i - c_i)$ is negative, then factor primarily is receiving influence from other factors (Huang et al.,2007; Liou et al., 2007; Tamura et al., 2002).

DEMATEL-based ANP = DANP

- DEMATEL based Analytic Network Process (DANP) (9/14) -

- Now we call the total-influence matrix $\boldsymbol{T}_C = \left[t_{ij} \right]_{nxn}$ obtained by criteria and $\boldsymbol{T}_D = \left[t_{ij}^{D} \right]_{nxn}$ obtained by dimensions (clusters) from $\boldsymbol{T}_C$.
- Then we normalize the unweighted supermatrix $\boldsymbol{W}$ based on weights of dimensions (clusters) by using the normalized influence matrix $\boldsymbol{T}_D$.

$$\boldsymbol{T}_D = \begin{bmatrix} t_{11}^{D_{11}} & \cdots & t_{1j}^{D_{1j}} & \cdots & t_{1m}^{D_{1m}} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{D_{i1}} & \cdots & t_{ij}^{D_{ij}} & \cdots & t_{im}^{D_{im}} \\ \vdots & & \vdots & & \vdots \\ t_{m1}^{D_{m1}} & \cdots & t_{mj}^{D_{mj}} & \cdots & t_{mm}^{D_{mm}} \end{bmatrix} \begin{array}{l} \longrightarrow d_1 = \sum_{j=1}^{m} t_{1j}^{D_{1j}} \\ \\ \longrightarrow d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} \;, d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}}, i = 1, \ldots, m \\ \\ \longrightarrow d_m = \sum_{j=1}^{m} t_{mj}^{D_{mj}} \end{array}$$

DEMATEL-based ANP = DANP

DEMATEL based Analytic Network Process (DANP) (11/14)

- Step 6: normalize the total-influence matrix and represent it as T_D

$$\boldsymbol{T}_D^{\alpha} = \begin{bmatrix} t_{11}^{D_{11}}/d_1 & \cdots & t_{1j}^{D_{1j}}/d_1 & \cdots & t_{1m}^{D_{1m}}/d_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}}/d_i & \cdots & t_{ij}^{D_{ij}}/d_i & \cdots & t_{im}^{D_{im}}/d_i \\ \vdots & \vdots & & \vdots & \vdots \\ t_{m1}^{D_{m1}}/d_m & \cdots & t_{mj}^{D_{mj}}/d_m & \cdots & t_{mm}^{D_{mm}}/d_m \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\alpha n1} & \cdots & t_D^{\alpha nj} & \cdots & t_D^{\alpha nn} \end{bmatrix}$$

DEMATEL-based ANP = DANP

DEMATEL based Analytic Network Process (DANP) (12/14)

- Step 7: Calculate the unweighted supermatrix W based on T_c^{α}.

$$W = (T_c^{\alpha})' = \begin{array}{cc} & \begin{array}{ccccc} D_1 & & D_i & & D_n \\ c_{11}\ldots c_{1m_1} & \cdots & c_{i1}\ldots c_{im_i} & \cdots & c_{n1}\ldots c_{nm_n} \end{array} \\ \begin{array}{cc} D_1 & \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ \vdots \end{array} \\ \vdots & \\ D_j & \begin{array}{c} c_{j1} \\ c_{j2} \\ \vdots \\ c_{jm_j} \\ \vdots \end{array} \\ \vdots & \\ D_n & \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array} \end{array} & \begin{bmatrix} W^{11} & \cdots & W^{i1} & \cdots & W^{n1} \\ \vdots & & \vdots & & \vdots \\ W^{1j} & \cdots & W^{ij} & \cdots & W^{nj} \\ \vdots & & \vdots & & \vdots \\ W^{1n} & \cdots & W^{in} & \cdots & W^{nn} \end{bmatrix} \end{array}$$

DEMATEL-based ANP = DANP

DEMATEL based Analytic Network Process (DANP) (13/14)

➢ Step 8: Calculate the weighted supermatrix $\boldsymbol{W}^{\alpha}$.

$$\boldsymbol{W}^{\alpha}=\boldsymbol{T}_{D}^{\alpha}\boldsymbol{W}=\begin{bmatrix} t_{D}^{\alpha 11}\times\boldsymbol{W}^{11} & \cdots & t_{D}^{\alpha i1}\times\boldsymbol{W}^{i1} & \cdots & t_{D}^{\alpha n1}\times\boldsymbol{W}^{n1} \\ \vdots & & \vdots & & \vdots \\ t_{D}^{\alpha 1j}\times\boldsymbol{W}^{1j} & \cdots & t_{D}^{\alpha ij}\times\boldsymbol{W}^{ij} & \cdots & t_{D}^{\alpha nj}\times\boldsymbol{W}^{nj} \\ \vdots & & \vdots & & \vdots \\ t_{D}^{\alpha 1n}\times\boldsymbol{W}^{1n} & \cdots & t_{D}^{\alpha in}\times\boldsymbol{W}^{in} & \cdots & t_{D}^{\alpha nn}\times\boldsymbol{W}^{nn} \end{bmatrix}$$

DEMATEL-based ANP = DANP

DEMATEL based Analytic Network Process (DANP) (14/14)

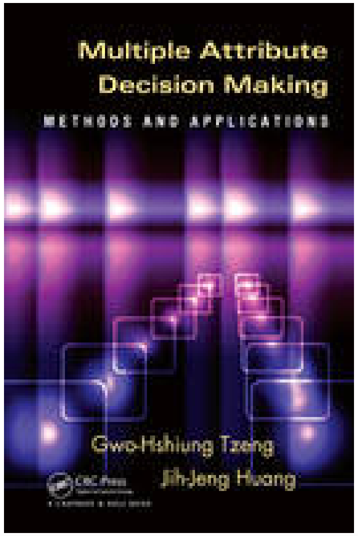
- Step 9: Limit the weighted super-matrix by raising it to a sufficiently large power *z*, as this equation, until the super-matrix has converged and become a long-term stable super-matrix to get the global priority influential vectors or called DANP influential weights.

$$\lim_{z\to\infty}(\boldsymbol{W}^{\alpha})^{z}$$

DEMATEL-based ANP = DANP

VIKOR mothod - Minimize average gaps for all dimensions/criteria and improve the maximal gaps for priority improvement based on influential network relation map

New Methods



VIKOR method (1)

- The rating performance scores are normalised by the best value and the worst value; for example, the scale **performance scores from 0** (**the worst value**, $f_j^- = 0$) **to 10** (**the best value**, called **the aspiration level**, $f_j^* = 10$), and the scores of the criterion are denoted by f_{kj} **for an alternative as gap . The new VIKOR is more appropriate to the analysis of real-world situations. T**hese models can be used to resolve other real business questions.

VIKOR method (2)

Development of the VIKOR method began with the following form of L_p-metric:

$$L_k^p = \left\{ \sum_{j=1}^{n} [w_j(\left|f_j^* - f_{kj}\right|)/(\left|f_j^* - f_j^-\right|)]^p \right\}^{1/p}$$

where $1 \le p \le \infty; k = 1, 2, \ldots, m$ and influential weight w_j is derived from the DANP. To formulate the ranking and gap measure $L_k^{p=1}$ (as S_k) and $L_k^{p=\infty}$(as Q_k**)** are used by VIKOR method (Tzeng et al., 2002, 2005; Opricovic and Tzeng, 2002, 2004, 2007).

$$S_k = L_k^{p=1} = \sum_{j=1}^{n} [w_j(|\, f_j^* - f_{kj} \,|)/(|\, f_j^* - f_j^- \,|)]$$

$$Q_k = L_k^{p=\infty} = \max_j \left\{ (|\, f_j^* - f_{kj} \,|)/(|\, f_j^* - f_j^- \,|) \,\middle|\, j = 1, 2, \ldots, n \right\}$$

VIKOR method (3)

- The new VIKOR method consists of the following:
- **Step 1: Finding the normalised gap.**

$$r_{kj} = (|f_j^* - f_{kj}|)/(|f_j^* - f_j^-|)$$

- **Step 2: Computing the gap for minimal and the maximal gap for priority improvement.**

$$S_k = L_k^{p=1} = \sum_{j=1}^{n} w_j \times r_{kj}, \qquad \forall k$$

$$Q_k = L_k^{p=\infty} = \max_j \{r_{kj} | j = 1,2,\ldots,n\}, \qquad \forall k$$

VIKOR method (4)

Step 3: Obtaining the comprehensive indicator

Based on the above concepts, the comprehensive indicator of the compromise VIKOR can be written as follow.

$R_k = v(S_k - S^*)/(S^- - S^*) + (1-v)(Q_k - Q^*)/(Q^- - Q^*)$

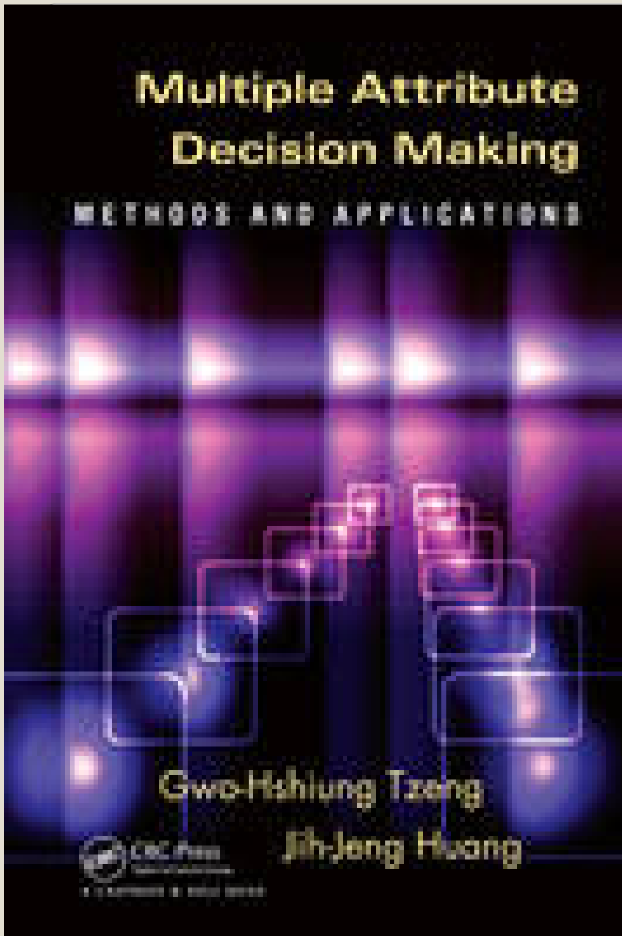
$$R_k = v(S_k - S^*)/(S^- - S^*) + (1-v)(Q_k - Q^*)/(Q^- - Q^*)$$

Then, based on the concept above, the best situation, when $S^* = 0$ and $S^- = 1$, and the worst situation, when $Q^* = 0$ and $Q^- = 1$, can be rewritten as follow:

$$R_k = vS_k + (1-v)Q_k$$

VIKOR method (5)

This research seeks to combine the influential weights of the DANP with the VIKOR method to determine how to minimise the average gap (or regret) and prioritise improvement in the maximum gap overall and in each dimension based on the INRM by the DEMATEL technique. Thus, this study focuses on how to improve and reduce the performance gaps to achieve the aspiration level based on INRM. Please ensure that the intended meaning has been maintained in this edit.



Fuzzy Integral

Hybrid MADM Model
Non-additive / Super-additive
Based concept from Kahneman in 1969S
[Kahneman, 2002 Novel Prize, from experiment]
Kahneman-Tversky (prospect theory)
Von Neumann-Morgeustern (Expected utility model
Fishburn (bilateral independence)
Keeney (Utility independence)
Tzeng (New hybrid MCDM field for Tomorrow)

Fuzzy Integral (1)

- Multiple attribute decision making (MADM) involves
  - Determining the optimal alternative among multiple, conflicting, and interactive criteria (Chen and Hwang, 1992).
- Many methods, which are based on multiple attribute utility theory (MAUT), have been proposed to deal with the MCDM problems
  - E.g. the weighted sum and the weighted product methods

Fuzzy Integral (2)

- The concept of MAUT
  - To aggregate all criteria to a specific uni-dimension (called utility function) to evaluate alternatives.
- Therefore, the main issue of MAUT
  - To find a rational and suitable aggregation operator (fusion operator) which can represent the preferences of the decision-maker.

Fuzzy Integral (3)

- Although many papers have been proposed to discuss the aggregation operator of MAUT (Fishburn, 1970), the main problem of MAUT
  - The assumption of preferential independence (Hillier, 2001; Grabisch, 1995); but in real world, it is a non-additive/super-additive MAUT problem.

[Kahneman, 2002 Novel Proze, from his experiment, he also found "it is a non-additive/super-additive MAUT problem" in 1960S] Von Neumann-Morgeustern

Fuzzy Integral (4)

- Preferential independence can be described as the preference outcome of one criterion over another criterion is not influenced by the remaining criteria.
- However, the criteria are usually interactive in the practical MCDM problems.
- In order to overcome this non-additive problem, the Choquet integral was proposed (Choquet, 1953; Sugeno, 1974).

Fuzzy Integral (5)

- The Choquet integral can represent a certain kind of interaction among criteria using the concept of redundancy and support/synergy.

Fuzzy Integral (6)

- In 1974, Sugeno introduced the concept of fuzzy measure and fuzzy integral
  - Generalizing the usual definition of a measure by
    - Replacing the usual additive property with a weaker requirement
      - I.e. the monotonicity property with respect to set inclusion.

Fuzzy Integral (7)

Definition 3.2.1: Let X be a measurable set that is endowed with pro $\aleph \to [0,1]$ perties of σ-algebra, where $\aleph$ is all subsets of X. A fuzzy measure g defined on the measurable space $(X, \aleph)$ is a set function g: , which satisfies the following properties: (1) $g(\varnothing) = 0, g(X) = 1$; (2) for all $A, B \in \aleph$, if $A \subseteq B$ then $g(A) \leq g(B)$ (monotonicity).

Fuzzy Integral (8)

As in the above definition, $(X, \aleph, g)$ is said to be a fuzzy measure space. Furthermore, as a consequence of the monotonicity condition, we can obtain: $g(A \cup B) \geq \max\{g(A), g(B)\}$, and $g(A \cap B) \leq \min\{g(A), g(B)\}$.

In the case where $g(A \cup B) = \max\{g(A), g(B)\}$, the set function g is called a possibility measure (Zadeh 1978), and if $g(A \cap B) = \min\{g(A), g(B)\}$, g is called a necessity measure.

Fuzzy Integral (9)

Definition 3.2.2: Let $h = \sum_{i=1}^{n} a_i \cdot 1_{A_i}$ be a simple function, where 1_{A_i} is the characteristic function of the set $A_i \in \aleph, i = 1, \cdots, n$; the sets A_i are pairwise disjoint, and $M(A_i)$ is the measure of A_i. Then the Lebesque integral of h is

$$\int h \cdot dM = \sum_{i=1}^{n} M(A_i) \cdot a_i \ .$$

Fuzzy Integral (10)

Definition 3.3.3 Let $(X, \aleph, g)$ be a fuzzy measure space. The Sugeno integral of a fuzzy measure $g : \aleph \to [0,1]$ with respect to a simple function h is defined by $\int h(x) \circ g(x) =$

$\bigvee_{i=1}^{n} (h(x_{(i)}) \wedge g(A_{(i)})) = \max_{i} \min \left\{ a_i^{'}, g(A_i^{'}) \right\}$, where

$h(x_{(i)})$ is a linear combination of a characteristic function $1_{A_i^{'}}$ such that $A_1 \subset A_2 \subset \cdots \subset A_n$,and

$A_i^{'} = \{ x \mid h(x) \geq a_i^{'} \}$.

Fuzzy Integral (11)

Definition 3.3.4 Let $(X, \aleph, g)$ be a fuzzy measure space. The Choquet integral of a fuzzy measure $g: \aleph \to [0,1]$ with respect to a simple function h is defined by $\int h(x) \cdot dg \cong \sum_{i=1}^{n} \left[h(x_i) - h(x_{i-1}) \right] \cdot g(A_i)$, with the same notions as above, and $h(x_{(0)}) = 0$.

Fuzzy Integral (12)

Let g be a fuzzy measure which is defined on a power set P(x) and satisfies the definition 3.3.1 as above. The following characteristic is evidently,

$$\forall A, B \in P(X), A \cap B = \phi \;\Rightarrow\; g_\lambda(A \cup B) =$$

$$g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B)$$, for $-1 \leq \lambda \leq \infty$.

Fuzzy Integral (13)

Set $X = \{x_1, x_2, \cdots, x_n\}$, the density of fuzzy measure $g_i = g_\lambda(\{x_i\})$ can be formulated as follows: $g_\lambda(\{x_1, x_2, \cdots, x_n\}) = \sum_{i=1}^{n} g_i + \lambda \sum_{i_1=1}^{n-1} \sum_{i_2=i_1+1}^{n} g_{i_1} \cdot g_{i_2} +$

$\cdots + \lambda^{n-1} \cdot g_1 \cdot g_2 \cdots g_n = \frac{1}{\lambda}\left| \prod_{i=1}^{n} (1 + \lambda \cdot g_i) - 1 \right|$, for

$-1 \le \lambda \le \infty$.

Fuzzy Integral (14)

Let h is a measurable set function defined on the fuzzy measurable space $(X, \aleph)$, suppose that $h(x_1) \geq h(x_2) \geq \cdots \geq h(x_n)$, then the fuzzy integral of fuzzy measure $g(\cdot)$ with respect to $h(\cdot)$ can be defined as follows (Ishii & Sugeno, 1985; see Fig. 1).

Fuzzy Integral (15)

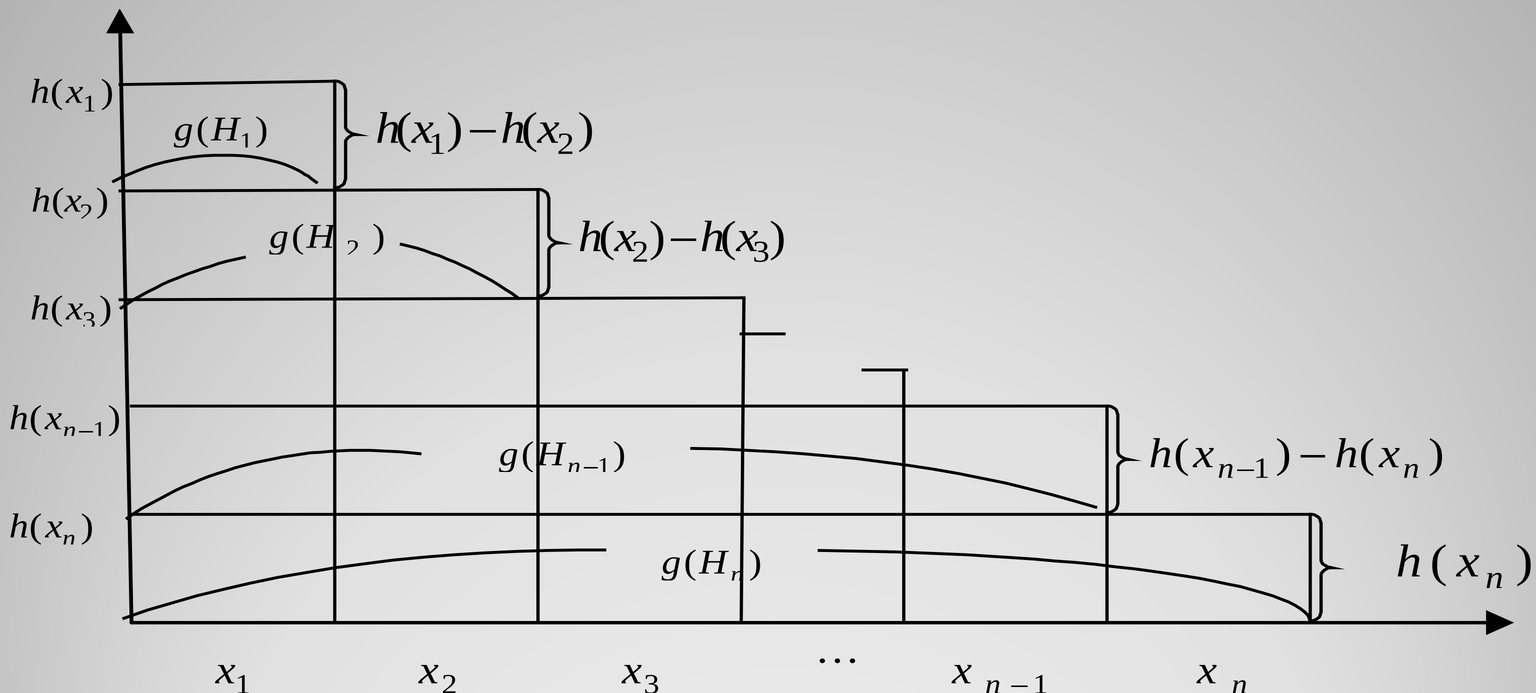


Figure 1 The concept of the Choquet integral

Fuzzy Integral (16)

$\int h \cdot dg = h(x_n) \cdot g(H_n) + [h(x_{n-1}) - h(x_n)] \cdot g(H_{n-1}) +$

$\cdots + [h(x_1) - h(x_2)] \cdot g(H_1) = h(x_n) \cdot$

$[g(H_n) - g(H_{n-1})] + h(x_{n-1}) \cdot [g(H_{n-1}) - g(H_{n-2})] +$

$\cdots + h(x_1) \cdot g(H_1)$, where $H_1 = \{x_1\}$, $H_2 = \{x_1, x_2\}$,

$\cdots$, $H_n = \{x_1, x_2, \cdots, x_n\} = X$. In addition, if $\lambda = 0$

and $g_1 = g_2 = \cdots = g_n$ then $h(x_1) \geq h(x_2) \geq$

$\cdots \geq h(x_n)$ is not necessary.

Fuzzy Measure with Variable Additivity Degree (1)

- A fuzzy measure with variable degree of additivity is proposed to overcome the above mentioned problems

Empirical case

Evaluating mobile learning adoption in higher education based on new hybrid MCDM models

In real case
For solving real problems

An empirical case-mobile learning adoption in higher education of Taiwan

- This section presents an empirical case involving Taiwan to emulating mobile learning adoption in higher education based on a new hybrid MCDM model.

Basic concept

- This study investigated the mobile learning adoption of evaluation in higher education. Mobile learning is a new form of learning utilizing the unique of mobile devices. However, students' readiness for mobile learning has yet to fully explore in Taiwan.

Introduction

This study contributes in higher education in three ways.

- First, the adoption of mobile learning is explored from a multi-faceted perspective including: **(1) attitude-related behaviours to mobile learning**, **(2) perceived behavioural control**, **and (3) trust-related behaviours**. This implies that university practitioners should consider these three factors before **employing m-learning**.
- Second, the current study shows the relative importance **of perceived behaviour control** (i.e**., perceptions of internal and external constraints on behaviour)** (Taylor and Todd, 1995) in the decision to adopt mobile learning.
- Lastly, the current findings reveal that **usefulness and ease of use affect students' attitude for adopting mobile learning**. Thus, to facilitate the acceptance of mobile learning, the learning environment should be perceived as useful and easy to use.

Purpose

- The purpose of the present study is to address these issues; we develop a new hybrid MADM model that combines DEMATEL, DANP (DEMATEL-based ANP), and VIKOR.
- The new hybrid method overcome the limitations of existing decision models and can be used to help us analyze the criteria that influence mobile learning issue (relieve and relax some unrealistic assumptions or hypotheses in the real world).
- In particular, we use Taiwan’s college students as an example to study the interdependence among the factors that influence the user behavior of mobile learning in the higher education as well as evaluate alternative user behavior processes to achieve the aspired levels of performance from mobile learning.

Framework of dimensions and criteria

Dimensions	Criteria
Attitude-related behaviours D_1	Relative advantage C_1
	Compatibility C_2
	Complexity C_3
Perceived behavioural control D_2	Self-efficacy C_4
	Resource facilitating conditions C_5
	Technology facilitating conditions C_6
Trust-related behaviours D_3	Disposition to trust C_7
	Structural assurance C_8
	Trust belief C_9

Data Collection

- The data was collected from 32 education experts who understand mobile learning trend and usage (in consensus, significant confidence is 96.375%, more than 95%; i.e., gap error =3.265%, smaller less 5%).
- Most of the education experts have teaches more than ten years in higher education.
- Expert perspectives on all criteria within the criteria were collected via personal interviews and a questionnaire.
- Expert elicitation was conducted in Nov., 2012, and it took 60 to70 minutes for each subject to complete a survey.

DEMATEL

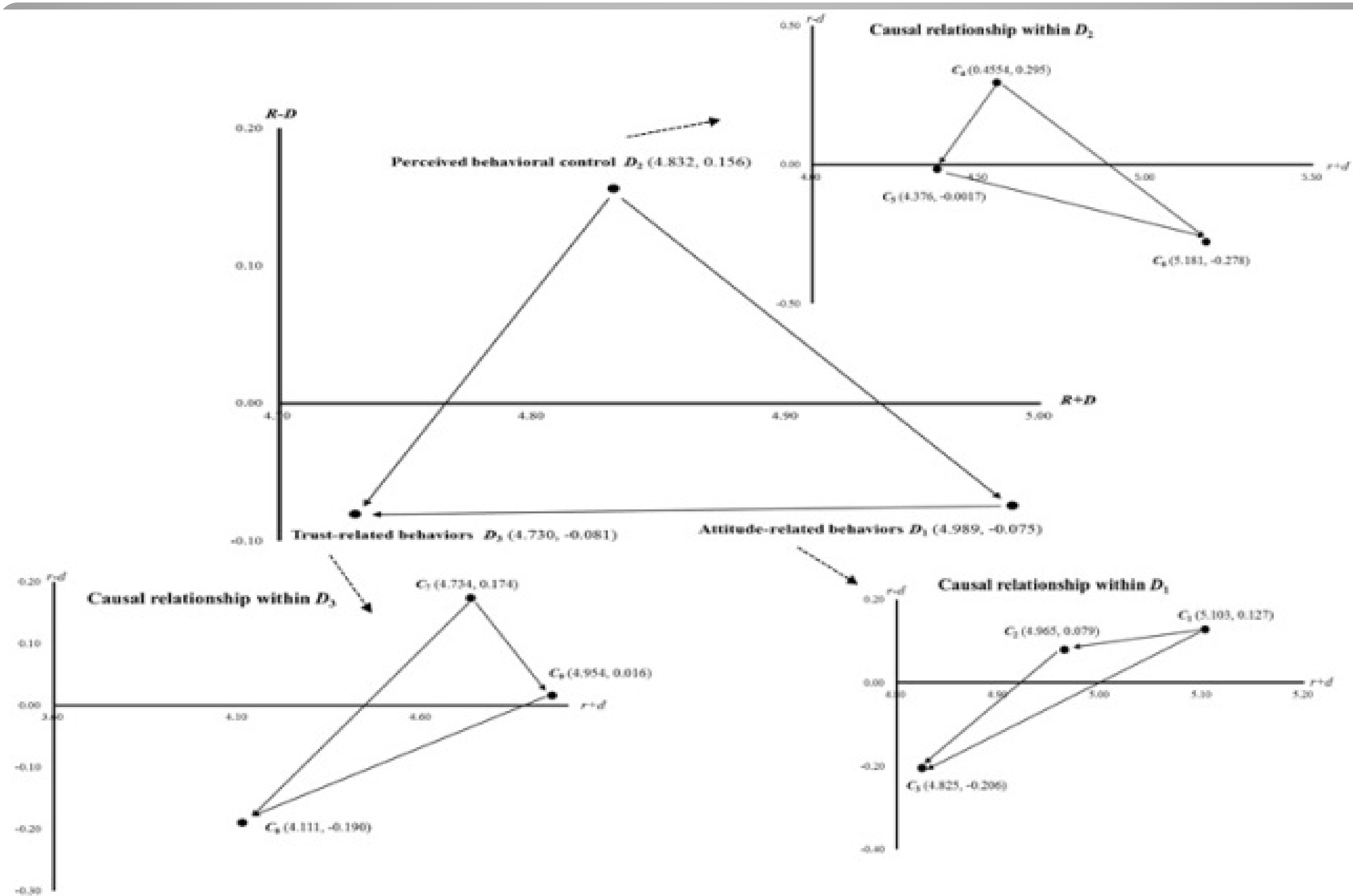
- This study obtained the total influential matrix ***T*** of the dimensions, as shown in Table 1.

D	D_1	D_2	D_3	d_i	s_i	$d_{i+}s_i$	$d_{i-}s_i$
D_1	0.827	0.813	0.817	2.457	2.532	**4.989**	**-0.075**
D_2	0.888	0.784	0.822	2.494	2.338	**4.832**	**0.156**
D_3	**0.817**	**0.741**	**0.767**	**2.325**	**2.406**	**4.730**	**-0.081**

DEMATEL

- This study obtained the total influential matrix ***T*** of the criteria, as shown below.

Dimensions/ Criteria	r_i	d_i	$r_i + d_i$	$r_i - d_i$	Degree of importance (Global weights)	Ranking
Attitude-related behaviors (D_1)					**0.348**	**1**
Relative advantage (C_1)	2.522	2.443	4.965	0.079	0.115	5
Compatibility (C_2)	2.615	2.488	5.103	0.127	0.118	3
Complexity (C_3)	2.310	2.515	4.825	-0.206	0.116	4
Perceived behavioral control (D_2)					**0.322**	**3**
Self-efficacy (C_4)	2.425	2.129	4.554	0.295	0.097	9
Resource facilitating conditions (C_5)	2.179	2.196	4.376	-0.017	0.100	8
Technology facilitating conditions (C_6)	2.451	2.729	5.181	-0.278	0.125	1
Trust-related behaviors (D_3)					**0.331**	**2**
Disposition to trust (C_7)	2.454	2.280	4.734	0.174	0.109	6
Structural assurance (C_8)	1.961	2.150	4.111	-0.190	0.102	7
Trust belief (C_9)	2.485	2.469	4.954	0.016	0.119	2


Causal relationship within D_2
C_4 (0.4554, 0.295)
C_5 (4.376, -0.0017)
C_6 (5.181, -0.278)
R-D
R+D
Perceived behavioral control D_2 (4.832, 0.156)
Trust-related behaviors D_3 (4.730, -0.081)
Attitude-related behaviors D_1 (4.989, -0.075)
Causal relationship within D_3
C_7 (4.734, 0.174)
C_9 (4.954, 0.016)
C_8 (4.111, -0.190)
Causal relationship within D_1
C_1 (5.103, 0.127)
C_2 (4.965, 0.079)
C_3 (4.825, -0.206)

The gap evaluation of mobile learning by DANP & VIKOR

D/C	Local Weight	Global weight (DANP)	Mobile learning gap (r_{kj})
D_1	**0.348**		**0.197**
C_1	0.329	0.115	0.113
C_2	0.339	0.118	0.213
C_3	0.332	0.116	0.266
D_2	**0.322**		**0.296**
C_4	0.300	0.097	0.228
C_5	0.310	0.100	0.366
C_6	0.389	0.125	0.294
D_3	**0.331**		**0.295**
C_7	0.331	0.109	0.266
C_8	0.310	0.102	0.338
C_9	0.359	0.119	0.284
	Total gaps		**0.261**

Sequence of improvement priority for mobile learning user behaviour

Formula	Sequence of improvement priority
F1:Influential network of dimensions	$(D_2),(D_1),(D_3)$ (D_1): $(C_1),(C_2),(C_3)$ (D_2): $(C_4),(C_5),(C_6)$
F2:Influential network of criteria within individual dimensions	$(D_3),(D_2),(D_1)$
F3:Sequence of dimension to rise to aspired/desired level (by gap value, from high to low)	(D_1): $(C_3),(C_2),(C_1)$ (D_2): $(C_5),(C_6),(C_4)$ (D_3): $(C_7),(C_9),(C_8)$
F1:Influential network of dimensions	$(D_2),(D_1),(D_3)$ (D_1): $(C_1),(C_2),(C_3)$ (D_2): $(C_4),(C_5),(C_6)$

Conclusions

- Mobile learning service has an important role in the training of higher education. Its decisions are complicated by the fact that various criteria are uncertainty and may vary across the different product categories and use situations.
- Based on the export and literature review, we developed the three dimensions and 9 criteria that align with the mobile learning service of environment.
- The main reason is among the numerous approaches that are available for conflict management, hybrid MCDM is one of the most prevalent. VIKOR is a method within MCDM; it is based on an aggregating function representing closeness to the ideal (aspiration level), which can be viewed as a derivative of compromise programming for avoiding “choose the best among inferior alternatives (i.e., pick the best apple among a barrel of rotten apples)”.

Empirical case

A New Hybrid MADM Model for Problems-Improvement

In real case

For solving real problems

An empirical case-TDC of Taiwan

- This section presents an empirical case involving Taiwan to explore strategies for improving tourism destination competiveness (TDC) based on a new hybrid MCDM model.

Background

(why this topic is the most significant issues?)

- Tourism industry should be considered as a key contributor to Taiwan’s overall economic growth.
- World Economic Forum (2009) presented the world Travel & Tourism Competitiveness Index, on which Taiwan ranked 9th in the Asia Pacific and 43th in the world.
- However, few studies have focused on exploring strategies for improving TDC in Taiwan.

Research Purposes

- Exploring strategies for improving tourism destination competitiveness (TDC) in Taiwan based on a new hybrid MCDM model.

Data collection

- A list of dimensions/criteria that can enhance TDC was gathered based on a tourism competitiveness report from World Economic Forum in 2009.
  - **Regulatory framework(D_1)**
    - policy rules and regulations(C_1), environmental sustainability(C_2), safety and security(C_3), health and hygiene(C_4), prioritization of Travel & Tourism(C_5)
  - **Business environment and infrastructure(D_2)**
    - air transport infrastructure(C_6), ground transport infrastructure(C_7), tourism infrastructure(C_8), Information and Communication Technology (ICT) infrastructure(C_9), price competitiveness(C_{10})
  - **Human, cultural, and natural resources(D_3)**
    - human resources(C_{11}), affinity for Travel & Tourism(C_{12}), natural resources(C_{13}), cultural resources(C_{14}).

Data collection

- This study used a four-point scale ranging from 0 (no influence) to 4 (very high influence) to identify the criteria and their influence on one another.
  - **The experts had backgrounds in travel and tourism fields (national and private universities in Taiwan).**
  - **Fifteen experts-the consensus rates of the dimensions and criteria were 96.89% and 96.71% (both exceeding 96% in confidence).**
- This study gathered secondary data on competitiveness score of dimensions and criteria from the tourism competitiveness report published in 2009.

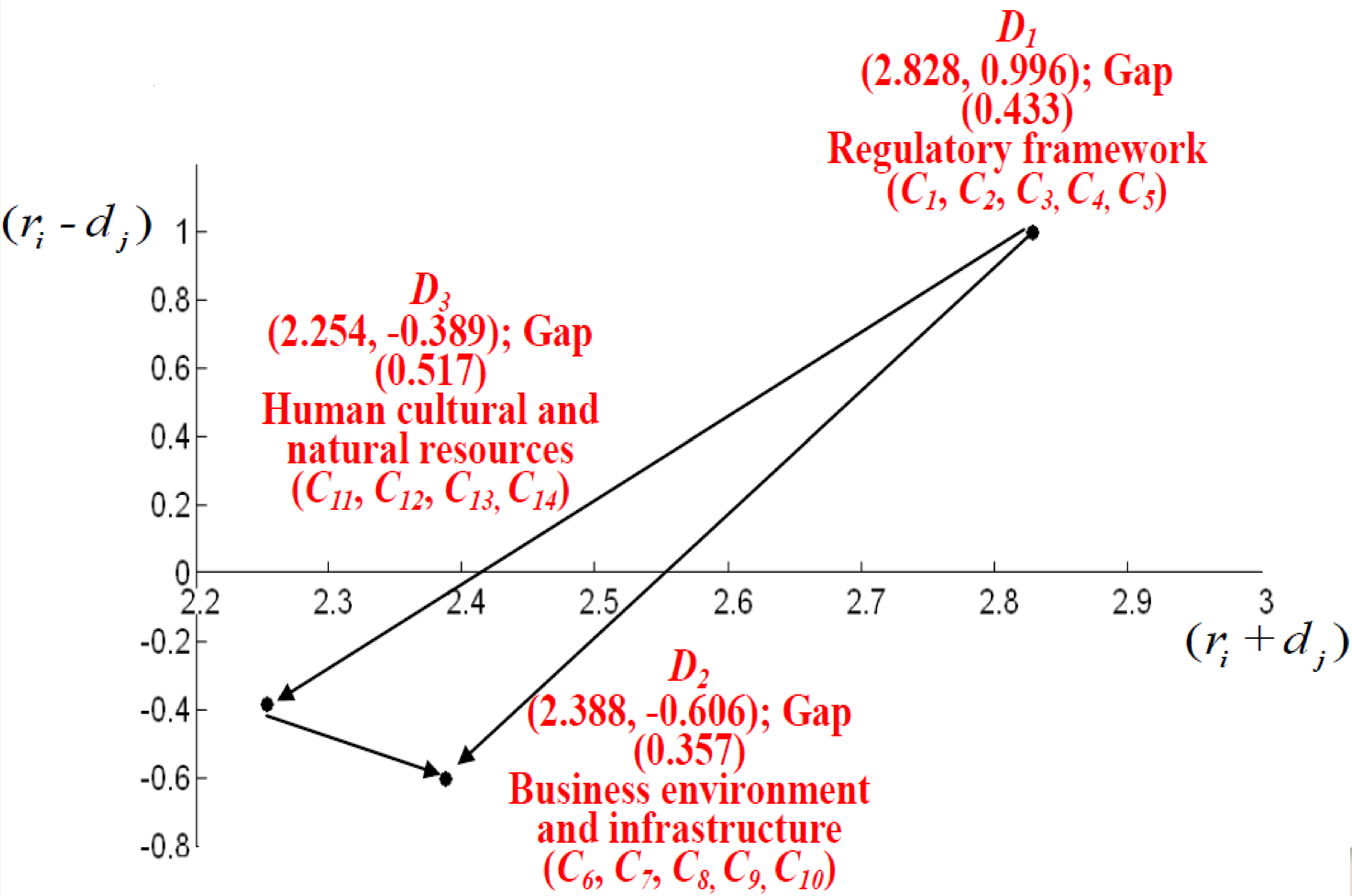
DEMATEL

- This study obtained the total influential matrix T of the dimensions, as shown in Table 1.

Table 1. Total influential matrix of T and the sum of the effects on the dimensions

Dimensions	D_1	D_2	D_3	r_i	d_i	r_i+d_i	r_i-d_i
D_1 Regulatory framework	0.305	0.825	0.782	1.912	0.916	2.828	0.996
D_2 Business environment and infrastructure	0.321	0.237	0.332	0.891	1.497	2.388	-0.606
D_3 Human cultural and natural resources	0.290	0.435	0.208	0.932	1.322	2.254	-0.389

DEMATEL



D_1
(2.828, 0.996); Gap (0.433)
Regulatory framework
(C_1, C_2, C_3, C_4, C_5)
D_3
(2.254, -0.389); Gap (0.517)
Human cultural and natural resources
(C_{11}, C_{12}, C_{13}, C_{14})
D_2
(2.388, -0.606); Gap (0.357)
Business environment and infrastructure
(C_6, C_7, C_8, C_9, C_{10})
$(r_i - d_j)$
$(r_i + d_j)$
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

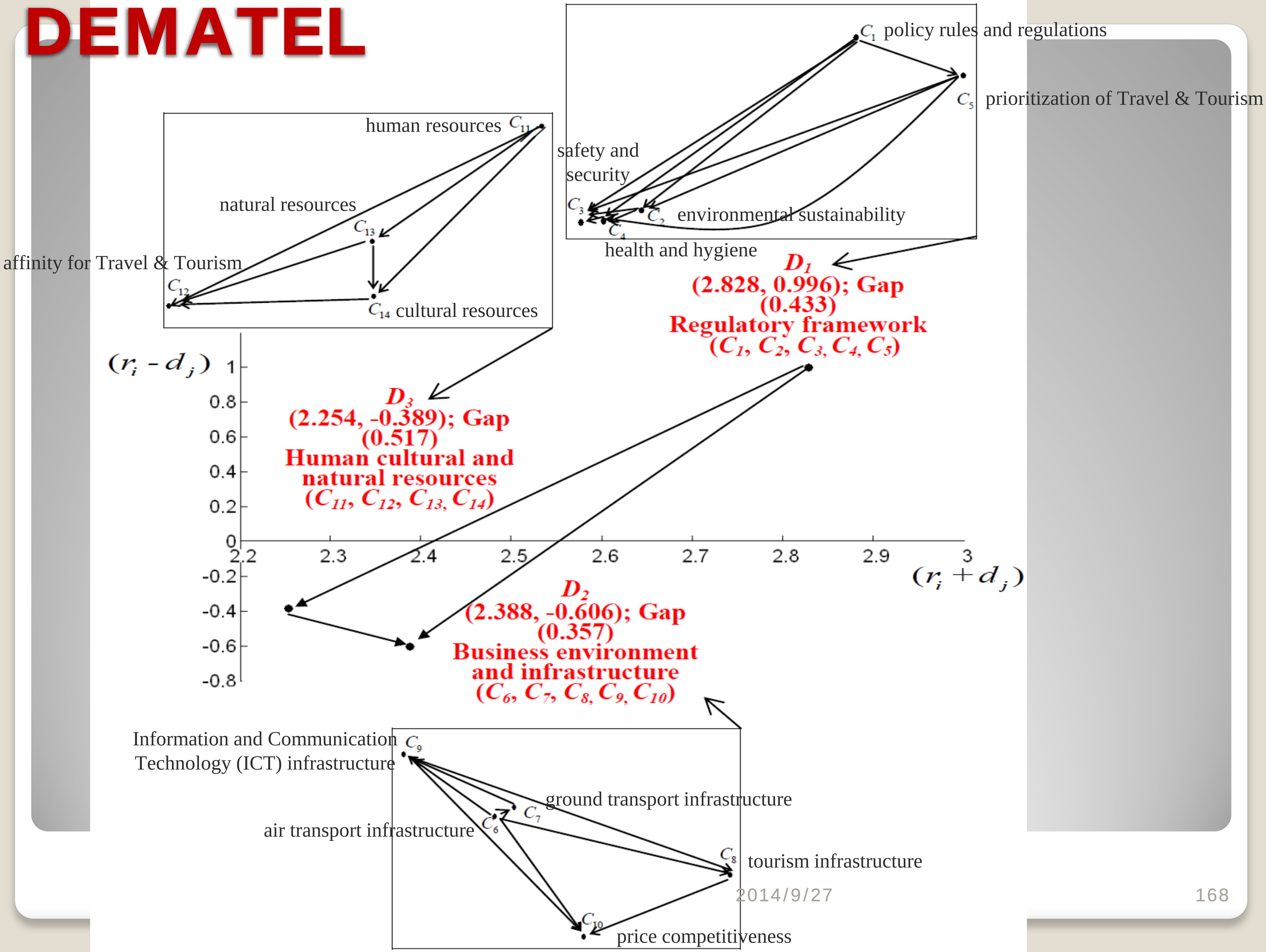
DEMATEL

- This study obtained the total influential matrix *T* of the criteria, as shown in Table 2.

Table 2. The sum of the effects, weights and rankings of each criterion

Criteria	r_i	d_j	$r_i + d_j$	$r_i - d_j$	Degree of importance (Global weight)	Ranking
D_1					0.2866	3
C_1	1.750	0.882	2.633	0.868	0.0544	3
C_2	0.865	0.933	1.798	-0.068	0.0546	2
C_3	0.716	0.846	1.562	-0.131	0.0500	5
C_4	0.764	0.886	1.651	-0.122	0.0537	4
C_5	1.857	1.192	3.048	0.665	0.0739	1
D_2					0.3803	1
C_6	0.726	0.935	1.661	-0.209	0.0744	3
C_7	0.735	0.936	1.670	-0.201	0.0739	4
C_8	0.754	1.020	1.774	-0.266	0.0809	1
C_9	0.734	0.884	1.618	-0.150	0.0717	5
C_{10}	0.690	1.014	1.704	-0.325	0.0794	2
D_3					0.3332	2
C_{11}	1.103	0.778	1.881	0.325	0.0769	4
C_{12}	0.729	0.930	1.659	-0.202	0.0837	3
C_{13}	0.884	0.896	1.780	-0.013	0.0841	2
C_{14}	0.803	0.977	1.781	-0.174	0.0885	1

DEMATEL



C_1 policy rules and regulations
C_5 prioritization of Travel & Tourism
safety and security
C_3
C_2 environmental sustainability
C_4
health and hygiene
human resources C_{11}
natural resources
C_{13}
affinity for Travel & Tourism
C_{12}
C_{14} cultural resources
D_1
(2.828, 0.996); Gap (0.433)
Regulatory framework
(C_1, C_2, C_3, C_4, C_5)
$(r_i - d_j)$
D_3
(2.254, -0.389); Gap (0.517)
Human cultural and natural resources
(C_{11}, C_{12}, C_{13}, C_{14})
$(r_i + d_j)$
D_2
(2.388, -0.606); Gap (0.357)
Business environment and infrastructure
(C_6, C_7, C_8, C_9, C_{10})
Information and Communication Technology (ICT) infrastructure
C_9
ground transport infrastructure
C_7
air transport infrastructure
C_6
C_8 tourism infrastructure
C_{10}
price competitiveness

DANP

- This study builds the assessment model using DEMATEL, which is combined with the DANP (DEMATEL-based ANP) model to obtain the influential weights of each criterion, as shown in Table 2.

Table 2. The sum of the effects, weights and rankings of each criterion

Criteria	r_i	d_j	$r_i + d_j$	$r_i - d_j$	Degree of importance (Global weight)	Ranking
D_1					0.2866	3
C_1	1.750	0.882	2.633	0.868	0.0544	3
C_2	0.865	0.933	1.798	-0.068	0.0546	2
C_3	0.716	0.846	1.562	-0.131	0.0500	5
C_4	0.764	0.886	1.651	-0.122	0.0537	4
C_5	1.857	1.192	3.048	0.665	0.0739	1
D_2					0.3803	1
C_6	0.726	0.935	1.661	-0.209	0.0744	3
C_7	0.735	0.936	1.670	-0.201	0.0739	4
C_8	0.754	1.020	1.774	-0.266	0.0809	1
C_9	0.734	0.884	1.618	-0.150	0.0717	5
C_{10}	0.690	1.014	1.704	-0.325	0.0794	2
D_3					0.3332	2
C_{11}	1.103	0.778	1.881	0.325	0.0769	4
C_{12}	0.729	0.930	1.659	-0.202	0.0837	3
C_{13}	0.884	0.896	1.780	-0.013	0.0841	2
C_{14}	0.803	0.977	1.781	-0.174	0.0885	1

VIKOR

- A real case involving Taiwan is used to assess the total competitiveness using the VIKOR method, as listed in Table 3.
- The scores of each criterion and the total average gap (S_k) of Taiwan are obtained, using the relative influential weights from DANP to multiply the gap(r_{kj}).

Table 3. The performance evaluation of the case study by VIKOR

Dimensions / Criteria	Local weight	Global weight (by DANP)	Case study of Taiwan	
			Score	Gap (r_{kj})
D_1	**0.2866(3)**		**4.40**	**0.433**
C_1	0.1898	0.0544(3)	4.80	0.367
C_2	0.1905	0.0546(2)	4.20	0.467
C_3	0.1745	0.0500(5)	5.50	0.250
C_4	0.1874	0.0537(4)	3.30	0.617
C_5	0.2579	0.0739(1)	4.20	0.467
D_2	**0.3803(1)**		**4.90**	**0.357**
C_6	0.1956	0.0744(3)	3.80	0.533
C_7	0.1943	0.0739(4)	5.70	0.217
C_8	0.2127	0.0809(1)	4.40	0.433
C_9	0.1885	0.0717(5)	5.30	0.283
C_{10}	0.2088	0.0794(2)	5.10	0.317
D_3	**0.3332(2)**		**3.90**	**0.517**
C_{11}	0.2308	0.0769(4)	5.70	0.217
C_{12}	0.2512	0.0837(3)	4.60	0.400
C_{13}	0.2524	0.0841(2)	2.40	0.767
C_{14}	0.2656	0.0885(1)	2.90	0.683
Total performances			**4.40**	-
Total gap (S_k)			-	**0.437**

Discussions and implications

- Figure 4 shows valuable cues for making correct decisions.
- The influential relation map demonstrate that the degrees of influence among dimensions and criteria.
- This study applies the most important and influential criteria as critical criteria()to improve the maximal gap () of TDC.

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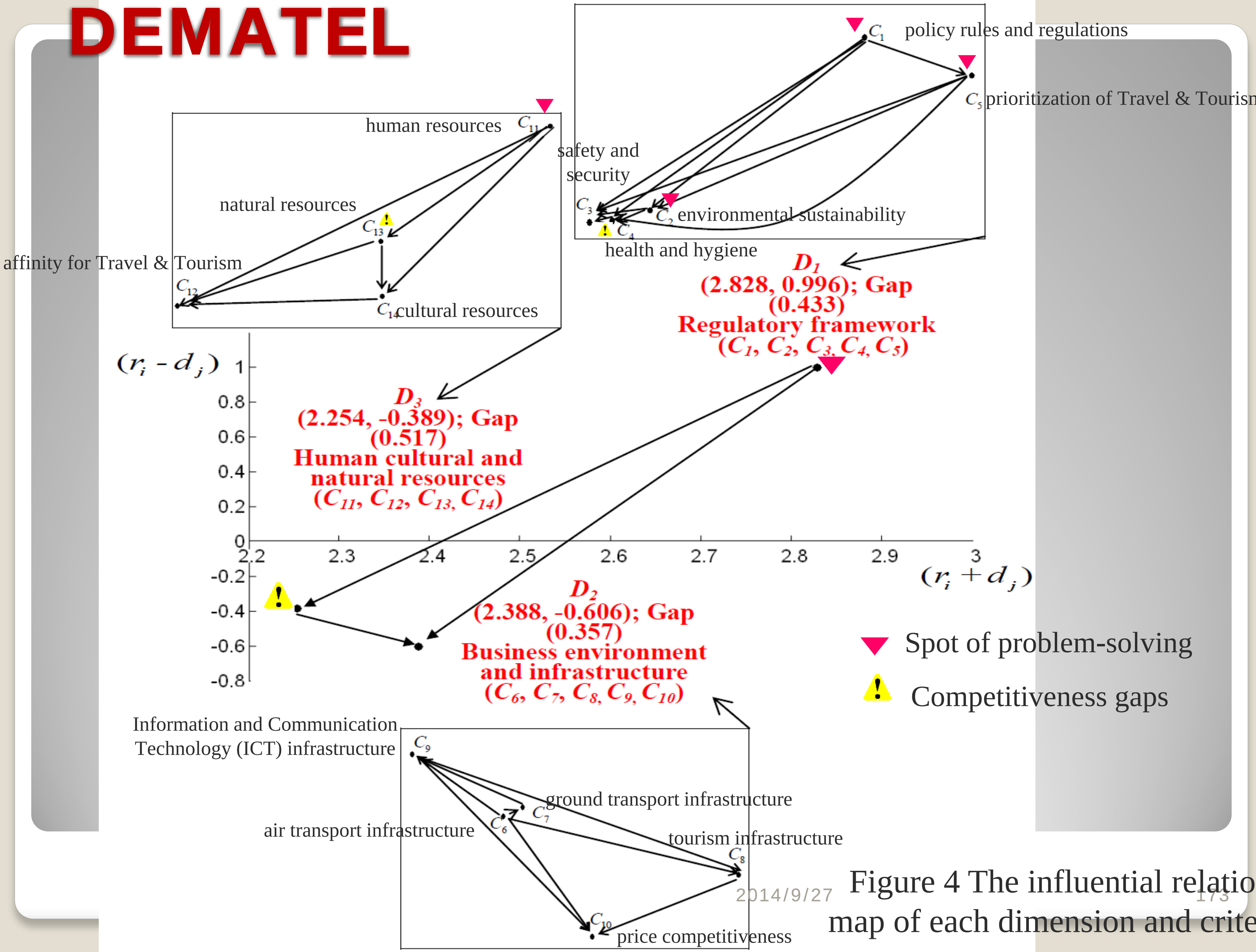


Figure 4 The influential relation map of each dimension and criteria

An empirical case- Conclusions

- This study can obtain valuable cues for making correct decisions to improve TDC.
- This study uses the DEMATEL to develop cause-and-effect influential relationships, calculates the weight using DANP and uses VIKOR method to evaluate competitiveness.
- The decision-maker should improve the cause criteria to successfully improve TDC to achieve the aspiration levels.

An empirical case-
Taiwanese company for supplier evaluation and improvement

- This section presents an empirical case involving Taiwanese company for supplier evaluation and improvement based on a novel fuzzy integral-based hybrid MCDM model that addresses the dependence/relationships among the various criteria and the non-additive gap-weighted analysis.

Data collection

- This discussion with the industry helped us to classify the various decision-making criteria into four dimensions (or called perspectives) and 11 criteria.
  - **Compatibility (D_1)**
    - Relationship(C_{11}), Flexibility(C_{12}), Information sharing (C_{13})
  - **Quality (D_2)**
    - Knowledge and skills(C_{21}), Customer satisfaction(C_{22}), On-time rate(C_{23})
  - **Cost (D_3)**
    - Cost saving(C_{31}), Flexibility in billing(C_{32})
  - **Risk (D_4)**
    - Labor union(C_{41}), Loss of management control(C_{42}), Information security(C_{43})

DEMATEL

- Following the DANP procedures, the managers were asked to determine the influence degrees of the relationships among the criteria.
- The sum of the influence given $(r_i - d_j)$ and received $(r_i + d_j)$ for each dimension and criterion (Table 7).

Table 7 Sum of influences given r_i and received d_j on dimensions and criteria

T^D	r_i	d_j	$r_i + d_j$	$r_i - d_j$	T^C	r_i	d_j	$r_i + d_j$	$r_i - d_j$
					C_{11}	3.73	3.61	7.34	0.12
D_1	1.21	1.18	2.39	0.04	C_{12}	3.12	3.02	6.14	0.09
					C_{13}	3.33	3.22	6.55	0.11
					C_{21}	2.43	2.11	4.54	0.33
D_2	0.78	0.89	1.67	-0.11	C_{22}	2.23	2.87	5.10	-0.65
					C_{23}	1.88	2.59	4.48	-0.71
					C_{31}	2.30	2.21	4.51	0.09
D_3	0.76	0.79	1.54	-0.03	C_{32}	1.89	2.17	4.07	-0.28
					C_{41}	3.09	2.76	5.85	0.34
D_4	1.11	1.00	2.12	0.11	C_{42}	3.68	2.96	6.64	0.72
					C_{43}	2.59	2.74	5.33	-0.16

DEMATEL

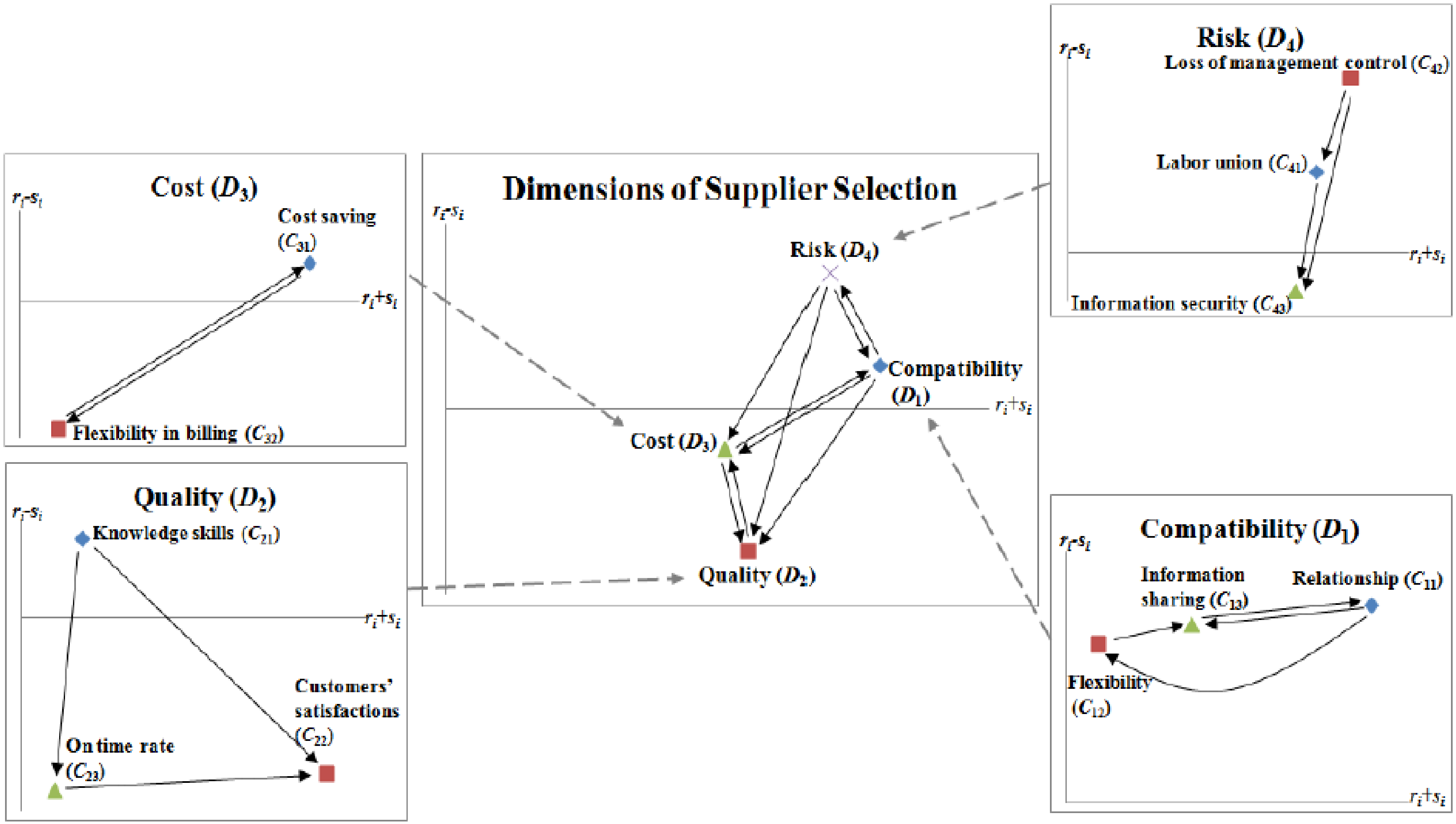


Figure 5 Influential network-relationship map within systems

DANP

- This study builds the assessment model using DEMATEL, which is combined with the DANP (DEMATEL-based ANP) model to obtain the influential weights of each criterion, as shown in Table 8.

Table 8 Influential weights of system factors

Dimensions	Local Weights	Rankings	Criteria	Local Weights	Rankings	Global Weights
			C_{11}	0.367	1	0.112
D_1	0.306	1	C_{12}	0.310	3	0.095
			C_{13}	0.324	2	0.099
			C_{21}	0.281	3	0.065
D_2	0.231	3	C_{22}	0.379	1	0.088
			C_{23}	0.340	2	0.079
D_3	0.204	4	C_{31}	0.506	1	0.103
			C_{32}	0.494	2	0.101
			C_{41}	0.327	2	0.085
D_4	0.259	2	C_{42}	0.351	1	0.091
			C_{43}	0.322	3	0.083

Fuzzy integrals

- This study first transform the performance values into the aspiration level gap values.
- Then, through the obtained global weights and gaps for each criterion and dimension, we synthesize the influential weights and gap values.
- In contrast to previous studies that only apply additive models (i.e., simple additive weight, VIKOR, TOPSIS, grey relation), we utilize fuzzy integrals to aggregate the weighted gaps.

Fuzzy integrals

- Through a questionnaire survey conducted by managers of the case company, the fuzzy integral λ values, which range from -1 to positive infinity , that represent the properties of substitutive or multiplicative between criteria are obtained.
- There are substitutive effects among attributes of risk and there is a multiplicative effect among compatibility, quality, and cost.
- The λ values and the fuzzy measures $g(\cdot)$ are shown in **Table 9**.

Table 9 Fuzzy measure $g(\lambda)$ of each parameter and parameter combination

Fuzzy Measure $g(\cdot)$			
Supplier Selection (evaluating systems) λ = -0.597, q = 1.358			
$g_\lambda(\{D_1\})$ = 0.415	$g_\lambda(\{D_1, D_2\})$ = 0.651	$g_\lambda(\{D_1, D_2, D_3\})$ = 0.821	$g_\lambda(\{D_1, D_2, D_3, D_4\})$ =1
$g_\lambda(\{D_2\})$ = 0.314	$g_\lambda(\{D_1, D_3\})$ = 0.624	$g_\lambda(\{D_1, D_2, D_4\})$ = 0.866	
$g_\lambda(\{D_3\})$ = 0.277	$g_\lambda(\{D_1, D_4\})$ = 0.680	$g_\lambda(\{D_1, D_3, D_4\})$ = 0.844	
$g_\lambda(\{D_4\})$ = 0.352	$g_\lambda(\{D_2, D_3\})$ = 0.539	$g_\lambda(\{D_2, D_3, D_4\})$ = 0.778	
	$g_\lambda(\{D_2, D_4\})$ = 0.600		
	$g_\lambda(\{D_3, D_4\})$ = 0.571		
Compatibility (D_1) λ = 0.358 , q = 0.900			
$g_\lambda(\{C_{11}\})$ = 0.330	$g_\lambda(\{C_{11}, C_{12}\})$ = 0.642	$g_\lambda(\{C_{11}, C_{12}, C_{13}\})$ = 1	
$g_\lambda(\{C_{12}\})$ = 0.279	$g_\lambda(\{C_{11}, C_{13}\})$ = 0.656		
Quality (D_2) λ = 3.902, q = 0.539			
$g_\lambda(\{C_{21}\})$ = 0.151	$g_\lambda(\{C_{21}, C_{22}\})$ = 0.476	$g_\lambda(\{C_{21}, C_{22}, C_{23}\})$ = 1	
$g_\lambda(\{C_{22}\})$ = 0.204	$g_\lambda(\{C_{21}, C_{23}\})$ = 0.443		
$g_\lambda(\{C_{23}\})$ = 0.183	$g_\lambda(\{C_{22}, C_{23}\})$ = 0.533		
Cost (D_3) λ = 1.268, q = 0.798			
$g_\lambda(\{C_{31}\})$ = 0.403	$g_\lambda(\{C_{31}, C_{32}\})$ = 1		
$g_\lambda(\{C_{33}\})$ = 0.395			
Risk (D_4) λ = -0.073, q = 1.025			
$g_\lambda(\{C_{41}\})$ = 0.336	$g_\lambda(\{C_{41}, C_{42}\})$ = 0.687	$g_\lambda(\{C_{41}, C_{42}, C_{43}\})$ = 1	
$g_\lambda(\{C_{42}\})$ = 0.360	$g_\lambda(\{C_{41}, C_{43}\})$ = 0.657		
$g_\lambda(\{C_{43}\})$ = 0.330	$g_\lambda(\{C_{42}, C_{43}\})$ = 0.681		

Fuzzy integrals

- Using the obtained $g(\cdot)$ and the original data (**Appendix**, **Table A**), we can obtain the gap-ratios $r_{kj} = (|f_j^* - f_{kj}|)/(|f_j^* - f_j^-|)$ for alternatives $k = 1,2,\ldots,m$, respective to each criterion (**Table 10)**.

Table 10 Gap ratio values of potential suppliers by SAW

Criteria	Weights (Global)	Weights (Local)	Alternative				
			A_1	A_2	A_3	A_4	A_5
Compatibility (D_1)		**0.306**	**0.241**	**0.198**	**0.197**	**0.183**	**0.264**
Relationship (C_{11})	0.112	0.367	0.264	0.208	0.199	0.198	0.268
Flexibility (C_{12})	0.095	0.310	0.214	0.211	0.198	0.176	0.264
Information sharing (C_{13})	0.099	0.324	0.242	0.175	0.194	0.173	0.258
Quality (D_2)		**0.231**	**0.290**	**0.231**	**0.236**	**0.236**	**0.221**
Knowledge skills (C_{21})	0.065	0.281	0.280	0.221	0.275	0.224	0.214
Customer satisfaction (C_{22})	0.088	0.379	0.286	0.255	0.227	0.265	0.203
On time rate (C_{23})	0.079	0.340	0.302	0.213	0.213	0.214	0.246
Cost (D_3)		**0.204**	**0.243**	**0.306**	**0.330**	**0.343**	**0.268**
Cost saving (C_{31})	0.103	0.506	0.246	0.333	0.313	0.324	0.267
Flexibility in billing (C_{32})	0.101	0.494	0.239	0.278	0.348	0.362	0.269
Risk (D_4)		**0.259**	**0.251**	**0.244**	**0.227**	**0.248**	**0.277**
Labor unions (C_{41})	0.085	0.327	0.257	0.292	0.214	0.219	0.275
Loss of management control (C_{42})	0.091	0.351	0.255	0.208	0.218	0.248	0.288
Information security (C_{43})	0.083	0.322	0.242	0.235	0.249	0.278	0.268
Total Gap (rank)			**0.255** (4)	**0.240** (1)	**0.241** (2)	**0.245** (3)	**0.258** (5)

Note: For example alternative A_1, D_1: $(0.264 \times 0.367) + (0.214 \times 0.310) + (0.242 \times 0.324) = 0.241$, and total gap ratio $= 0.241 \times 0.304 + 0.290 \times 0.231 + 0.243 \times 0.204 + 0.251 \times \; 0.259 = 0.225$ (additive); the original data are shown in the **Appendix**, Table A. The gap ratio is $r_{kj} = (|\, f_j^* - f_{kj} \,|) / (|\, f_j^* - f_j^- \,|)$ for alternatives $k = 1,2,\ldots,m$ and criteria j=1,2,…n.

Fuzzy integrals

- The integrated weighted gaps of each potential supplier are then calculated as shown in **Table 11**.

Table 11 Gap ratio values of potential suppliers by Fuzzy Integral

Criteria	Weights	Alternative				
	Local	A_1	A_2	A_3	A_4	A_5
Compatibility (D_1)	**0.306**	**0.240**	**0.179**	**0.197**	**0.182**	**0.263**
Relationship (C_{11})	0.367	0.264	0.208	0.199	0.198	0.268
Flexibility (C_{12})	0.310	0.214	0.211	0.198	0.176	0.264
Information sharing (C_{13})	0.324	0.242	0.175	0.194	0.173	0.258
Quality (D_2)	**0.231**	**0.286**	**0.224**	**0.227**	**0.227**	**0.214**
Knowledge skills (C_{21})	0.281	0.280	0.221	0.275	0.224	0.214
Customer satisfaction (C_{22})	0.379	0.286	0.255	0.227	0.265	0.203
On time rate (C_{23})	0.340	0.302	0.213	0.213	0.214	0.246
Cost (D_3)	**0.204**	**0.242**	**0.300**	**0.327**	**0.339**	**0.268**
Cost saving (C_{31})	0.506	0.246	0.333	0.313	0.324	0.267
Flexibility in billing (C_{32})	0.494	0.239	0.278	0.348	0.362	0.269
Risk (D_4)	**0.259**	**0.252**	**0.245**	**0.227**	**0.249**	**0.277**
Labor unions (C_{41})	0.327	0.257	0.292	0.214	0.219	0.275
Loss of management control (C_{42})	0.351	0.255	0.208	0.218	0.248	0.288
Information security (C_{43})	0.322	0.242	0.235	0.249	0.278	0.268
Total gap (rank)	-	**0.359** (3)	**0.350** (2)	**0.345** (1)	**0.361** (4)	**0.376** (5)

Note: For example Alternative A_1, D_1: (0.264-0.242) × 0.330)+(0.242-0.214) × 0.656)+(0.214 × 1)=0.240, total ratio gap: (0.286-0.252) × 0.314)+(0.252-0.242) × 0.600)+(0.242-0.240) × 0.778)+(0.240 × 1) = 0.359 (non-additive)

Fuzzy integrals

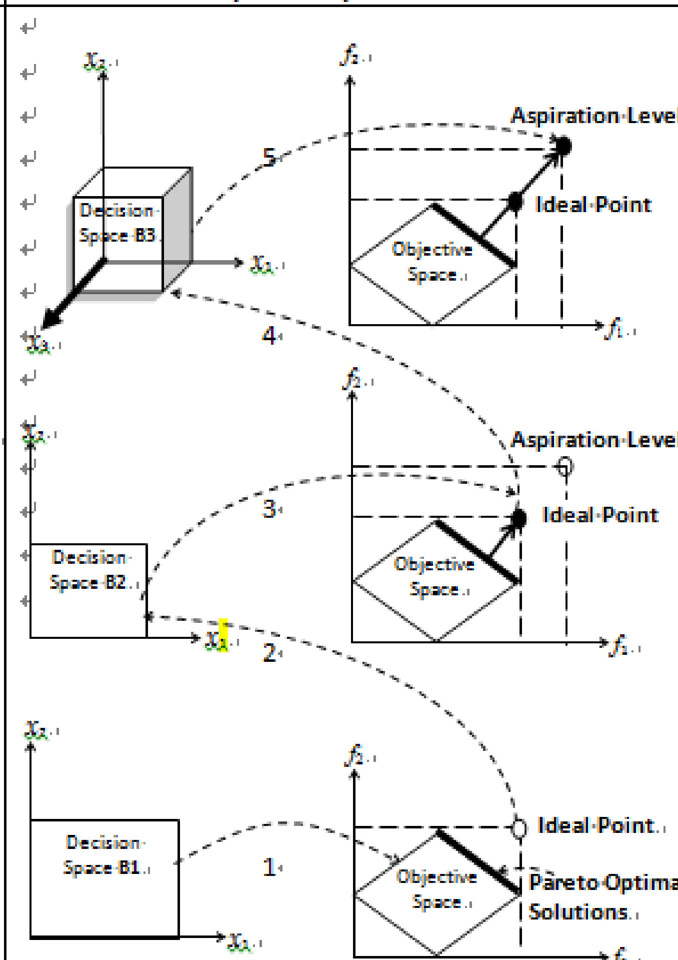
- The results of comparison between non-additive and additive methods are illustrated in Table 12.

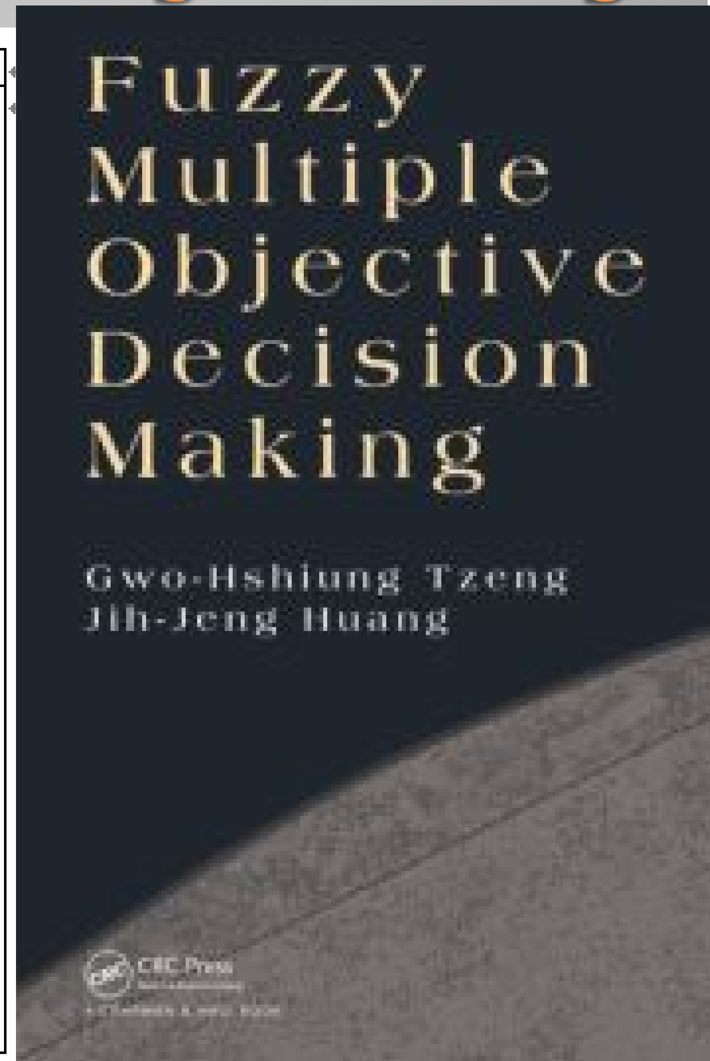
Table 12 Results comparison between non-additive and additive methods

	Dimension (Additive / Non-Additive)				
	A_1	A_2	A_3	A_4	A_5
D_1 Compatibility $\lambda = 0.358$	0.241 / 0.240 (-1%)	0.198 / 0.179 (-10%)	0.197 / 0.197 (0%)	0.183 / 0.182 (0%)	0.264 / 0.263 (0%)
D_2 Quality $\lambda = 3.902$	0.290 / 0.286 (-1%)	0.237 / 0.231 (-3%)	0.236 / 0.227 (-4%)	0.236 / 0.227 (-4%)	0.221 / 0.214 (-3%)
D_3 Cost $\lambda = 1.268$	0.243 / 0.242 (0%)	0.306 / 0.300 (-2%)	0.330 / 0.327 (-1%)	0.343 / 0.339 (-1%)	0.268 / 0.268 (0%)
D_4 Risk $\lambda = -0.073$	0.251 / 0.252 (1%)	0.244 / 0.245 (1%)	0.227 / 0.227 (0%)	0.248 / 0.249 (1%)	0.277 / 0.277 (0%)
Total gaps $\lambda = -0.597$	0.255 / 0.359 (40%)	0.243 / 0.350 (44%)	0.241 / 0.345 (42%)	0.245 / 0.361 (48%)	0.258/ 0.376 (46%)

Note. Parenthesis represents the increased gap ratio %

Changeable Spaces Programming

Concept	Graphical Representation	Approach
Value (Win-Win)		making aspired decisions by expanding competence sets through innovation
		Making Ideal decisions through re-allocating limited resources
Price (Win-Lose)		Making Pareto optimal decisions through traditional MOP methods



Jih-Jeng Huang, Gwo-Hshiung Tzeng (**Corresponding author**) (**2013**), **New thinking of multi-objective programming with changeable space - In search of excellence**, ***Technological and Economic Development of Economy***, **Accepted** (forcoming**, SSCI, IF: 5.605, 2011; IF: 3.235, 2012).**

Gwo-HshiungTzeng, Kuan-Wei Huang, Ching-Wei Lin, and Benjamin J. C. Yuan (2014), **New idea of multi-objective programming with changeable spaces for improving the unmanned factory planning**, PICMET 2014.

Resources reallocation problem

- Pareto Optimal Solutions

$$\text{Max } \left\{ z_k = \boldsymbol{c}_k \boldsymbol{x} \mid k = 1, \ldots, q \right\}$$

$$s.t. \;\; \boldsymbol{Ax} \le \boldsymbol{b} \;\rightarrow\; \boldsymbol{pAx} \le \boldsymbol{pb} \rightarrow \boldsymbol{vx} \le B \;\left(B \text{ is total budget} \right)$$

$$\boldsymbol{x} \ge 0,$$

- Ideal Point solution (De Novo Programming)

$$\text{Min } \; B = \boldsymbol{vx}$$

$$s.t. \quad \boldsymbol{c}_k \boldsymbol{x} \ge z_k^* \left(\text{Ideal point} \right), \; k = 1, \ldots, q$$

$$\boldsymbol{x} \ge 0$$

Resources reallocation problem

- Aspiration level (Changeable spaces programming)

$$\text{Min} \quad \boldsymbol{v}'\boldsymbol{x}$$

$$s.t. \quad \boldsymbol{c}'_{k'}\boldsymbol{x} \geq z^{**}_{k'} \text{ (Aspiration level)}, \; k' = 1,\ldots,q'; \; q' \geq q$$

$$\boldsymbol{x} \geq \boldsymbol{0}$$

where $\boldsymbol{pA}^{*}\boldsymbol{x} \leq \boldsymbol{pb} \rightarrow \boldsymbol{v}'\boldsymbol{x} \leq B \; \left(B \text{ is total budget}\right)$ change technological coefficients in efficiency (Resource Requirement)

Resource Allocation of Zeleny's Example

Table 1 Resource allocation of Zeleny's example.

Unit price	Resource	Technological coefficients $x_1 = 1$	Technological coefficients $x_2 = 1$	No. of units
30	Nylon	4	0	20
40	Velvet	2	6	24
9.5	Silver thread	12	4	60
20	Silk	0	3	10.5
10	Golden thread	4	4	26

De Novo Programming Method

- The costs of the given resources portfolio:

$$(30\times 20)+(40\times 24)+(9.5\times 60)+(20\times 10.5)$$
$$+(10\times 26)=\$2600$$

- Unit costs of producing one unit of each of the two products:

$$x_1 \Rightarrow (30\times 4)+(40\times 2)+(9.5\times 12)+(20\times 0)+(10\times 4)=\$354$$
$$x_2 \Rightarrow (30\times 0)+(40\times 6)+(9.5\times 4)+(20\times 3)+(10\times 4)=\$378$$

- Expected profit margins (price-cost) are:

$$x_1 = 754-354=\$400/\text{unit}$$
$$x_2 = 678-378=\$300/\text{unit}$$

Decision Space and Objective Space

$$\max \quad f_1 = 400x_1 + 300x_2$$

$$\max \quad f_2 = 6x_1 + 8x_2$$

$$s.t. \quad 4x_1 \le 20,$$

$$2x_1 + 6x_2 \le 24,$$

$$12x_1 + 4x_2 \le 60,$$

$$3x_2 \le 10.5,$$

$$4x_1 + 4x_2 \le 26,$$

$$x_1, x_2 \ge 0$$

Objective Space

Decision Space

De Novo Programming Method

- Maximizing total value of function f_1:

$$f_1 = 400x_1 + 300x_2$$

- Maximizing total quality index f_2:

$$f_2 = 6x_1 + 8x_2$$

De Novo Programming Method

- Maximizing levels of two products can be calculated by mathematical programming:

$$
\begin{aligned}
\max \quad & f_1 = 400x_1 + 300x_2 \\
\max \quad & f_2 = 6x_1 + 8x_2 \\
s.t. \quad & 4x_1 \le 20 \\
& 2x_1 + 6x_2 \le 24 \\
& 12x_1 + 4x_2 \le 60 \\
& 3x_2 \le 10.5 \\
& 4x_1 + 4x_2 \le 26 \\
& x_1, x_2 \ge 0
\end{aligned}
$$

- Maximum f_1 in profit:

$$\max \quad f_1 \to x_1 = 4.25, x_2 = 2.25; \quad f_1^* = 400 \times 4.25 + 300 \times 2.25 = \$2375$$

- Maximum f_2 in total quality index

$$max \quad f_2 \to x_1 = 3.75, x_2 = 2.75; \quad f_2^* = 6 \times 3.75 + 8 \times 2.75 = \$44.5$$

De Novo Programming Method

- Minimizing the total cost by considering the following constraints:

$$\begin{aligned} &min \quad 354x_1 + 378x_2 \\ &s.t. \quad f_1 = 400x_1 + 300x_2 \geq 2375 \\ &\qquad\;\; f_2 = 354x_1 + 378x_2 \geq 44.5 \end{aligned}$$

- Maximum f_1 in profit:

$$max \quad f_1 \rightarrow x_1 = 4.03, x_2 = 2.54; \quad f_1^* = 400 \times 4.03 + 300 \times 2.54 = \$2375$$

- Maximum f_2 in total quality index:

$$\max \quad f_2 \rightarrow x_1 = 4.03, x_2 = 2.54; \quad f_2^* = 6 \times 4.03 + 8 \times 2.54 = \$44.5$$

- Cost of the newly designed system:

$$(30 \times 16.12) + (40 \times 23.3) + (9.5 \times 58.52) + (20 \times 7.62) + (10 \times 26.28) = \$2386.74$$

De Novo Programming Method

- The new portfolio of resources proposed by the consultant is as following:

Unit price $	Resources (Raw material)	Technological coefficients (Resource Requirement)		No. of units (Resource portfolio)
30	Nylon	4	0	16.12
40	Velvet	2	6	23.3
9.5	Silver thread	12	4	58.52
20	Silk	0	3	7.62
10	Golden thread	4	4	26.28

- Pareto optimal solutions B=$2600
- De Novo programming, ideal point solution B^*=$2386.74, $B^* < B$.

Modified Example to Demonstrate Yu's Model

Table 2 Modified example to demonstrate Yu's model.

Resource	Technological coefficients $x_1 = 1$	$x_2 = 1$	No. of units	Unit Purchase Benefit
Nylon	4	0	20	0.3
Velvet	2	6	24	0.3
Silver thread	12	4	60	0.3
Silk	0	3	10.5	0.3
Golden thread	4	4	26	0.3

New Decision Space and Objective Space

$$\max \quad f_1 = 400x_1 + 300x_2 + y(3x_1 + 4x_2)$$

$$\max \quad f_2 = 6x_1 + 8x_2 + y(0.3x_1 + 0.2x_2)$$

Objective Space

$$s.t. \quad 4x_1 \le 20 + 0.3z,$$

$$2x_1 + 6x_2 \le 24 + 0.3z,$$

$$12x_1 + 4x_2 \le 60 + 0.3z,$$

$$3x_2 \le 10.5 + 0.3z,$$

$$4x_1 + 4x_2 \le 26 + 0.3z,$$

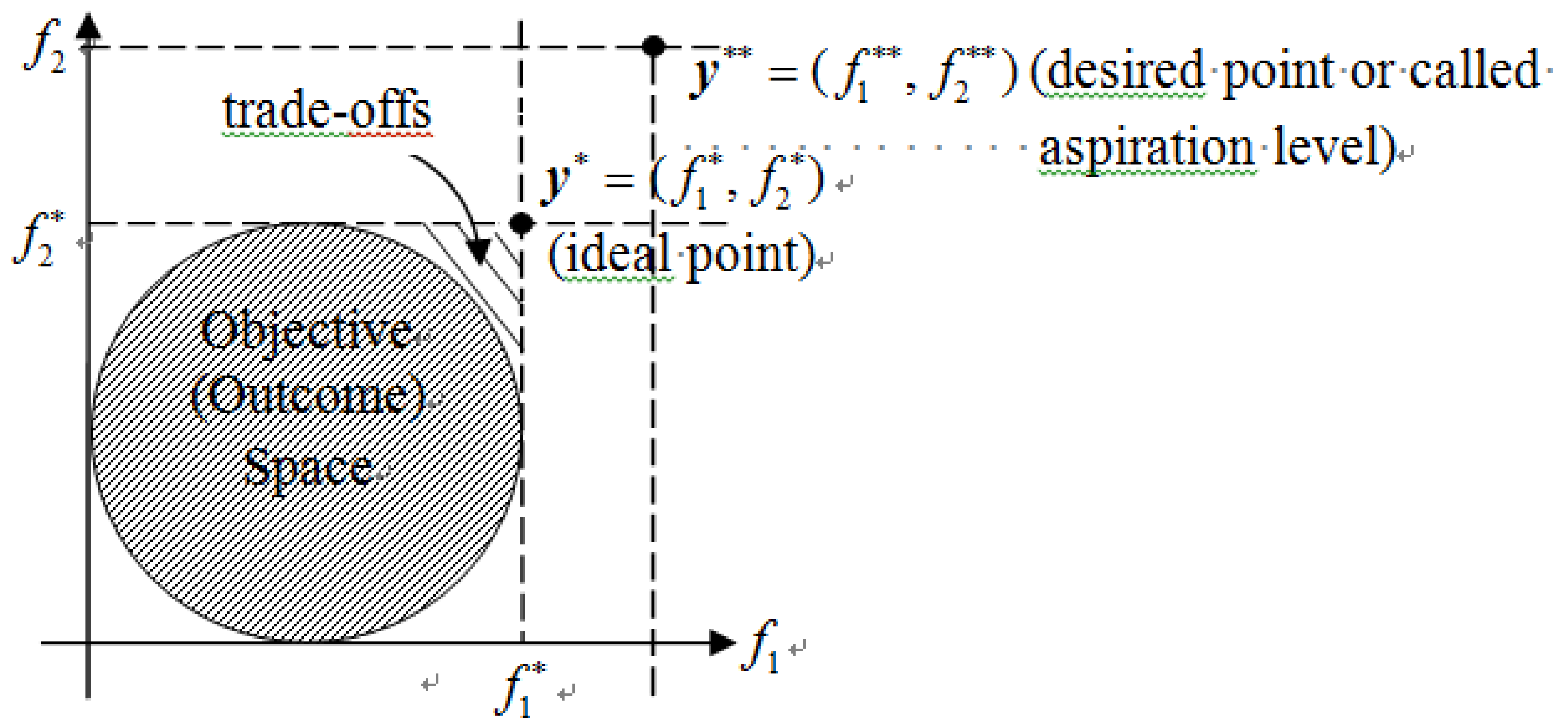
$$0 \le y, z \le 7,$$

$$y + z \le 10,$$

$$x_1, x_2, y, z \ge 0.$$

Decision Space

Basic concept of the desired point or called aspiration level



MOP with changeable parameters

<Model 1: MOP with changeable budgets>

$$\min \quad \widehat{B} \qquad (10)$$

$$s.t. \quad \sum_{j=1}^{m} c_{ij} x_{ij} = f_i^{**}(\boldsymbol{x}), \quad i = 1, \ldots, n,$$

$$\boldsymbol{p}'\boldsymbol{A}\boldsymbol{x} \le B + \widehat{B},$$

<extra conditions for $\widehat{B}$ >

$$\boldsymbol{x} \ge \boldsymbol{0},$$

Information Table for Example 1

Table 3 Information Table for Example 1.

Unit price	Resource	Technological coefficients $x_1 = 1$	$x_2 = 1$	No. of units
30	Nylon	4	0	b_1
40	Velvet	2	6	b_2
9.5	Silver thread	12	4	b_3
20	Silk	0	3	b_4
10	Golden thread	4	4	b_5

Solving the problem of Example 1

$$
\begin{aligned}
\min \quad & \widehat{B} \\
s.t. \quad & 400x_1 + 300x_2 = 2600, \\
& 6x_1 + 8x_2 = 60, \\
& 30 \times 4x_1 + 40 \times (2x_1 + 6x_2) + 9.5 \times (12x_1 + 4x_2) + 20 \times 3x_2 \\
& + 10 \times (4x_1 + 4x_2) \le 2600 + \widehat{B}, \\
& x_1, x_2 \ge 0.
\end{aligned}
$$

MOP with changeable objective coefficient

<Model 2: MOP with changeable objective coefficients>

$$\min \quad \hat{B} \qquad (11)$$

$$s.t. \quad \sum_{j=1}^{m} (c_{ij} + \hat{c}_{ij}) x_{ij} = f_i^{**}(\boldsymbol{x}), \quad i = 1, \ldots, n,$$

$$\boldsymbol{p}'\boldsymbol{A}\boldsymbol{x} + \sum_{i=1}^{n} \sum_{j=1}^{m} p_{ij}^{c} \hat{c}_{ij} \le B + \hat{B},$$

<extra conditions for p_{ij}^{c} and $\hat{c}_{ij}$>

$$\boldsymbol{x} \ge \boldsymbol{0},$$

Information Table for Example

Table 4. Information Table for Example 2.

Objective coefficients $x=1$	Objective coefficients $y=1$	Unit price	Resource	Technological coefficients $x_1=1$	Technological coefficients $x_2=1$	No. of units
400 ($0.200)	300 ($0.289)	30	Nylon	4	0	b_1
6 ($2.225)	8 ($2.487)	40	Velvet	2	6	b_2
		9.5	Silver thread	12	4	b_3
		20	Silk	0	3	b_4
		10	Golden thread	4	4	b_5

Mathematical programming to consider achieving the desired points via improving the objective coefficients

$$\min \quad \hat{B}$$

$$s.t. \quad (400+\hat{c}_{11})x_1+(300+\hat{c}_{12})x_2=2600,$$

$$(6+\hat{c}_{21})x_1+(8+\hat{c}_{22})x_2=60,$$

$$30\times 4x_1+40\times(2x_1+6x_2)+9.5\times(12x_1+4x_2)+20\times 3x_2$$

$$+10\times(4x_1+4x_2)+(0.200\hat{c}_{11}+0.289\hat{c}_{12}+2.225\hat{c}_{21}+2.487\hat{c}_{22})\leq 2600+\hat{B},$$

$$x_1,x_2\geq 0.$$

MOP with Changeable Technological Coefficients

<Model 3: MOP with Changeable technological coefficients >

$$\min \quad \hat{B} \tag{12}$$

$$s.t. \quad \sum_{j=1}^{m} c_{ij} x_{ij} = f_i^{**}(\boldsymbol{x}), \quad i = 1, \ldots, n,$$

$$\boldsymbol{p}'(\boldsymbol{A} - \hat{\boldsymbol{A}})\boldsymbol{x} + \sum_{k=1}^{r} \sum_{j=1}^{m} p_{kj}^{a} \hat{a}_{kj} \leq B + \hat{B},$$

<extra conditions for p_{ij}^{a} and $\hat{a}_{ij}$ >

$$\boldsymbol{x} \geq \boldsymbol{0},$$

Information Table for Example

Table 5. Information Table for Example 3.

Objective coefficient $x=1$	$y=1$	Unit price	Resource	Technological coefficients $x_1=1$	$x_2=1$	No. of units
400	300	30	Nylon	4 (\$0.5)	0	b_1
6	8	40	Velvet	2 (\$0.5)	6 (\$0.27)	b_2
		9.5	Silver thread	12 (\$0.27)	4 (\$0.26)	b_3
		20	Silk	0	3 (\$0.25)	b_4
		10	Golden thread	4 (\$0.25)	4 (\$0.25)	b_5

Incorporating the information of the unit updating cost of the technological coefficients

$$
\begin{aligned}
\min \quad & \hat{B} \\
s.t. \quad & 400x_1 + 300x_2 = 2600, \\
& 6x_1 + 8x_2 = 60, \\
& 30 \times (4 - \hat{a}_{11})x_1 + 40 \times ((2 - \hat{a}_{21})x_1 + (6 - \hat{a}_{22})x_2) + 9.5 \times ((12 - \hat{a}_{31})x_1 \\
& +(4 - \hat{a}_{32})x_2) + 20 \times (3 - \hat{a}_{42})x_2 + 10 \times ((4 - \hat{a}_{51})x_1 + (4 - \hat{a}_{52})x_2) \\
& +0.5\hat{a}_{11} + 0.5\hat{a}_{21} + 0.27\hat{a}_{22} + 12\hat{a}_{31} + 4\hat{a}_{32} + 3\hat{a}_{42} + 4\hat{a}_{51} + 4\hat{a}_{52} \le 2600 + \hat{B}, \\
& x_1, x_2 \ge 0.
\end{aligned}
$$

A more general model of changeable parameters

$$\min \quad \hat{B} \qquad (13)$$

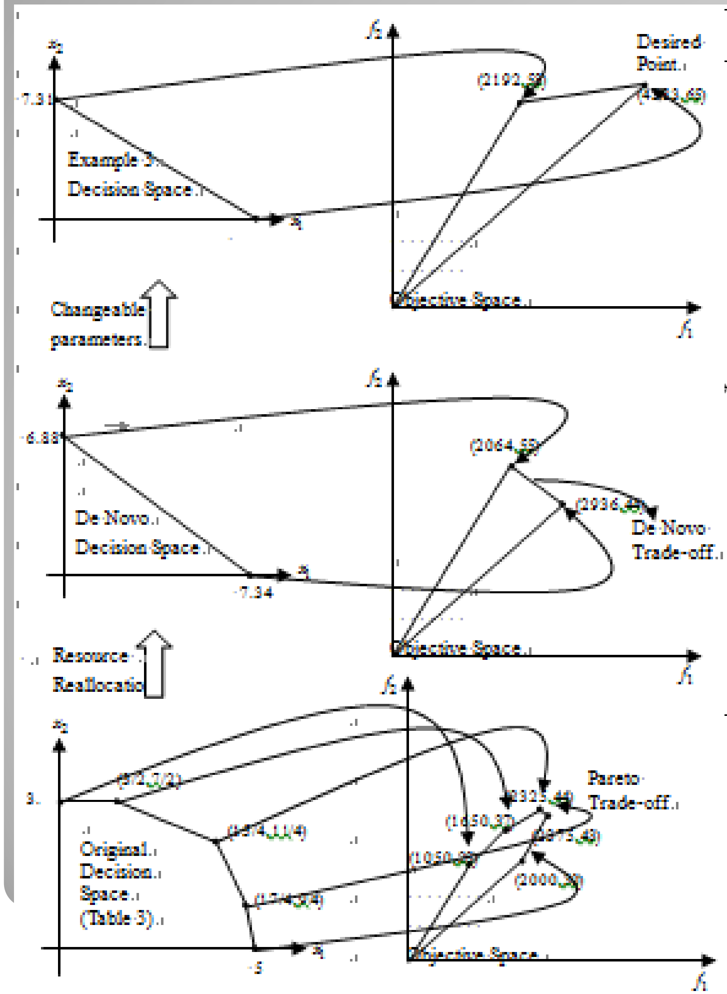
$$s.t. \quad \sum_{j=1}^{m} (c_{ij} + \hat{c}_{ij}) x_j \geq f_i^{**}(\boldsymbol{x}), \quad i = 1, \ldots, n,$$

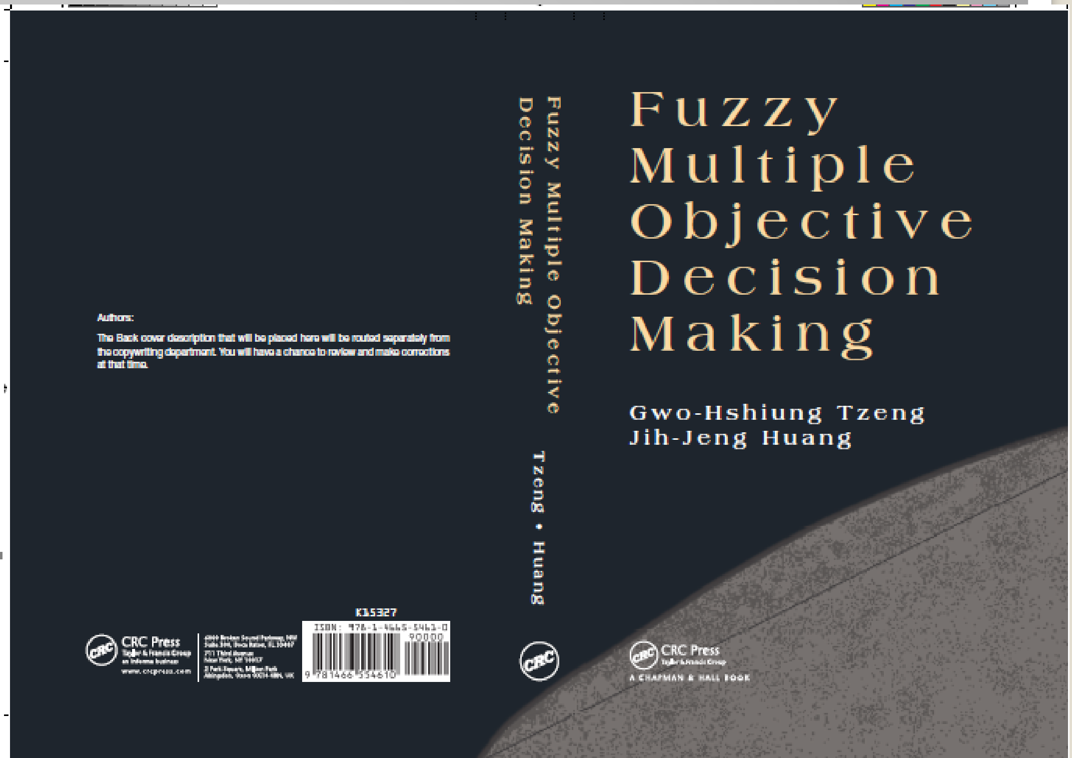
$$\boldsymbol{p}'(A - \hat{A})\boldsymbol{x} + \sum_{i=1}^{n}\sum_{j=1}^{m} p_{ij}^{c}\hat{c}_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m} p_{ij}^{a}\hat{a}_{ij} \leq B + \hat{B},$$

<extra conditions for $\hat{B}$, p_{ij}^{c}, $\hat{c}_{ij}$, p_{ij}^{a} and $\hat{a}_{ij}$>

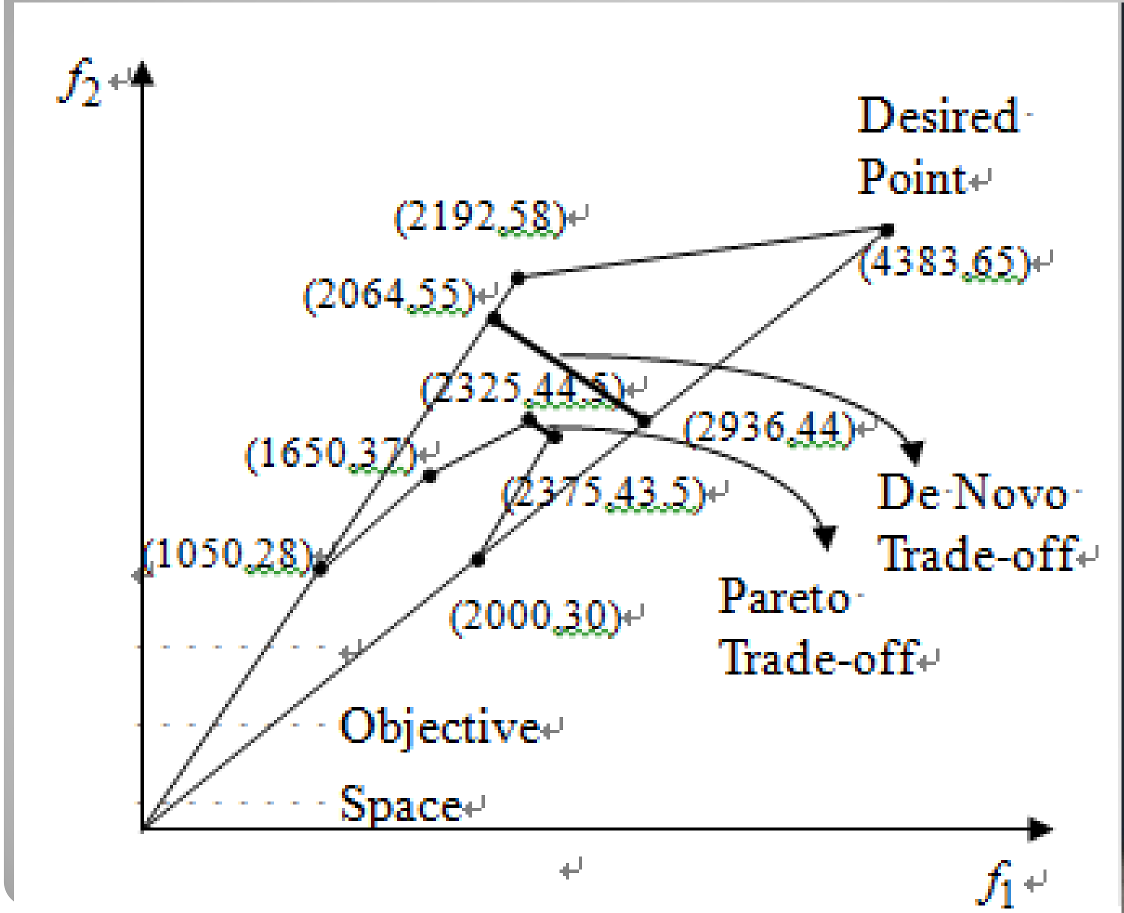
$$\boldsymbol{x} \geq \boldsymbol{0}.$$

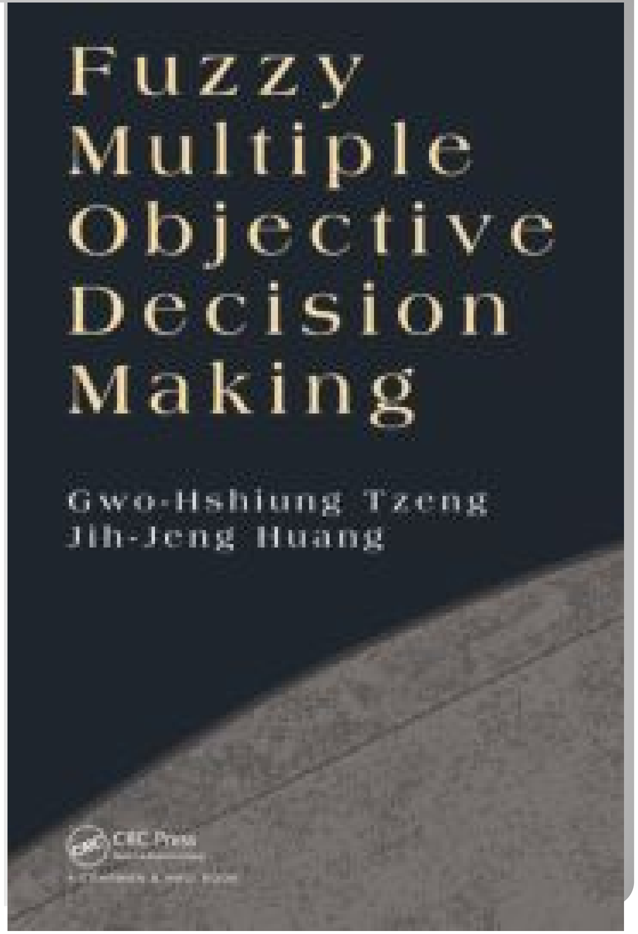
Changeable spaces for achieving the desired point.





A comparison of objective space





Talk

- New concepts and trends of hybrid MCDM model for Tomorrow
- How consider for solving the real world
- Basic concepts of ideas and thinking in trends
- Some examples for the real cases: New hybrid MCDM model
  - MADM: DEMATEL, DANP (DEMATEL-based ANP), Integration (Additive: SAW, VIKOR, Grey Relation Analysis, PROMETHEE, ELECTRE; Non-additive: Fuzzy Integral)
  - MODM: Changeable Spaces Programming
- Conclusions

Conclusions

Conclusions

- This study proposed a series of **new Hybrid Dynamic Multiple Criteria Decision Making (HDMCDM) method** in order to overcome the defects of conventional MCDM methods.

- First, applies the characteristics of influential network relation map (INRM) and influential weights (DEMATEL-based ANP, called DANP) and by using DEMATEL technique to solve interdependence and feedback problems of multi-criteria.

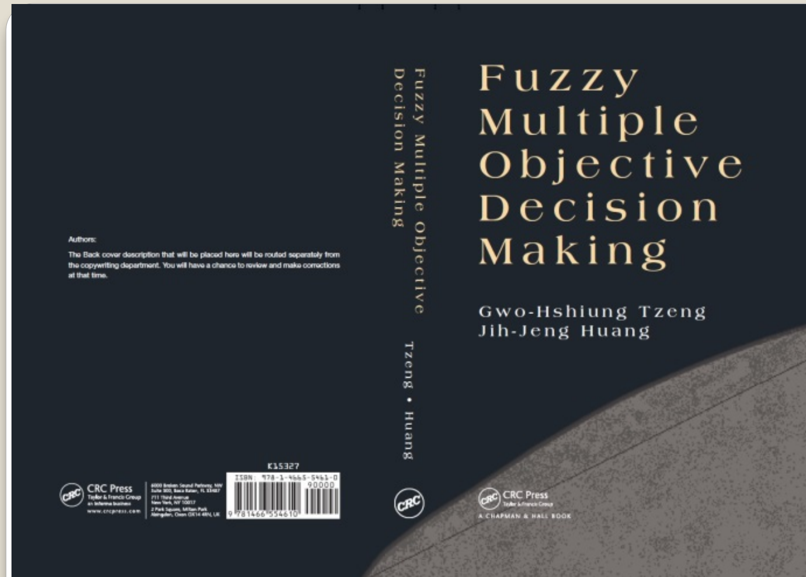
- Second, this study set the best f_j^* values to be the **aspiration level** and the worst f_j^- values as the tolerable level for all criterion functions $(j = 1, 2, \ldots, n)$ to avoid "Choose the best among inferior choices/options/ alternatives".

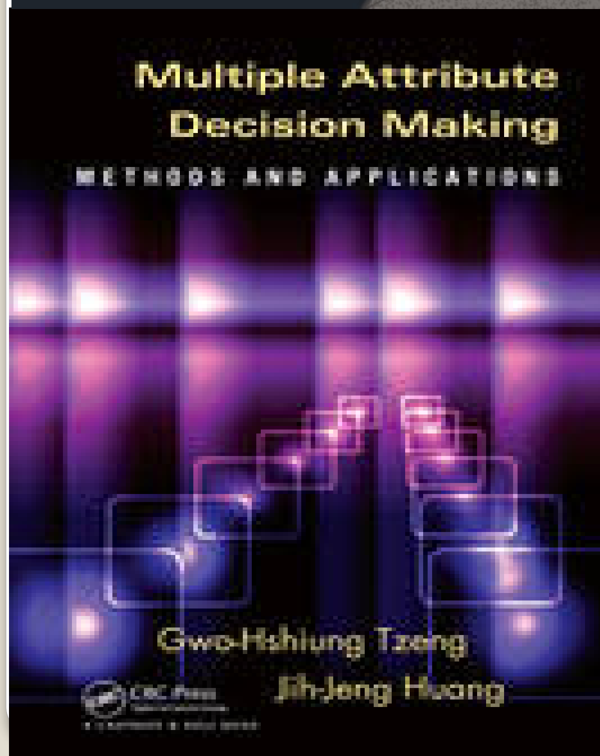
Conclusions

- Third, this study shifted the concept from the “ranking” or “selection” of the most preferable alternatives to the “**improvement**” of their performances to achieve the aspiration level for each dimension and criterion.

- Fourth, information fusion/aggregation such as fuzzy integrals, basically, **a non-additive/super-additive model**, has been developed to aggregate the performances.

- Finally, we should change basic concepts and thinking from traditional mathematic programming (Goal Programming, Multiple Objective Programming, etc.) into **Changeable Spaces Programming** in future trends





The End

Thank you attention

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