An Extended Model of Decision Field Theory Integrated with AHP Structure for Complex Decision Making Problems

University of Oulu
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Science
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Abstract

Decision Field Theory (DFT) provides an approach to explain the deliberation process of decision making under dynamic environment. However, the performance of original DFT theory is imperfect when the dynamic environment is getting complex. This research is aimed to build an extended model of DFT with good explanation and prediction abilities under complex dynamic environment. The dynamic structure of Analytic Hierarchy Process (AHP) was used in order to improve the flexibility and adaptability of extended model.

In this study, the systematic literature review (SLR) was conducted to explore the previous research in dynamic decision making field. The review protocol, regarding to review questions, review purpose and review method was developed during planning phase. After performing several steps of selection, 62 primary studies were selected. According to the results of analysis, limited number of primary studies are related to the practical application of DFT in specific context. Therefore, it is necessary to extend the DFT model.

In practice, class attending behavior of students was selected, as one example of complex dynamic making problems, to evaluate the extended model. In order to collect relevant data of decision making, three rounds of web survey were conducted. The students from University of Oulu are the respondents of the web survey.

In conclusion, the analysis results of data proved that proposed model is able to explain and predict the dynamic behavior of decision making well. This research opens space for future research about model studying and building.

Keywords
Decision Field Theory, Analytic Hierarchy Process, Systematic Literature Review, Class Attendance.

Supervisor
Dr. Jouni Markkula
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>DFT</td>
<td>Decision Field Theory</td>
</tr>
<tr>
<td>AHP</td>
<td>Analytic Hierarchy Process</td>
</tr>
<tr>
<td>SEU</td>
<td>Subjective Expected Utility</td>
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<tr>
<td>DSR</td>
<td>Design Science Research</td>
</tr>
<tr>
<td>SLR</td>
<td>Systematic Literature Review</td>
</tr>
<tr>
<td>BSDA</td>
<td>Basic of Statistical Data Analysis of Information Processing Science</td>
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</table>
Foreword

First of all, I would like to express the sincerest thanks to my supervisor Jouni Markkula and Markus Kelanti who continually gave me patient and professional guidance on design science research and thesis writing. In addition, I am so thankful to the students of BSDA course who participate in the web survey and make great contribution to the success of data collection. This thesis would not have been completed without all involved people, thus I own my thanks to them.

I also appreciate the University of Oulu where I had my best experience of studying and living abroad for two years. Moreover, I not only increased knowledge but also broadened my horizons here. Of course, I want to thank my friends and parents who gave me support and encouragement.

During the whole period, I went through many difficulties and gained quite much through problems solving. I have learnt how to conduct SLR and how to analysis data, what’s more important, I have deeper understanding on the process of DSR method. The process of doing research and writing thesis is a tough but harvest experience that would help me a lot in the future.

Lan Shao

Oulu, May 19, 2015
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1. Introduction

Decision making is a human deliberation process that can be seen everywhere from personal event to group activity. There are three categories of decision making process: economic decision making, psychological decision making and synthetic engineering-based decision making (Lee, Son, & Jin, 2008). The psychological decision making is discussed in this research. In usual, people need consider every factor and the effect each of them in order to make an optimal decision. However, the environment that people experience is dynamic because new information continuously enter into. Consequently, decision making is a dynamic process that take much time on repeating and changing consideration for factors. At this sense, psychological decision making is abstract and complicated. Apparently, it’s difficult to understand and explain the deliberation process.

Decision Field Theory (DFT), initial proposed in 1989, is widely known as a dynamic cognitive approach to explain the dynamic decision making under dynamic environment (Roe, 2001). It provides a mathematical model to account for the evolution of human decision making and provides insights into preference reversal between options (Busemeyer & Townsend, 1993). Before the theory applied to solve multiple options problems of decision making, it has experienced several stages that are the foundation for present theory. Deterministic subject expected utility (SEU) theory, originally proposed in 1954 and followed the laws of mathematical probability theory, is restricted to the choices between two options (Savage, 1954). This theory can be applied to predict the trend of preferences on options, but it can’t explain the dynamic change of preference. This weakness motivated other researchers to have a further study. The researchers assumed the process of attention switching on relevant factors, occurs within a sequential and regular period. This theory is referred to Sequential SEU Theory (DeGroot, 1970). However, the main problem of Sequential SEU theory is that the preference value at first time point is always set to zero. It means the knowledge and experience in the past has no influence on current decision making, which goes against with real human deliberative process. The Random Walk SEU Theory (Busemeyer, 1985) solves this problem by setting an initial preference state. The decision making theories of deterministic originate from the basic proposal that the action is either true or false between two conflict actions, which is referred to binary preference relation (Fishburn, 1988). In subsequent, it was used for two or more attributes decision making under dynamic environment (Diederich, 1997). After that, DFT was gradually mature and widely used.

The decision field theory as a dynamic decision making method is adopted in many fields. In the field of supply chain management, a method of dynamic decision making is structured in order to realize strategic vendor selection or switching based
on the principle of hierarchical planning (Sucky, 2007). The results show the proposed method is able to explain behavior of vendor selection, and then decision maker could choose the optimal solution of vendor management among alternative offers. In the stock market, DFT is used to analyze and avoid risks based on the experiences (Cohen et al., 2008). The authors set up a model representing preferences under uncertain environment where current risk are dependent on experience. Vescoukis et al. (2011) propose an architecture based on dynamic decision making in disaster management for plan constructing, retrieving, and exchanging. This architecture not only predicts human decision making in disaster management, but also provides recommendation and evaluation for solution of disaster management. Moreover, DFT is also adopted in many other context, for example, transportation, agriculture and military (Cheung et al., 1999; Pearson et al., 2010; Du et al., 2010).

Amount of successful empirical research discussed above prove that DFT theory is able to explain human’s dynamic behavior in many areas. In general, the attribute value and weight value are two important components when people make decision. The attribute normally represents the influential factor in decision making problems. The attribute value is the evaluation of relevant influence factors, while the weight value is the attention of decision maker allocated to each attribute. For example, people would consider economy and quality as two attributes (influence factors) when they make decision on buying car A or B. The evaluation value of attribute economy and quality can refer to the car price and performance index respectively. Of course, it is possible to have another way to calculate the evaluation value. In addition, the weight value indicates how important each attribute is to the decision making of car purchase. If the economy is more important that quality, the weight value of former one is higher than that of latter one. In the original DFT model, the evaluation value is fixed and the weight value of attribute is changeable during the process of decision making. Because the evaluation value in the case, for example the car purchase, are relatively stable in terms of economy and quality. While the importance of attributes for decision maker is changing, as they getting know more about decision making problem.

However, the evaluation value of attribute and attribute number are dynamic as well under the complex dynamic environment. The class attendance of students, as one of such complex cases, can be used to clarify this situation. Student would take into consideration the two attributes of time arrangement and class quality when they make decision on class attending. The evaluation value of students on attributes are dynamic because situation of every class is different. In addition, students would consider another attribute for example course subject, when they know the course better. In this research, the complex decision making environment is the environment in which the evaluation value and attribute value are dynamic, while the complex decision making problems is the problems under such environment. Overviewing the related research of DFT, there is no suitable model that can be adopted for such complex dynamic decision making problem. Therefore, the goal of this research is to
develop an extended model of DFT that is able to remedy the limitation of original DFT model.

In addition to extended model construction, the context of class attendance is studied in this research. Nowadays, the main mode of instruction in universities is face-to-face lecture (or exercise). Along with development of technology, the teaching mode, for example remote education, online video or electronic materials studying (Brookfield, 2012) gradually replace the face-to-face teaching. Consequently, the decline of class attendance rate in physical class becomes an increasingly evident issue. Therefore, the application of extended model under context of class attendance has theoretical and practical significance.

In conclusion, this research builds an extended DFT model and adopts it under complicated decision making problem of class attendance. Firstly, a systematic literature review (SLR) is conducted to explore the basic knowledge of existing DFT-related studies. The review results provide motivation for this research. Then, the extended model is built through studying the principles of original DFT theory and AHP structure. Next, a web survey is conducted in University of Oulu in order to collect data for model evaluation. Lastly, the discussion of contribution and limitation is discussed based on the analysis of survey results.
2. Research Problem and Methodology

Looking back to the empirical research, decision field theory make great achievement in problem solving of dynamic decision making. However, obvious limitation of DFT is existing when decision making environment is complex. In order to address this research problem, two main research questions are identified. Based on the questions, the methodology adopted in this research are presented.

2.1 Research problems

The model of DFT has been generated for over twenty years. A number of researchers studied and improved the model for the purpose of better outcomes. Up to now, the theory of DFT can account for dynamic decision making under uncertainty. However, it is imperfect when the dynamic environment of decision making is complex. It is necessary to know whether the practical application in existing research is able to solve decision making problem under complex environment. Therefore, the first research question is defined as follow:

*Can the practical application of DFT in existing research be used to solve the complex problems of decision making?*

The systematic literature review was conducted to collect the evidence about current situation of DFT. Consequently, the results of SLR show that no proper study can be directly used to explain behavior under complex decision making environment. The critical part of decision field theory is the mathematical model, then the goal of this research is to extend the DFT model for complex problem of decision making. Based on the overall goal, the second research question is proposed as follow.

*How to extend the DFT model that can be used to solve the complex problems of decision making?*

To refine the main research question, it is divided into three sub-questions as follow:

- What additional feature does the original DFT model should have?

- How to merge the additional feature into the extended DFT model?

- How well does the extended DFT model suit to explaining and predicting the behavior of decision making?

By studying the principle of original DFT model, the specific limitation can be discovered. Then, it’s able to identify the additional feature that original DFT model
2.2 Research methodology

Design Science Research (DSR) is selected to answer the research questions above. DSR is a scientific research method that makes basic science and applied science work together with new insights (Offermann et al., 2009). Hevner et al. (2004) published very influential paper that proves DSR is a valuable method. Then, this research method was gradually accepted and widely used in IS field and other academic sector. In general, DSR is a method researcher use artifact to provide solutions to solve the human-relevant problem. The artifact being model, method, construct or instantiation, can improve the existing solution or even create a new solution to solve the certain problems.

The prime focus of this research is the extended model of DFT that is an object of artifact, therefore DSR is a suitable research method for this research. Nunamker et al. (2001) put forward five stages that depict the process of system development research: (1) construct a conceptual framework, (2) develop system architecture, (3) analyze and design the system, (4) build the system, (5) observe and evaluate the system. Because the core artifact in this research is an model rather than system, the process is modified slightly and adopted as Table 1

*Construct a conceptual framework.* As the first step of model development research, it builds basic knowledge for later work. In typical, it includes problem identification, objective definition, theory studying, and conception definition.

*Analyze and design the model.* Hevner et al. (2004) made a precise and concise conception for artifact: it is created in form of model, method, construct or instantiation and is independent of people or object. In this research, this step analyzes original DFT model, and then propose extra feature for extended model.

*Build the model.* The research method of design-science is a process of solving problems via building artifact that is perceived as “core subject matter” in relevent field (Orlikowski & Iacono, 2001). The artifact in this research is extended model that is expected to work well in complex decision making environment.

*Observe and evaluate the model.* It is a necessary and important process of research process. Evaluation of a designed artifact requires a set of metrics and a series of data. If analysis results of data match with the pre-defined metrics, the artifact is regarded as successful case with good performance and quality.
### Table 1. Research process for model development research.

<table>
<thead>
<tr>
<th>Model Development Research Process</th>
<th>Research issues</th>
</tr>
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</table>
| Construct a conceptual framework  | • Make a systematic literature review to know the situation of application of DFT theory.  
|                                   | • Collect and categorize adopted fields of DFT theory via literature review.  
|                                   | • Estimate practical necessity of extending DFT model. |
| Analyze and design the model      | • Study basic knowledge and principle of DFT theory.  
|                                   | • Confirm strength and limitation of original model |
| Build the model                   | • Identify additional feature that original DFT model should have.  
|                                   | • Discover and adopt an assistive technique that supplement to DFT theory (AHP structure in this research).  
|                                   | • Merge DFT theory and AHP structure properly to build extended model. |
| Observe and evaluate the model    | • Select class attendance as the case of complex environment of decision making.  
|                                   | • Conduct three rounds of web survey to collect data for model evaluation. |

#### 2.2.1 Systematic literature review

According to the process and issues of research depicted in Table 1, this research begins with systematic literature review. The SLR is a widely used approach to identify, evaluate, and interpret all available research relevant to a particular research question, topic area, or phenomenon (Keele, 2007). Compared with traditional literature review, SLR is able to avoid personal biases on the process of paper selection. The purpose of systematic literature review in this research is to get the current situation of practical application of DFT, and know the necessity of building an extended DFT model.

There are three phases of systematic literature review: review planning, review conducting and review analyzing (Felizardo et al., 2014). In practice, review questions and respective purpose are identified at first phase. Additional, review method regarding to search resource, search strategy and selection criteria are defined. Based on review plan, literature review is performed. There are four forms proposed for article categorization: support, automatic, application, and theory. Accordingly, all articles are divided into these four categories. Through observing primary studies, results of literature review are analyzed and summarized.
2.2.2 Extended model building

The extended model is built based on the three phases of work: discovering the limitation of original DFT model, identify additional feature that DFT model need, and merging the additional feature into extended model.

Studying the knowledge and principles of original DFT model is able to discover the limitation of its problem-solving ability under complex decision making environment. Then, the additional feature should be identified to remedy the limitation of DFT. What’s more, the dynamic structure of AHP is selected and studied because it has good flexibility and adaptability for dynamic decision making problems. The AHP structure right correspond to the needed additional feature of DFT. By integrating with dynamic structure of AHP, the extended model of DFT is set up. Apart from original feature of DFT model, the proposed model has extra feature that improve its performance under complex decision making environment.

2.2.3 Data collection

Class attendance is considered as an example of complex dynamic environment, to apply the extended DFT-related model. Furthermore, the class attendance of the bachelor-level course in the University of Oulu is selected in this research. Web survey is the approach to collect data for model evaluation.

The participant is the enrolled students who are voluntary to take part in web survey. In addition, whole process of survey is divided into three rounds, each of them requires participated students to answer course-related question. The collected data are used to quantify variables of proposed model.

2.2.4 Evaluation for model

The abilities of explanation and prediction are two standards to measure the quality of proposed model. Through observing the characteristics of variables value of model, evaluation results are analyzed.

Specifically, the explanation ability of extended DFT model is evaluated by analyzing the data difference among three rounds of web survey. Through discovering the relationships between attributes and options, the dynamic behavior of students is explained. In addition, the prediction ability of DFT is evaluated through comparing survey results with real data of class attendance.
3. Systematic Literature Review

The systematic literature review in this research follows the guidelines proposed by Kitchenham (2004). Through aggregating evidence of practical application from large amount of studies, the situation of DFT research at present are summarized. What’s more important, the necessity of extending the original DFT model is evaluated.

3.1 DFT and dynamic decision making

In addition to DFT, the dynamic decision making is also key terms in this thesis. It is necessary to state the relationship between DFT and dynamic decision making. Decision field theory is a mathematical approach to explain and formalize the deliberation process of human behavior (Busemeyer & Townsend, 1993). In some papers (Johnson et al., 2005; Scheibehene et al., 2009), DFT is introduced as a one of methods to solve problems of dynamic decision making. From the perspective of problem solving, the DFT and dynamic decision making are used on an equal basis. Compared with studies about dynamic decision making, the research related DFT is much less because DFT is an relatively new theory. Thus, taking into consideration the research about dynamic decision making is able to explore the prior knowledge of DFT in all direction. Therefore, the terms of DFT and dynamic decision making appear in this thesis concurrently.

3.2 Classification of paper related to DFT

Decision field theory is original proposed to solve the human-centered problem of decision making. Along with development of technology, the DFT theory are studied to solve the decision making problem of E-mechanical products, such as robot and military aircraft (Liang et al., 1993; Ahituv et al., 1998). In addition, the existing research vary in terms of the core subject. Some papers focus on the application of DFT in certain context while some papers study the pure theory of DFT. According to the situation, the DFT-related studies are typical divided into four classification: (1) automatic decision making, (2) human supported decision making, (3) application of DFT, and (4) theory of DFT.

The papers related to automatic decision making are excluded because the concern of this research is complex human-centered problem of decision making. Moreover, the focus of this SLR is the application situation of DFT in existing research, which is able to support next-step direction of this research. Although the research related to pure theory studying is excluded in SLR, they are very important and valuable for DFT studying of this research.
3.3 Review questions and purposes

With observation of existing research, it is known that the DFT theory were adopted under different context through different research methods. In order to know the current state of DFT and analyze existing literature better, four review questions (RQ) of literature review are identified, along with respective review purpose as below.

- **RQ 1: How do the existing research distribute in four classifications?**

  This question is proposed to know the distribution situation of existing research in four classifications. This research belong to the classification of human supported decision making and application of decision making. By summarizing situation of previous research, the value of this research is evaluated.

- **RQ 2: What context does decision field theory be applied in primary studies?**

  The purpose of this question is to discover the context, varying in all sectors of society from education to transportation, which are studied associated with decision field theory. By review the primary papers, the possibility of extending DFT model under complex decision making environment can be assessed approximately.

- **RQ 3: What practical application of DFT are developed in primary studies?**

  Through gathering and reviewing the practical application of DFT, the development of DFT in practice is analyzed. For solving the complex decision making problem, whether choosing one feasible application from existing research or building an extended DFT model, is able to be decided subsequently.

3.4 Review method

In this SLR, paper review is a process of paper selection. In order to avoid personal basis, two reviewers are involved: the author and the supervisor. The author took responsibilities of main review work, while the supervisor was in charge of reviewing the papers that confused the author. Before reviewing papers, the rules regarding to search resource, search strategy and selection criteria were defined.

3.4.1 Search resources

The digital resources that are used to collect evidence supporting primary study. In this literature review, there are four digital resources selected as below:

- **Scopus:** A large abstract and citation database covering over 21,000 peer-reviewed titles from more than 5,000 international publishers and over 5.5 million conference papers.
3.4.2 Search strategy

In general, SS is consist of several key terms and used in search field of search resources. To identify appropriate and effective search strings, the following procedure was carried out (Torre et al., 2014).

- Define major terms according to research questions;
- Formulate a series of synonyms, abbreviations and alternative spellings as alternative terms by splitting research question into facets;
- Obtain other alternative terms from subject heading or keywords in existing available papers;
- Use the Boolean “AND” and “OR” to combine and construct SS.

As the result of conducting above procedure, the major terms were decided to be “Decision Field Theory” and “Application”. It is because this research focuses on the application decision field theory. The synonyms, abbreviations and alternative spellings were identified (see in Table 2), along with using Boolean “AND” and “OR”.

Table 2. Major terms and alternative terms

<table>
<thead>
<tr>
<th>Major terms</th>
<th>Alternative terms</th>
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<tbody>
<tr>
<td>decision field theory</td>
<td>OR dynamic decision(-) making OR dynamic make decision(s) OR decision making analysis</td>
</tr>
<tr>
<td>AND application</td>
<td>OR system OR model OR framework OR software OR design OR implementation</td>
</tr>
</tbody>
</table>

After several trials to search papers by making different combination of terms, the papers searched were over capacity and irrelevant to topic in some cases. In order to make sure reasonable amount of paper, some terms listed in Table 2 were removed when searching. Meanwhile, narrowing the scale of terms can also reduced the gap
between topic of this research and that of searched articles in aspect of relevance. Finally, the SS were refined as below:

\[(\text{decision field theory OR dynamic decision making OR dynamic make decision}^*)\]

\[\text{And}\]

\[(\text{application OR model OR system OR framework OR software})\]

3.4.3 Selection criteria

Paper selection is a complex stage that can’t be completed within a quick operation. In general, the primary papers experience several steps of selection until they are selected finally. Based on the characteristics of review questions, the inclusion and exclusion criteria were predefined as follow.

**Inclusion criteria (IC):**

- IC0: The title, abstract and keywords of article should meet the requirement of search strings defined above.
- IC1: The articles should be conference paper, or journal paper, or book chapter, or survey report and written in English.
- IC2: The articles propose context in which the decision field theory or dynamic decision making approach is applied. Meanwhile, corresponding application or model (or system or framework or software) is developed.
- IC3: The articles detail the generation process of application or model (or system or framework or software).

**Exclusion criteria (EC):**

- EC1: The duplicated articles caused by different search engines and resources should be removed.
- EC2: The context addressed is related to automatic decision making, for example, robotic studying, military command management, multi-core chip research and so forth.
- EC3: The article only introduce basic and general conception or history of decision making.

Then, paper selection was conducted rigorously complying with inclusion and exclusion criteria step by step. Each step and respective criteria applied are presented in Figure 1.
In the step 0, inclusion criteria 0 was used in all retrieved paper after using search strings.

In the step 1, IC1 and EC1 acted at the same time in the papers that were filtered from step 1. The search result was restricted to electronic papers written in English. Moreover, the type of paper should be journal articles, conference proceedings, monograph, books or sections. The characteristics of paper, publication year and number of being cited, were not considered when searching. Of course, all the duplicated study were removed. References management tool was used to detect exact and close duplicated papers. Even though, manual work was also taken to check duplication in case any detection mistake.

In the step 2, IC2 and EC2 co-affected on all the papers selected after step 1. There are four classifications DFT-related study: (1) automatic decision making, (2) human supported decision making, (3) application of DFT, and (4) theory of DFT. The target of this step was the studies that are belong to human supported decision making and application of DFT. Meanwhile, target paper must has clear context in which DFT theory is applied. Therefore, the studies with regarding to automatic decision making and theory of theory were removed.
In step 3, IC3 and EC3 functioned together on papers remained after step 2. The requirements in this step was that the paper should clarify development process of DFT application in detail rather than general description.

After four steps of paper selection, the paper distribution was summarized in Table 3. At the initial step (S0), 790 papers, from 4 databases, were selected according to given search strings. Scopus contributes the largest amount of studying: 477, followed by ACM and ScienceDirect that respectively have 133 and 91. IEEE, the least one, provides 89 papers. After performing the S0, 619 articles were remaining to step 1. After executing a series of inclusion and exclusion criteria, only 62 (8%) primary studies were remained at last.

Table 3. Summary of paper distribution after 4 steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Scopus</th>
<th>IEEE</th>
<th>ACM</th>
<th>ScienceDirect</th>
<th>Total</th>
<th>Step remained Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>477</td>
<td>89</td>
<td>133</td>
<td>91</td>
<td>790</td>
<td>100%</td>
</tr>
<tr>
<td>S1</td>
<td>306</td>
<td>87</td>
<td>130</td>
<td>91</td>
<td>614</td>
<td>78%</td>
</tr>
<tr>
<td>S2</td>
<td>92</td>
<td>35</td>
<td>30</td>
<td>40</td>
<td>197</td>
<td>25%</td>
</tr>
<tr>
<td>S3</td>
<td>22</td>
<td>11</td>
<td>10</td>
<td>19</td>
<td>62</td>
<td>8%</td>
</tr>
<tr>
<td>Final remained Percentage</td>
<td>5%</td>
<td>12%</td>
<td>8%</td>
<td>21%</td>
<td>8%</td>
<td></td>
</tr>
</tbody>
</table>

3.5 Process of paper classification

The stage of data extraction and synthesis also can be called classification stage (Petersen, 2008). In order to perform inclusion and exclusion criteria objectively and efficiently, all the studies were divided into different classifications. In addition, the work of paper classification helped synthesize the data and answer review questions.

The inclusion or exclusion states was showed by state terms: accept, reject, or can’t decide, and each paper was marked by one of state terms. The state term of paper was decided by 6 labels. The selection process of step 2 was executed in two rounds. During the process of round 1, the papers was labeled by the keywords: automatic (short for “automatic decision making”), support (short for “human supported decision making”), irrelevant (nothing to do with subject), others (related to subject indirectly). To be specific, paper labeled in others means it can’t be identified after simply reviewing the paper. Moreover, paper labeled in irrelevant implies the content or subject has no relationship with this research. After reading keywords, abstract and title, the papers labeled in support, automatic and others were marked by term accept while papers labeled in irrelevant were marked by term reject. Consequently, the accepted papers were passed to round 2 for further selection and the rejected papers were excluded.
In round 2, there were four labels used to continue mark papers. They were *application* (short for “application of DFT”), *theory* (short for “theory of DFT”), *irrelevant*, *others*. The meanings of labels *irrelevant* and *others* are same as that of labels in round 1. It is worth noting that papers labeled in *support /others* (in round 1) and *others /application* (in round 2) were marked by *can’t decide*, and they were passed to supervisor who made the last decision to give them a clear mark. Finally, papers labeled in *support* (in round 1) and *application* (in round 2) were marked by *accept* and included, while the rest of papers were excluded. To be specific, the sequential diagram of papers classification is illustrated as follow.

![Flowchart](image.png)

**Figure 2.** Process of papers classification in two rounds

### 3.6 Results and implications

The review results was analyzed according to paper classification. Based on the results, the answers for review questions were summarized in terms of classification situation, trend of publication year and application context, which also gave some implications for this research.
3.6.1 Paper classification

In the step 2, 614 papers were classified. The classification of papers after round 1 is presented as follow Figure 3.

**Figure 3.** Paper Classification in round 1

Papers were labeled in *support*, *automatic*, *others* and *irrelevant*. There were 270 papers related to the subject of human supported decision making, while 95 papers study about automatic decision making. The number of *others* and *irrelevant* were 134 and 115 respectively. The situation of paper classification in round 2 is displayed as Figure 4.

**Figure 4.** Paper Classification in round 2
The papers labeled in support, automatic and others were the source of round 2. In round 2, the papers were divided into application, theory, others and irrelevant. The number of theory papers was 354 that is almost three times more than that of application paper.

From the perspective of classification, each paper can be marked as one of 9 label combinations. To be specific, the largest amount of paper is occupied by the label: {automatic, theory}, accounting for 208 which is followed by the labels: {others, theory} with 134 papers. The primary papers only belong to one label combination: {support, application}, with 62 papers. To get the precise number of each label, please see Table 4 below.

**Table 4. Paper amount of each label**

<table>
<thead>
<tr>
<th>Classification</th>
<th>support</th>
<th>automatic</th>
<th>others</th>
<th>In total</th>
</tr>
</thead>
<tbody>
<tr>
<td>application</td>
<td>62</td>
<td>73</td>
<td>0</td>
<td>135</td>
</tr>
<tr>
<td>theory</td>
<td>208</td>
<td>12</td>
<td>134</td>
<td>354</td>
</tr>
<tr>
<td>others</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>In total</td>
<td>270</td>
<td>95</td>
<td>134</td>
<td></td>
</tr>
</tbody>
</table>

All the data presented above is able to answer for the RQ 1: How do the existing research distribute in four classifications?

In summary, the direction of this research is untraversed but promising. The number of papers labeled in support is much more than that of papers labeled in automatic. Obviously, researchers mainly focused on studying human supported decision making currently. The subject of this research is human-centered behavior of decision making, which corresponds to current situation of DFT research.

In addition, there is big difference between the paper amount of application and theory. The latter one is more twice time as much as the former one. It is clear to know that the studying on pure theory of DFT is abundant and mature while the practical application of DFT is lack of research. In general, the overall goal of this research is to provide solution for complex problems of decision making. Undoubtedly, this research is classified into practical application of DFT and is supposed to make contribution to the application classification. The analysis for classification situation of existing research confirm the practical significance and value of this research in decision field theory.
3.6.2 Application context

The decision field theory has been widely applied into every walk of life, for example manufacturing, economic, medical science. Through reviewing the primary studies, the contexts applied in papers were extracted statistically. The context of primary studies were divided into 8 categories: (1) Energy use management; (2) Decision making behavior and process of Human; (3) Manufacturing and retail industry; (4) Transportation tool allocation or routing; (5) Disaster management; (6) IT technology; (7) Social & Economic & Medical issues; (8) Others (see Table 5).

**Table 5.** Context categories of all primary studies.

<table>
<thead>
<tr>
<th>Category</th>
<th>Context</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use management</td>
<td>Electricity market (3); Power market; Mineral resource; Water management(2); Petroleum industry; Material recycle</td>
<td>9</td>
<td>15%</td>
</tr>
<tr>
<td>Decision making behavior and process of Human</td>
<td>Market participant behavior (3); Pedestrian behavior; Human behavior (3); Human decision making process(2);</td>
<td>9</td>
<td>15%</td>
</tr>
<tr>
<td>Manufacturing and retail industry</td>
<td>Supply chain; Supplier and retailer; Supplier selection (3); Vendor selection; Garment style design; Strategic planning forecast;</td>
<td>8</td>
<td>13%</td>
</tr>
<tr>
<td>Transportation tool allocation or routing</td>
<td>Vehicle allocation; Port berth allocation; Container dispatching; Routing(4);</td>
<td>7</td>
<td>11%</td>
</tr>
<tr>
<td>Disaster management</td>
<td></td>
<td>5</td>
<td>8%</td>
</tr>
<tr>
<td>IT technology</td>
<td>Air combat tactics; Ubiquitous; Game playing; Spam mail mitigation; Future call predication; Multi-sensor detection;</td>
<td>6</td>
<td>10%</td>
</tr>
<tr>
<td>Social &amp; Economic &amp; Medical issues</td>
<td>Trading (2); Stock market; Business risk management; Social security(3); Patient management; Medicine (2);</td>
<td>10</td>
<td>16%</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>8</td>
<td>13%</td>
</tr>
</tbody>
</table>

Seeing from the context categories of all primary studies, DFT theory is widely used in all sector of society. Broadly speaking, most researchers focus on social, economic and medical industries that account for 10 out of 62 papers. The energy management industry and manufactory industry are right behind, with 9 relevant papers.
respectively. The information obtained from these application context was analyzed for answering the **RQ 2: What context are decision field theory applied in?**

This research is aimed to solve decision making problem under complex decision making environment. There is amount of complex decision making environment in real world. The context of class attendance as one example of such complex environment, was selected to evaluate proposed model. Among the 8 categorizes listed above, some context are also examples of complex environment. However, researchers simplify the context and ignore the complex dynamic characteristic. Therefore, it is possible to apply DFT model in complex environment of decision making.

Furthermore, class attendance that should belong to field of Education. However, there is no primary studies focused on this field. This study is aware of the weakness and make improvement on it. Therefore, it is promising and novel to adopt extended model in class attendance.

In addition, the practical application of DFT were studied through further reviewing the primary studies. The results is able to answer the **RQ 3: What practical application of DFT are developed in primary studies?**

The primary studies includes much practical application of DFT, for example rule-based decision field theory, multi-criteria decision field theory, multi-alternative decision field theory, and time critical decision field theory. The researchers (Roe et al., 2001) rebuild decision field theory as a connectionist network and use it to encompass multi-alternative decision making that is adopted successfully in economic or psychological context (Usher, 2004). The rule-based decision field theory is firstly generated by Johnson et al. (2005) and subsequently apply in routing field to study driver behavior (Gao, 2011) or control driving speed (Zhao, 2011). Lin et al. (2008) propose a dynamic multi-attribute decision making model to deal with the problem of uncertain information and aggregate the multi-period evaluations.

However, almost no application of DFT model in primary papers is able to be adopted directly under complex environment of decision making. Thus, it is necessary to build an extended DFT model for complex problems of decision making.

### 3.6.3 Publication year of paper

Apart from the implication discussed above, the finding getting from publication year of papers also provided implication for this research. The Figure 5 below shows two groups trend of paper publication between 1965 and 2014. One group is the 614 papers remained in step 1 while the other group is the 62 primary studies. They are termed as “All papers” and “Primary studies”.
Figure 5. Trend of publication year

Seeing both from “All papers” group and “Primary studies” group, the number of latter group is much less than that of former on. However, a clear growth of publication amount appears since around 2005 in both groups. It indicates that practical application of DFT attracts increasing attention of professional fellows although no much existing studies focusing on this direction.

The answers for review question 3 proves the necessity of extending DFT model. The trend of publication year shown above implies that this research not only contributes application classification, but also follows the research trend in the direction of application of DFT.
4. Decision Field Theory Extension

Decision field theory is proposed to explain human decision making behavior under dynamic environment. Typically, the human behavior of decision making is difficult to understand and predict because the decision is changeable frequently over time. Xiang et al (2002) define the decision making as time-critical dynamic decision making. It is the time that is regarded as influence factor, which produces the behavior of dynamic decision making (Horvitz et al., 1995). Considering further, dynamic environment is the primary cause rather than the time. The environment changes frequently because new information enter into it at any time. As time goes on, the dynamic behavior caused by new information is illustrated as Figure 6 below.

![Figure 6](image)

**Figure 6.** Influence of new information on decision making

In actual, the dynamic decision making is a process of preference switch from one option to another option. At the initial time state t1, decision makers would like to choose the option 3 (O3) among the four options under current environment. Since some new information obtained, however they may switch preference from O3 to O1 after taking into consideration all available information and possible consequences. At every moment the information coming in, decision makers undertake a new round of estimation, and then make a new optimal decision.

The DFT is able to interpret and explain the process of preference evolution in a mathematical approach. In normal, research related DFT regard the changes of weight value as the reason for the process of preference evolution. Under the dynamic
environment, it is true that weight values of decision maker on relevant attributes are dynamic. In this case, DFT can’t account for dynamic behavior well.

However, this explanation is limited when environment is complex dynamic. Therefore, the focus of this chapter is on building an extended model. The principles and components of original DFT are studied firstly. In terms of the limitation of original DFT, the dynamic structure of analytic hierarchy process is adopted. By integrating with AHP structure, the extended DFT model is built.

### 4.1 Review of decision field theory

As mentioned above, DFT is a cognitive approach to understand the mechanism of deliberation process under uncertain environment. DFT is a method that provides insights into relationship between preference evolution and dynamic decision making. The original and classic mathematical equation (see Eq. (1)) is used to explain the dynamic evolution of preferences during the deliberation time.

\[
P(t + h) = SP(t) + V(t + h)
\]  

(1)

The row vector, \( P(t) = [P_1(t), P_2(t), ..., P_n(t)] \) represents the preference state at time \( t \) for the \( n \) options. The Eq. (1) can be decomposed further as

\[
p_i(t + h) = s_{ii} \cdot p_i(t) + \sum_{k \neq i} s_{ik} \cdot p_k(t) + v_i(t + h)
\]  

(2)

In general, DFT consider time as a dynamic factor which lead to frequent change in human’s preference among various options. So for the time series \( \{t_0, t_1, t_2, ..., t_i, t_j, ..., t_n\} \), the preferences on options fluctuate upon specific time point and forms preferences series \( \{p_{0i}, p_{1i}, p_{2i}, ..., p_{ji}, p_{ki}, ..., p_{ni}\} \). In Eq. (1), time point \( t \) and \( t+h \) are two adjacent time moments, and parameter \( h \), referred as time unit, denotes the distance between two moments of decision making. From microscopic side, decision making is a continuous process when the moment is sequential. So the length of \( h \) approaches to zero in the limit (Abad, 2014). While from the macroscopic side, decision making is intervallic. Thus, time unit \( h \) is equal to an arbitrary value. Apart from \( h \), each variable of Eq. (1) is described below.

#### 4.1.1 Growth-decay matrix \( S \)

The decision makers’ perception of decision case is not only determined by current information, but it also would be affect by their previous knowledge or similar experience (Van Horne, 1967). Consequently, the preferences value in current moment are influenced positively or negatively by decision makers’ memory. The matrix \( S \), referred as feedback vector, is formed as \( S = (I - h\Gamma) \) that is assumed to be
symmetric ($r_{ij} = r_{ji}$ for all $i, j$). The diagonal elements of $s_{ii}$ provide memory for previous states of the system. The off-diagonal values of $s_{ik}$ allow for competitive interactions among competing alternatives. The researchers (Busemeyer et al., 2008; Qin et al., 2013) explain the implication of $s_{ii}$ value in four conditions as follow.

- $0 < s_{ii} < 1$ indicates that memory of decision maker has positive feedback on current decision problem.
- $s_{ii} > 1$ suggests that memory of decision maker has negative feedback on current decision problem.
- $s_{ii} = 0$ means that memory of decision maker has no influence on current decision problem.
- $s_{ii} = 1$ expresses that memory of decision maker has perfect impact, not decay or growth, on current problem.

4.1.2 Valence vector $V$

The row vector, $V(t) = [v_1(t), v_2(t), ..., v_n(t)]$ represents the valence input at time $t$ for the $n$ options. The valence vector $V(t)$ is consist of three matrix (see Eq. (3)).

$$V(t) = C M W(t)$$

At time $t$, the anticipated value of an option on an attribute is compared with the anticipated values of other options on the same attribute. These comparisons produce a valence for each option, denoted $v_i(t)$, for the valence of option $i$ at time $t$.

The matrix $C$ is called contrast matrix, the elements of which are valued as $c_{ii} = 1$ and $c_{ij} = -1/(n-1)$ for $i \neq j$ where $n$ is the number of option. For instance,

$$C = \begin{bmatrix}
1 & -1/(n-1) & \cdots & -1/(n-1) \\
-1/(n-1) & 1 & \cdots & -1/(n-1) \\
\vdots & \vdots & \ddots & \vdots \\
-1/(n-1) & -1/(n-1) & \cdots & 1
\end{bmatrix}$$

Matrix $C$ is defined to compare all the options between each other and the structure of it guarantees the sum of $V(t)$ components always equals to 0.

$M$ is called attribute matrix that is an $n \times m$ matrix ($n$ is the number of options and $m$ is the number of attribute). The expression of it is presented as
The attribute matrix $M$ represents decision makers’ evaluations for each option on each attribute under certain conditions. Take class attendance for example, students would consider time arrangement and quality of class as attributes when they make decision on attending lecture or exercise. Of course, there are other attributes influencing students’ decision, which is discussed further next chapter. Apparently, some or all attributes have opposite effect on evaluation of decision. That’s the reason why people always feel hard to make a decision.

<table>
<thead>
<tr>
<th>Example</th>
<th>Time arrangement</th>
<th>Quality of class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>$m_{11}$</td>
<td>$m_{12}$</td>
</tr>
<tr>
<td>Exercise</td>
<td>$m_{21}$</td>
<td>$m_{22}$</td>
</tr>
</tbody>
</table>

$W(t)$, called weight matrix, is a $m \times 1$ matrix (m is the number of attribute) that indicates the weights of attention people allocates to each attribute of $M$. Simply put, the number of each weight value indicates how important the attribute is in decision. The decision of people is changing moment by moment, which is caused by the variability of $W(t)$.

The Figure 7 illustrates how the mechanism of each element act on preferences. It is clear to see deliberation process of people and the reasons causing dynamic decision making.

![Figure 7. Mechanism of each element (revised from Qin et al. (2013))](image-url)
The essence of dynamic decision making is the changes on preferences value on options. The evolution process of preference state is the result of dynamic valence that is consist of three elements: contrast matrix, attribute matrix and weight matrix. In original DFT model, the value of contrast matrix and attribute matrix is constant while the value of weight matrix is changeable. Under the dynamic environment, weight of attention switches from on attribute to another as new information entering. Accordingly, valence value and preference states changes. Consequently, decision making becomes a dynamic process.

In summary, the limitation of original DFT model motivate this study to build an extended model. In order to improve flexibility of model, the structure of analytic hierarchy process was adopted.

4.2 Definition of Analytic Hierarchy Process

Analytical hierarchy process (AHP) founded by Saaty (1977), is original structured to manage the problems of multi-criteria decision making. In our daily life, people are required to consider multiple conflicting criteria in problems of decision making. For example, economy and quality are two conflicting criteria in decision making case of car purchase. Since the weight values of attributes in some problems are scalable, AHP is improved to solve complex scaling problem by mathematical method.

4.2.1 Why is AHP

In original DFT model, the number of attribute and each value of them are given at first and no changes along with dynamic decision making. It is regarded as a limitation because fixed attribute matrix can’t adapt to complex dynamic environment. Taking class attendance as example again, evaluation for each attributes are dynamic along with students getting know the course better. In addition, new attribute of class attendance would be taken into consideration as time goes on. So, both the evaluation value of decision maker on relative attributes and the number of attribute are changing when the environment is complex dynamic. Therefore static attribute matrix $M$ should be extended. During the development process of AHP, its structure is refined from static to dynamic. AHP can adapt to complex environment for solving dynamic decision making problem. Importantly, the feature of dynamic structure of AHP is able exactly to remedy the limitation of original DFT model. Therefore, the dynamic AHP structure was adopted to extend DFT model in this research.

4.2.2 Static AHP structure

AHP provides a structured method to value and quantify each element related to overall goal for evaluating every options (Saaty, 1984). It is widely used all over the world in the industries, for example public services and facilities, organization
management and education. Since AHP is developed, it is used to solve many types of problems, such as group decision making (Saaty, 1989) or fuzzy multi-criteria decision making (Shee, 2003). The static structure of AHP is displayed as Figure 8 below.

![Figure 8](image_url)  
**Figure 8.** Static structure of AHP

In this structure of AHP, the environment of decision making is static. The value distribution of criteria is the only influence on final decision. In static structure of AHP, user is required to identify all criteria at the beginning and pre-evaluate the weight value on each criteria. Moreover, the value and number of criteria will not be changed. As a result, the option with highest numerical result is most able to achieve the goal. However, Benítez et al. (2012) argues that the feature of static is a biggest weakness that can’t make AHP theory adapt to dynamic cognition of people and uncertainty of environment.

In order to solve dynamic decision making problem, dynamic structure of AHP with good flexibility and adaptability is proposed as follow.

### 4.2.3 Dynamic AHP structure

Just as the principle of DFT model, the weight value on each criteria would be changed since decision makers obtain information continuously. In this sense, the new information can be regarded as new criteria. Therefore, the reason for decision maker changing mind is that they consider new criteria. Saaty (1999) also suggests that criteria set can be changed to adapt to new condition even they have been set up initially. Compared with the static AHP structure showed above, two situation of dynamic structure are illustrated as follow (see Figure 9 and Figure 10).

Add (delete) a criteria:

In this dynamic AHP structure, criteria is allowed to be added (deleted) as time goes on. Accordingly, the weight value of each criteria should be re-allocated. And one important rule has to be mentioned here is that the total weight value of all criteria is always equal to 1 although the structure of AHP is changing over time.
For extended DFT model, the attribute matrix should be dynamic to adapt to complex dynamic environment. The characteristic of this dynamic AHP structure is that the number of criteria is dynamic, which right meets the extra feature of extended model. Therefore, this dynamic AHP structure is adopted for extended model building.

Delete (add) an option:

In some cases, decision maker would have more or less options along with environment changing. Hence, this dynamic AHP structure is able to add or delete options to adapt to dynamic environment. However, this situation is not suitable for the context of class attendance in this research. Therefore, this dynamic structure is not considered to use in extended DFT model.

### 4.3 Extended DFT model

The extended DFT model is built by integrating with dynamic structure of AHP. The improved mathematical equation is composed as Eq. (6)

\[ P(t + h) = SP(t) + CM(t + h)W(t + h) \]  

(6)
Compared with the original DFT equation, the variable calculation of contrast matrix \( C \) and feedback matrix \( S \) are same while that of the attribute matrix \( M \) and weigh matrix \( W \) are different. All elements extended are explained and the contribution each of them to model are discussed as follow.

**Attribute matrix \( M(t+h) \)**

In original model, the attribute matric \( M \) is described as a static parameter. But in some complex dynamic environment, the attributes can’t be defined at one time as the explanation of dynamic structure of AHP. More importantly, the value of evaluation on each attribute are also dynamic along with people getting know the problem better. The dynamic AHP structure (see Figure 10) suggests that add or delete attributes are feasible. With integration of DFT and AHP, the matrix \( M \) is defined as a variable \( M(t+h) \). The time unit \( h \) represents the time interval between two points of decision making.

\[
M(t+h) = \begin{bmatrix}
m_{11}(t+h) & m_{12}(t+h) & \cdots & m_{1n}(t+h) \\
m_{21}(t+h) & m_{22}(t+h) & \cdots & m_{2n}(t+h) \\
\vdots & \vdots & \ddots & \vdots \\
m_{n1}(t+h) & m_{n2}(t+h) & \cdots & m_{nn}(t+h)
\end{bmatrix}
\]

OR

\[
M(t+h) = \begin{bmatrix}
m_{11}(t+h) & m_{12}(t+h) & \cdots & m_{1n}(t+h) & m_{1(n+1)}(t+h) \\
m_{21}(t+h) & m_{22}(t+h) & \cdots & m_{2n}(t+h) & m_{2(n+1)}(t+h) \\
\vdots & \vdots & \ddots & \vdots \ddots & \vdots \\
m_{n1}(t+h) & m_{n2}(t+h) & \cdots & m_{nn}(t+h) & m_{n(n+1)}(t+h)
\end{bmatrix}
\] (7)

The first matrix means the value of evaluation on each attribute are dynamic upon the time, while the second matrix indicates the number of attribute also can be added (deleted) later. The specific content of this matrix is discussed in the next chapter.

**Weight matrix \( W(t+h) \)**

The weight attention of each attribute in matrix \( W(t+h) \) is changeable in original DFT theory, which is similar to the definition of that in dynamic AHP structure. In DFT model, the sum of all weight values of attributes are in random number. In order to standardize the DFT model, the sum of weight values are set always to be equal to 1 which learn from dynamic AHP structure as well.

So, \( W(t+h)^T = (w_1(t+h), w_2(t+h), \ldots, w_n(t+h)) \), and for any time point \( t \),

\[
w_1(t+h) + w_2(t+h) + \ldots + w_n(t+h) = 1
\]
5. Class Attendance Context

Class attendance has been a dominant teaching and studying method for a very long time in university. It is considered as a good channel that provides connection between teachers and students in regular time and place. However, the phenomenon that students would like to choose other ways instead of attending lecture for acquiring knowledge, has been increasingly obvious. This problem causes curiosity and concern of educational researchers. In this chapter, the viewpoints regarding to class attendance are discussed from the perspective of teacher and student, and summarized four main reasons for class missing and not missing. In summary, all the discussion are used for model construction.

5.1 Reasons for class attendance or non-attendance

The phenomenon that students do not attend classes attracts increasing attention of educational fellows. There are much study related to the discussion of strength and weakness of class attending. Bonwell (1996) pointes out the advantages and disadvantage of lecture as an educational way. He argued that lecture could present large amount information through face-to-face communication way and meet requirements of particular students. In addition, the lecture provides a platform where teacher and students can have interaction regarding to questions and answers. In addition, Hunter et al. (1999) also demonstrates that attending class can give students an overview of subject, and then stir up students’ interest for subject. What’s more, teacher could present some materials that are not available for students in other ways.

As a traditional way, however, some typical characteristics of attending class are considered as disadvantages sometimes. Both research of Bonwell (1996) and Hunter et al. (1999) mention one weakness that class attending is a teacher-centered ways and students are passive because there is no method to judge students are really listening intellectually. The information is inflexible and limited to get from traditional class, compared with online education (Volery, 2000). Allen et al. make comparisons of online education and face-to-face instruction, which provides support for non-attendance.

From the early stage of 20th century, many researchers attempt to provide insights into why students do or do not attend class. They propose reasons for attendance or non-attendance of students in terms of life-style changing, teaching and attitudes (Fleming, 1992; Fleming, 1995; Hunter, 1999). Hunter also suggests that non-attendance trend can be explained by lack of acknowledgement for the use of class. An email survey organized by Clay et al. (2004) is aimed to find the attitudes of
students to class attending and investigate the percentage of attendance. Finally, the results shows that 67% students attended more than 90% classes, 76% students attended more than 75 classes and almost 93% students attended more than 50% classes. Moreover, Kottasz (2005) conducts an empirical research to explore the factors underlying attendance and non-attendance via study a 155 undergraduates at the University of London Metropolitan. He analyzes students’ viewpoints and give the most prominent reasons for class attendance and non-attendance.

**Reasons for class attendance**

The researcher offer 6 main reasons for class attendance (see Table 6), and they can be divided into intrinsic reasons and extrinsic reasons. To be specific, the intrinsic reasons include the interest students have in course subject (approximately 80% students attending class for this reason), their feeling about teacher (about 75% students appraise teacher good), and the pressure that get from parents and other assignments (only 15% students state stressful). On the other hands, the extrinsic reasons are consist of the motivation of good grade (more than 90% students claims desire to achieve good grade), the available material and guidance from teacher.

**Table 6. Reasons for class attendance (Kottasz, 2005)**

<table>
<thead>
<tr>
<th>Reasons for NOT missing:</th>
<th>TUTORIALS: % agreeing or strongly agreeing with these statements</th>
<th>LECTURES: % agreeing or strongly agreeing with these statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance is vital if I want to achieve good grades</td>
<td>93%</td>
<td>97%</td>
</tr>
<tr>
<td>The subject is difficult and complex to learn without help and guidance</td>
<td>65%</td>
<td>73%</td>
</tr>
<tr>
<td>Tutor/ Lecturer is good</td>
<td>77%</td>
<td>76%</td>
</tr>
<tr>
<td>Lot of material is handed out and it would be difficult to catch up</td>
<td>69%</td>
<td>82%</td>
</tr>
<tr>
<td>Parents/ family put pressure on me to attend tutorials/ lectures</td>
<td>8%</td>
<td>20%</td>
</tr>
<tr>
<td>I am genuinely interested in this subject</td>
<td>81%</td>
<td>82%</td>
</tr>
</tbody>
</table>

**Reasons for class non-attendance**

There are 11 reasons proposed by the causes for non-attendance of class (see Table 7). 61% students claim that they are absent from lecture because they have to spend time on the assignments of other courses. Almost in same percentage level, the students
miss lecture caused by the problems of transportation. It is also indicates that students (61%) explain the time of lecture sometimes conflict with other events, while 72 percentage of students don’t attend lecture for the illness excuse. Interestingly, the students with 23% miss the lecture just because they think the tutor or lecture is not good, or the content of tutorial/lecturer is poor. The rest of reasons listed are materials available, worthy of class, other works, attitudes of lecture or tutor and others.

**Table 7. Reasons for class non-attendance (Kottasz, 2005)**

<table>
<thead>
<tr>
<th>Reasons for missing:</th>
<th>TUTORIALS: % agreeing or strongly agreeing with these statements</th>
<th>LECTURES: % agreeing or strongly agreeing with these statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can get the tutorial or lecture material in other ways</td>
<td>15%</td>
<td>38%</td>
</tr>
<tr>
<td>Tutorials or lectures are not worth attending</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Times are not always right</td>
<td>38%</td>
<td>50%</td>
</tr>
<tr>
<td>Illness</td>
<td>45%</td>
<td>72%</td>
</tr>
<tr>
<td>Transportation problems</td>
<td>44%</td>
<td>61%</td>
</tr>
<tr>
<td>Work commitments elsewhere</td>
<td>26%</td>
<td>14%</td>
</tr>
<tr>
<td>Poor content of tutorial or lecture</td>
<td>20%</td>
<td>23%</td>
</tr>
<tr>
<td>Poor tutor or lecturer</td>
<td>19%</td>
<td>23%</td>
</tr>
<tr>
<td>Tutor or lecturer has disregard for the student</td>
<td>10%</td>
<td>14%</td>
</tr>
<tr>
<td>Have to work on other assignments</td>
<td>28%</td>
<td>61%</td>
</tr>
<tr>
<td>Cannot be bothered</td>
<td>9%</td>
<td>15%</td>
</tr>
</tbody>
</table>

There is amount of research focusing on increasing trend of non-attendance, however less scholar focus on how to solve this problem. There are few methods and technologies that are applied in order to raise attendance rate, Wilder et al. (2001) use random extra credit quizzes in an undergraduate course. Consequently, the results show that the method positively increase and maintain students’ attendance. Interestingly, the lecturer (Shannon, 2006) provides MP3 uploads and set iPod nanos in classroom to encourage students to listen in lecture. This technology makes contribution to manage students’ participation.
5.2 Attribute matrix construction

The class attendance is an example of complex decision making environment. It is used to evaluate the performance of the extended DFT model. In DFT model, attribute matrix represents the evaluation for each option on each attribute. All the reasons discussed above can be seen as the relevant factors that influence students’ behavior independently of each other. In the context of this research, the complex problem of class attendance or non-attendance can be analyzed in terms of several aspects.

Four reasons of attendance and non-attendance were extracted as the elements of attribute matrix (see Table 8). Although all the reasons stated above are relative attributes of class attendance, but only four were selected in order to simplify model. One characteristic of attribute matrix is that all or part of attributes effect oppositely on decision making about class attending. Therefore, the representative reasons are from each of Table 6 and Table 7. For the class attendance, two reasons with highest percentage of students’ agreement were selected. They are named as expectation for good grade and interest in subject. For the class non-attendance, uncontrollable reasons (such as illness or transportation problems) were firstly excluded, and then two reasons with most strongly agreement were selected. They are termed as time management and workload from other tasks. The number and value of evaluation of attributes are dynamic, so these four attribute are temporary initially. According to the results of web survey (see chapter 6), the fifth attribute will add.

**Table 8. Attribute selection for matrix**

<table>
<thead>
<tr>
<th>No</th>
<th>Attribute</th>
<th>Decision</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Time management</td>
<td>Non-attendance</td>
<td>Times are not always right</td>
</tr>
<tr>
<td>A2</td>
<td>Workload from other tasks</td>
<td>Non-attendance</td>
<td>Have to work on other assignments</td>
</tr>
<tr>
<td>A3</td>
<td>Expectation for good grade</td>
<td>Attendance</td>
<td>Attendance is vital if I want to achieve good grades</td>
</tr>
<tr>
<td>A4</td>
<td>Interest in subject</td>
<td>Attendance</td>
<td>I am genuinely interested in the subject</td>
</tr>
</tbody>
</table>

Until now, the attributes are identified. In summary, students take into consideration these four attributes when they are making decision on class attendance. In order to test the performance of model, the matrix elements should be valued in certain number. The next chapter discusses how the data is collected to value relevant elements of proposed model.
6. Data Collection for Extended DFT Model

The extended model was constructed by importing dynamic structure of AHP. According to the results of systematic literature review, web survey was determined to collect data for DFT model. In this chapter, data collection was conducted to not only test the possibility of adopting the DFT model in complex dynamic environment, but also provide data for further evaluation.

6.1 Background

This web survey was undertaken based on the course: Basic of Statistical Data Analysis of Information Processing Science (BSDA) which is a Bachelor-level course aimed to deliver the contents about statistic data, data collection methods, measurement and variables, sampling, management of statistical data, descriptive statistics, graphical presentation of data, basics of data analysis. It was held in the spring semester from January to March, 9 weeks in total. The course was delivered by face to face and organized in two formations: lecture and exercise. The lecture was arranged once per week and aimed to deliver knowledge of statistical methodologies, while the exercise was arranged once per week and aimed to teach students how to manipulate statistical tools. Moreover, the students were allowed to participate in classes by four ways: attending lecture, attending exercise, attending both of them and self-studying instead of attending classes. They were free to choose any way, each of which has equal effect on final grade. Based on the attributes and options of class attending, the attribute matrix $M(t)$ and weight matrix $W(t)$ are defined as below.

### Table 9. Attribute matrix and weight matrix

<table>
<thead>
<tr>
<th>Attribute Matrix $M(t)$</th>
<th>Time management</th>
<th>Workload from other tasks</th>
<th>Expectation for good grade</th>
<th>Interest in subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend lecture</td>
<td>$m_{11}$</td>
<td>$m_{12}$</td>
<td>$m_{13}$</td>
<td>$m_{14}$</td>
</tr>
<tr>
<td>Attend exercise</td>
<td>$m_{21}$</td>
<td>$m_{22}$</td>
<td>$m_{23}$</td>
<td>$m_{24}$</td>
</tr>
<tr>
<td>Attend both</td>
<td>$m_{31}$</td>
<td>$m_{32}$</td>
<td>$m_{33}$</td>
<td>$m_{34}$</td>
</tr>
<tr>
<td>Self-study</td>
<td>$m_{41}$</td>
<td>$m_{42}$</td>
<td>$m_{43}$</td>
<td>$m_{44}$</td>
</tr>
<tr>
<td>Weight Matrix $W(t)$</td>
<td>$w_1$</td>
<td>$w_2$</td>
<td>$w_3$</td>
<td>$w_4$</td>
</tr>
</tbody>
</table>
The person in charge of this survey were the author of this thesis and the supervisor who was also the lecturer of BSDA course. Both of them involved in, controlling and managing the whole process of this web survey. In addition to gather the data required in this thesis, the other motivation was to follow the student studying statues and collect feedback related to teaching things. But the results of this aspect are not mentioned in this thesis.

6.2 Design of Web Survey

The overall purpose of this survey is to study dynamic process of decision making of students on options of attending class and study out-of-class regarding to specified aspects. There were three separate and successive rounds of web survey, the data getting from each of round were analyzed in order to quantify proposed DFT model.

6.2.1 Participant

The survey was carried out based on the BSDA course, and the participants were the students who enrolled in this course. There were 55 students enrolled in the course, most of them were third-year students of bachelor’s degree in the department of Information Processing Science. Therefore, all the participants were assumed to have the educational background of ICT and able to have the basic idea about this web survey. In real course, students being present at class were required to sign their own name on attendance list, which was aimed to summarize participant rate.

To be specific, brief description of next round was announced in the lecture before start of web survey. After that, every student received an invitation email that contains private link to survey page. During validate period of each round, one or more reminding email were sent to the students who didn’t participate in web survey. It is worth noting that this web survey was optional and anonymous for the students, therefore they were voluntary to take part in any or all rounds of survey. Students was allowed to submit web survey only once, and they can not submit it any more once survey is stop.

6.2.2 Time arrangement

In order to describe the dynamic decision making of students, the web survey had three rounds, respectively conducting at the beginning, middle and end stage of course span. The web survey begun from January 12th, and ended on March 15th. The duration of whole web survey was 9 weeks and it was divided into three rounds. Table 10 shows the time duration for each round.
Table 10. Time duration for three rounds

<table>
<thead>
<tr>
<th>Round</th>
<th>Start date</th>
<th>End date</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1</td>
<td>Jan 12th</td>
<td>Feb 8th</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Round 2</td>
<td>Feb 9th</td>
<td>Mar 1st</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Round 3</td>
<td>Mar 2nd</td>
<td>Mar 15th</td>
<td>2 weeks</td>
</tr>
</tbody>
</table>

At the beginning of the round 1, relevant instruction and guideline were given to all the students regarding to how to handle with the web survey. The round 1 begun in Jan 12th when was one week after course opening. It lasted four weeks, and located in course week 2, 3, 4, 5. The course settings and web survey were new for all the participants, therefore the period of round 1 was arranged longest. While the round 2 started in Feb 9th and right followed the round 1 finish. It continued three weeks, and located in course week 6, 7, 8. For the last round survey, it conducted from Mar 2nd to 15th. The round 3 only lasts two weeks, and located in course week 9 and one week after closure of course. At end of the course, some students lose their motivation to take part in web survey. Therefore, the duration of this round was shortest.

6.2.3 Questions

The answers of question was used to quantify the extended model. Because the elements of the model is dynamic, the questions were not exactly same in each round (see Appendix B, C, D). In order to make students much clearer about questions setting, all questions were categorized into different parts. Some parts of web survey were used for the sake of management of teaching quality, therefore the part only related to DFT model was Study practice for BSDA part.

Background information part was set to gather students’ personal information, such as age, study year, number of credits and number of courses. The questions of this part were removed because the answers of them are objective and not necessary to collect again. Moreover, Study practice for BSDA course part was used to explore how students perceive the attending ways in this course. It was the common part of three rounds because the data from those questions were used to value variables of DFT model. Importantly, the questions of Study practice for BSDA course part were changed slightly in content and number, in order to fit with dynamic process of decision making.

In round 1, there were 6 web survey questions (WS-Q) asked to quantify the components of extended model. For the questions from WS-Q2 to WS-Q5, the grading scale was set from number 1 to 7. For the question WS-Q7, the scale was from number 1 to 5. Higher numerical number represents more strongly agree with
the statement of question. The specific question and respective purpose are explained as follow.

**WS -Q1:** *Which way do you prefer to study this course?* The question was designed to get the intended behavior of students on class attending ways. The answers of this question were used to compare with actual behavior of students.

**WS -Q2:** *To what extent do you agree or disagree the statement that studying in the following way makes my personal time management easier?* The studying ways are four options of class attending: Attending lecture, Attending exercise, Attending both lectures and exercise, and Self-studying instead of attending lecture or exercise. This question was set to get the evaluation values \((m_{11}, m_{21}, m_{31}, m_{41})\) of four options in attribute of *Time management.*

**WS –Q3:** *To what extent do you agree or disagree the statement that workload from other tasks makes me willing to studying in the following way instead of the other ways?* The answers of this question was used to value the elements of attribute \((m_{12}, m_{22}, m_{32}, m_{42})\) *Workload from other tasks* on four options.

**WS –Q4:** *To what extent do you agree or disagree the statement that studying in following way helps me achieve better grade?* This question was set to get the evaluation values \((m_{13}, m_{23}, m_{33}, m_{43})\) in the attribute of *Expectation for good grade* on four class attending options.

**WS –Q5:** *To what extent do you agree or disagree the statement that learning the subject in the following way is interesting to me?* The answers of this question was used to value the elements of attribute \((m_{14}, m_{24}, m_{34}, m_{44})\) *Interest in subject* on four ways of class attending.

**WS –Q6:** *Besides the four attributes mentioned above, please select one or more attribute from below that you feel important to your decision on attending lecture/exercise or not.* This was the key question that change the attribute number of extended model. It was assumed that there maybe have new attribute that influence students’ decision on class attending as they getting know course more. The options of this question were possible additional attribute. The option selected most by students was the fifth attribute of proposed model.

**WS –Q7:** *Please rate the attributes below in terms of how important they are for you when you think about attending lectures/exercises or not.* The answer of this question is used to calculate the weight value \((w_1, w_2, w_3, w_4)\) of each attributes.
In round 2 and round 3, the fifth attribute was added according to students’ answers. Therefore, the web survey in round 2 and round 3 had an additional question which was set to get the evaluation value in the fifth attribute on four options. Hence, the number of attributes listed in WS–Q7 increased from 4 to 5.

6.3 Results

The three rounds of web survey successfully collected the data that was analyzed generally as follow.

6.3.1 Participation rate

The number of participants in three round web surveys is showed on Table 1. In addition, the participation rate and decrease rate compared with previous round of web survey are calculated as well.

<table>
<thead>
<tr>
<th>Round</th>
<th>Number of students in total</th>
<th>Number of participant</th>
<th>Participation rate</th>
<th>Decrease on ROR basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st round</td>
<td>55</td>
<td>48</td>
<td>87%</td>
<td>_</td>
</tr>
<tr>
<td>2nd round</td>
<td>55</td>
<td>48</td>
<td>87%</td>
<td>0%</td>
</tr>
<tr>
<td>3rd round</td>
<td>55</td>
<td>38</td>
<td>69%</td>
<td>20.8%</td>
</tr>
</tbody>
</table>

In the round 1, there were 48 students participated in web survey after sending three times reminding email. The age of those respondents are ranging from 18 to 47, averaged 25. The purpose of this round was to know the first impression on the course as well as their initial intended behavior on class attending ways. In typical, the number of participants was less and less as time goes on. However in the round 2, there were still 48 students participated in the web survey, which was much more than what expected. In the round 3, there were 38 students involved in the web survey. Though it decreases by 10 students, the participant amount is still good.

6.3.2 Answer to questions

There were 7 common questions of three rounds and 1 additional question of latter 2 rounds. The results of those questions were summarized as follow.

**WS –A1:** Through collect and sort the answers of WS- Q1 in three rounds of web survey, the intended behavior of students on four options of class attending is depicted in the Figure 11.
Figure 11. Intended behavior of students on class attending

Seeing from the bar chart above, most of students were willing to attend both lecture and exercise. Then, attending exercise had second greatest favor of students. The next two options were self-study and attend both in descent order.

WS –A2: The evaluation value of participants regarding to attribute Time management are presented in the follow Table 12.

**Table 12. Evaluation value regarding to attribute Time management**

<table>
<thead>
<tr>
<th>elements</th>
<th>round 1</th>
<th>round 2</th>
<th>round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend lecture</td>
<td>$m_{11}$</td>
<td>4.33</td>
<td>3.73</td>
</tr>
<tr>
<td>Attend exercise</td>
<td>$m_{21}$</td>
<td>4.81</td>
<td>4.67</td>
</tr>
<tr>
<td>Attend both</td>
<td>$m_{31}$</td>
<td>4.46</td>
<td>4.</td>
</tr>
<tr>
<td>Self-study</td>
<td>$m_{41}$</td>
<td>4.23</td>
<td>4.56</td>
</tr>
</tbody>
</table>

Obviously, students’ evaluation for four options in this attribute experienced a dynamic process, which match with the real status under complex dynamic environment.

WS –A3: The evaluation value of participants regarding to attribute Workload from other tasks are displayed in the follow Table 13.

**Table 13. Evaluation value regarding to attribute Workload from other tasks**

<table>
<thead>
<tr>
<th>elements</th>
<th>round 1</th>
<th>round 2</th>
<th>round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend lecture</td>
<td>$m_{12}$</td>
<td>3.77</td>
<td>3.29</td>
</tr>
<tr>
<td>Attend exercise</td>
<td>$m_{22}$</td>
<td>4.77</td>
<td>4.83</td>
</tr>
<tr>
<td>Attend both</td>
<td>$m_{32}$</td>
<td>4.06</td>
<td>3.63</td>
</tr>
<tr>
<td>Self-study</td>
<td>$m_{42}$</td>
<td>4.52</td>
<td>4.40</td>
</tr>
</tbody>
</table>
WS –A4: The evaluation value of participants regarding to attribute *Expectation for good grade* are presented in the follow Table 14.

**Table 14. Evaluation value regarding to attribute Expectation for good grade**

<table>
<thead>
<tr>
<th>elements</th>
<th>round 1</th>
<th>round 2</th>
<th>round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend lecture</td>
<td>$m_{13}$</td>
<td>4.25</td>
<td>3.75</td>
</tr>
<tr>
<td>Attend exercise</td>
<td>$m_{13}$</td>
<td>5.83</td>
<td>5.46</td>
</tr>
<tr>
<td>Attend both</td>
<td>$m_{13}$</td>
<td>5.58</td>
<td>5.19</td>
</tr>
<tr>
<td>Self-study</td>
<td>$m_{13}$</td>
<td>3.81</td>
<td>3.9</td>
</tr>
</tbody>
</table>

WS –A5: The evaluation value of participants regarding to attribute *Interest in subject* are calculated in the follow Table 15.

**Table 15. Evaluation value regarding to attribute Interest in subject**

<table>
<thead>
<tr>
<th>elements</th>
<th>round 1</th>
<th>round 2</th>
<th>round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend lecture</td>
<td>$m_{14}$</td>
<td>4.02</td>
<td>3.77</td>
</tr>
<tr>
<td>Attend exercise</td>
<td>$m_{14}$</td>
<td>5.77</td>
<td>5.27</td>
</tr>
<tr>
<td>Attend both</td>
<td>$m_{14}$</td>
<td>4.77</td>
<td>4.56</td>
</tr>
<tr>
<td>Self-study</td>
<td>$m_{14}$</td>
<td>3.88</td>
<td>3.71</td>
</tr>
</tbody>
</table>

WS –A6: The question of WS –Q6 was used to identify the fifth attribute according to the students’ answer. There were six options: difficulty of content, quality of lecture or exercise, presentation of lecturer, size of lecture and exercise, entertainment of lecture or exercise and availability of materials in other ways. In these possible attributes, quality of lecture or exercise gained most agreement of students. Then it becomes the fifth attribute. The extended attribute matrix M is presented as Table 16.

**Table 16. Attribute matric in round 2 and 3.**

<table>
<thead>
<tr>
<th>No</th>
<th>Attribute</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Time management</td>
<td>Round 1, 2, 3</td>
</tr>
<tr>
<td>A2</td>
<td>Workload from other tasks</td>
<td>Round 1, 2, 3</td>
</tr>
<tr>
<td>A3</td>
<td>Expectation for good grade</td>
<td>Round 1, 2, 3</td>
</tr>
<tr>
<td>A4</td>
<td>Interest in subject</td>
<td>Round 1, 2, 3</td>
</tr>
<tr>
<td>A5</td>
<td>Quality of lecture or exercise</td>
<td>Round 2, 3</td>
</tr>
</tbody>
</table>

WS –A7: The weight attention that students allocate to each attribute is dynamic during decision making process. The weigh value of attributes in three rounds are depicted as follow Figure 12.
Figure 12. Weight value of attributes in three rounds.

There were four attributes in round 1 and five attributes in latter two rounds. Apparently, the values among these attributes have no big difference. In addition, the weight value on five attributes between round 2 and round 3 are almost same.

Due to the fifth attribute added, there was an additional question added into web survey of round 2 and round 3. It was asked to get the evaluation value \((m_{15}, m_{25}, m_{35}, m_{45})\) of four options in attribute Quality of lecture or exercise. The answer of this question is displayed as follow Table 17.

Table 17. Evaluation value regarding to Quality of lecture or exercise

<table>
<thead>
<tr>
<th>elements</th>
<th>round 2</th>
<th>round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend lecture</td>
<td>(m_{15})</td>
<td>4.27</td>
</tr>
<tr>
<td>Attend exercise</td>
<td>(m_{35})</td>
<td>5.25</td>
</tr>
<tr>
<td>Attend both</td>
<td>(m_{35})</td>
<td>4.81</td>
</tr>
<tr>
<td>Self-study</td>
<td>(m_{45})</td>
<td>3.75</td>
</tr>
</tbody>
</table>

In summary, same questions appeared repeatedly in different rounds were able to get the dynamic evaluation value and weight value of students, while the added questions made the number of attributes dynamic. Therefore, all the questions designed in this way confirms the possibility of adopting extended model in complex dynamic environment.
7. Evaluation

The extended DFT model was evaluated in terms of prediction ability and explanation ability. The collected data of each round were used to quantify the components of the proposed model firstly. Then, observation of influence of relevant factors on survey result was concluded to explain the student’s decision making. Last but not least, observation of influence of relevant factors on survey result was concluded to explain the student’s decision making.

7.1 Model quantification

In order to evaluate the performance of model, qualifying every parameters and variables was done by using collected data. Because the web survey was divided into three rounds, the deliberation process of students was broken into three segments. Accordingly, the value of each component of DFT and preferences state on each options vary from round to round.

The round 1

In the round 1 of web survey, five questions were related to model qualification. In the result part of chapter 6, brief summary of students’ answers to 7 questions was shown. The results of 7 questions was synthesized and the useful data of them was used to calculate the DFT. There are four unknown components: \( P(t), S, M(t) \) and \( W(t) \) in the mathematical formula of extended DFT model. The time point \( t \) are defined as 0, 1, 2, 3. It was assumed that the students not attended this course before, and it was first time for them to participate in this web survey. Thus, the prior knowledge and experience have no impact on students’ decision making. Therefore, all elements of \( p_i \) \((i = 1, 2, 3, 4)\) are equal to zero for initial preference state \( P(0) \). In addition, the elements \( s_{ik} = 0 \) (for any \( i, k \leq 4 \)) for feedback matrix \( S \) because no web survey was conducted beforehand.

The students’ answers to from question WS – Q2 to WS – Q5 were calculated to value attribute matrix \( M(1) \), while the value of weight matrix \( W(1) \) were calculated based on the answers of question WS – Q7. The resulting matrix are:

\[
\begin{bmatrix}
4.33 & 3.77 & 4.25 & 4.02 \\
4.81 & 4.77 & 5.83 & 5.77 \\
4.23 & 4.52 & 5.81 & 3.88 \\
4.46 & 4.06 & 3.58 & 4.77 \\
\end{bmatrix}, \quad \begin{bmatrix}
0.24 \\
0.27 \\
0.22 \\
0.27 \\
\end{bmatrix}
\]
In this round, the attributes were *Time management, Workload from other tasks, Expectation for good grade* and *Interest in subject* while the options of class attending were *Attend lecture, Attend exercise, Attend both* and *Self-study*. The elements $m_{ik}$ (for any $i, k \leq 4$) of attribute matrix $M(1)$ represents the evaluation value for option $i$ in attribute $k$, while the element $w_k$ (for any $k \leq 4$) of weight matrix $W(1)$ represents the weight value in attribute $k$. Consequently, the preference matrix $P(1)$ were calculated as

$$P(1) = P(0) \cdot S + C \cdot M(1) \cdot W(1) = \begin{bmatrix} -0.6179 & 0.9891 & -0.5594 & 0.1882 \end{bmatrix}.$$  \hspace{1cm} (9)$$

The value of $p_i$ is the preference value of student for option $i$ of class attending.

**The round 2**

Similar to round 1, the unknown components of DFT model were $M(2)$ and $W(2)$ in this round. In addition, an attribute was added to matrix according to students’ answer of an open question which required participants to propose other factors affecting them making decision (see Appendix C). Through ranking and filtering the proposals of students, the fifth attribute is *quality of lecture or exercise*. Thus, the attribute matrix $M(2)$ is a $4 \times 5$ vector, while the weight matrix $W(2)$ is a $5 \times 1$ vector. They were valued as

$$M(2) = \begin{bmatrix} 3.73 & 3.29 & 3.75 & 3.77 & 4.27 \\ 4.67 & 4.83 & 5.46 & 5.27 & 5.25 \\ 4.56 & 4.40 & 3.90 & 3.71 & 3.75 \\ 4.00 & 3.63 & 5.19 & 4.56 & 4.81 \end{bmatrix}, \quad W(2) = \begin{bmatrix} 0.22 \\ 0.21 \\ 0.17 \\ 0.21 \\ 0.19 \end{bmatrix}. \hspace{1cm} (10)$$

The time unit was discussed from the perspective of micro level and macro level. In most existing DFT studies, the deliberation of people is defined as a sequential process and the time interval between two decisions is not able to be calculated. As a result, the time unit of decision making period is quite short and hardly measured. However, the time unit between two decision makings was lengthened to several weeks in this case, in order to concertize the deliberation process. Because the effect of memory decay over time, the feedback effect of previous decision has no influence on current decision consequently. Thus, the value of $s_{ii}$ is equal to 0 ($i = 1, 2, 3, 4$) for feedback matrix $S$ in round 2 and round 3.

Consequently, the preference states of students on four options are calculated as

$$P(2) = P(1) \cdot S + C \cdot M(2) \cdot W(2) = \begin{bmatrix} -0.7653 & 0.9975 & -0.3256 & 0.0935 \end{bmatrix}. \hspace{1cm} (11)$$
The round 3

Except those questions asked before, some new questions were added in order to gather students’ feedback or comment on the course (see Appendix D). In this round, the number of attribute were same as round 2, but the value of them were still different. The values of attribute matrix and weight matric are

\[ M(3) = \begin{bmatrix} 3.58 & 3.29 & 4.16 & 3.76 & 3.95 \\ 4.55 & 4.39 & 5.34 & 4.82 & 4.47 \\ 4.34 & 3.84 & 3.84 & 3.26 & 3.42 \\ 4.20 & 3.63 & 5.16 & 4.50 & 4.32 \end{bmatrix}, \quad W(3) = \begin{bmatrix} 0.22 \\ 0.21 \\ 0.17 \\ 0.20 \\ 0.20 \end{bmatrix}. \]

Consequently, the preference states of students on four options are valued as

\[ P(3) = P(2) \cdot S + C \cdot M(3) \cdot W(3) = [-0.5277 \quad 0.7536 \quad -0.4980 \quad 0.2720]. \]

7.2 Explanation ability analysis

This part is aimed to explain the deliberation process of students’ decision making in terms of the preference evolution. Through gathering the values of preference in three round, the variation trend of preference state were observed on each options.

7.2.1 Preference states

The preference states on each options are depicted as Figure 13. Obviously, the preference value on four options went through both ascent and descent period during three rounds. To be specific, the preference states on *Attend lecture* and *Attend exercise* were highest in round 2, and then followed by round 1 and round 3 in descending order. For attributes of *Attend both* and *Self-study*, however, the preference value of them were lowest in round 2, and then followed by round 1 and round 3 increasingly or reversely.
Figure 13. Preference states on each options

The Figure above presents how decision of students was dynamic made during three rounds. The values of preference state on each attribute are determined by the evaluation values and weight values. Therefore, the evolution of preference states were result of two causes: changes of evaluation value and changes of weight value. The dynamic decision making of students is able to be explained if the relationship of cause and effect are found. Therefore, the influence of these two causes on the preference evolution was discussed.

7.2.2 Value changes of two causes

The weight values of attribute were dynamic over the time because participants’ attention were always switching from one attribute to another. The weight matrix in round 1 was a $4 \times 1$ vector while it turned into a $5 \times 1$ vector in round 2 and round 3, caused by the fifth attribute added in attribute matrix. The situation of weight allocation among four attributes were sign of students’ first impression on course. With getting more into it, their attention on five attributes were reassigned in round 2 and subsequently changed in round 3. Due to the number difference of attribute, there was no much comparison between the first two rounds. Then, the next two rounds were focused.

Changes of weight value

The weight values of attribute in each round and the percentage each of them are presented in Figure 12. Surprisingly, the weight values on each attribute in round 2 and round 3 appear almost no difference. The value differences between each of attribute are presented as Table 18.
Table 18. Differences of Weight value

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Weight value in round 2</th>
<th>Weight value in round 3</th>
<th>Value difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1: Time management</td>
<td>0.22</td>
<td>0.22</td>
<td>0</td>
</tr>
<tr>
<td>A2: Workload from other tasks</td>
<td>0.21</td>
<td>0.21</td>
<td>0</td>
</tr>
<tr>
<td>A3: Expectation for good grade</td>
<td>0.17</td>
<td>0.17</td>
<td>0</td>
</tr>
<tr>
<td>A4: Interest in subject</td>
<td>0.21</td>
<td>0.2</td>
<td>0.01</td>
</tr>
<tr>
<td>A5: Quality of lecture or exercise</td>
<td>0.19</td>
<td>0.2</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

The weight values each of them in first three attributes were same while the values of them on interest in subject and quality of lecture or exercise differed by ± 0.01. For this reason, the influence of the changes of weight value on preference evolution were ignored.

Changes of evaluation value

Based on the result discussed above, the changes of evaluation value were considered as main reasons for preference evolution. The preference value differences and weight value differences were defined as

\[
\Delta P = P(3) - P(2), \Delta M = M(3) - M(2)
\]

Through calculation of data in two rounds, the value of \( \Delta P \) is equal to \([0.2523, -0.2439, -0.1724, 0.1785]^T\) and the value of \( \Delta M \) is equal to \([-0.15, 0, 0.41, -0.01, -0.32, -0.12, -0.44, -0.12, -0.45, -0.78, -0.22, -0.56, -0.06, -0.45, -0.33, 0.20, 0, -0.03, -0.06, -0.49]^T\). Based on these results, the influence of changes of weight value on preference states were analyzed as follow.

7.2.3 Relationships between weight value and preference states

In order to discuss the relationship between the changes of weight value and preference states, a linear relation was proposed as below.

\[
\Delta P = \lambda \Delta M
\]

Because the changes of weight value was considered as only causes of preference evolution, the co-efficient \( \lambda \) is fixed. In fact, the \( \lambda \) is a vector that is composed by four elements: \( \{ \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5 \} \). Each of them is the influential factor of each option. Then, the relationship between the changes of weight value and preference states were analyzed as follow.
For Attend lecture:  \[ \Delta p_1 = \sum_{k=1}^{5} \lambda_k \Delta m_{1k} \]

It is worth noting that the \( \lambda \Delta m \) represent the effect on preference value changes rather than the specific value of \( \lambda \Delta m \). In terms of evaluation value, the value differences on *time management*, *interest in subject* and *quality of lecture or exercise* fall down. In contrast, the value difference on *expectation for good grade* increasingly by 0.41. Hence, value difference on *expectation for good grade* influences positively on preference increase while that on the other attributes have negative effect on it. As a result, preferences states of option *Attend lecture* increased by 0.2523 (\( \Delta p_1 = 0.2523 \)). That’s say, \( \lambda_1 \Delta m_{13} > \lambda_1 \Delta m_{11}, \lambda_2 \Delta m_{12}, \lambda_4 \Delta m_{14}, \lambda_5 \Delta m_{15} \). Therefore, changes of evaluation on *expectation for good grade* made greater contribution to preference change on option *Attend lecture*.

For Attend exercise:  \[ \Delta p_2 = \sum_{k=1}^{5} \lambda_k \Delta m_{2k} \]

For the option *Attend exercise*, the preference value declined dramatically. Seeing from the elements in \( \Delta M \), value differences of five attributes drop off without exception. Due to \( \lambda_2 \Delta m_{25} > \lambda_1 \Delta m_{11}, \lambda_2 \Delta m_{12}, \lambda_3 \Delta m_{13}, \lambda_4 \Delta m_{14}, \lambda_5 \Delta m_{15} \), the attribute *quality of lecture or exercise* was the biggest positive factor for preference change.

For Attend both:  \[ \Delta p_3 = \sum_{k=1}^{5} \lambda_k \Delta m_{3k} \]

*Attend both* decreased by 0.1724 on preference state. Similar to the situation of option *attend exercise*, evaluation value of all attributes were lessened. Obviously, the result is \( \lambda_2 \Delta m_{15} > \lambda_1 \Delta m_{11}, \lambda_2 \Delta m_{12}, \lambda_3 \Delta m_{13}, \lambda_4 \Delta m_{14}, \lambda_5 \Delta m_{15} \). So, descent of evaluation value on *workload from other tasks* was the top reason for why preference value fall.

For Self-study:  \[ \Delta p_4 = \sum_{k=1}^{5} \lambda_k \Delta m_{4k} \]

The last option, *self-study*, experienced a rising period on preference state. To be specific, evaluation value of attribute *time management* ascended by 0.2 and *workload from other tasks* had no different between two rounds. Reversely, the rest of three attributes reduced in value. Thus, *time management* had positive impact on preference increase while the other attributes affected negatively on it. That’s say,
Moreover, time management made greater contribution to preference change on option Attend both.

In summary, the students’ behavior of dynamic decision making were explained by analyzing the component value of the extended DFT model. Therefore, the extended DFT model performed well under complex decision making environment (class attendance), in terms of explanation ability.

### 7.3 Prediction ability analysis

Prediction ability is growing used as a criteria of evaluation in empirical research (Beaver et al., 1968). The extended model is practical valuable if it’s able to predict dynamic behavior of decision making. In this research, the real attendance list was used as a reference to know the actual behavior of students on class attending, while the preference value calculated by extended model represents predicted behavior. Only if the predicted behavior is consistent with actual behavior, the prediction ability of extended model is verified.

#### 7.3.1 Actual behavior versus intended behavior

Before compared with predicted behavior, the actual behavior was used to compare with intended behavior. The students’ intended behavior on class attending was questioned and analyzed by web survey. In this course, there were 9 lectures and 8 exercise (no exercise in last week). The number of enrolled students were 55 finally, while only 39 students passed the course. In practice, the student who passed the course was considered as valid participate in data statistics. The actual attendance data of students in physical class are presented as follow Table 19.

### Table 19. Attendance data of students in physical class

<table>
<thead>
<tr>
<th>Rounds</th>
<th>Weeks</th>
<th>Attend lecture</th>
<th>Attend exercise</th>
<th>Attend both</th>
<th>Self-study</th>
<th>Passed course</th>
<th>Enrolled course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1</td>
<td>week 1</td>
<td>26</td>
<td>30</td>
<td>23</td>
<td>7</td>
<td>39</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>week 2</td>
<td>31</td>
<td>31</td>
<td>25</td>
<td>2</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>week 3</td>
<td>20</td>
<td>36</td>
<td>19</td>
<td>2</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>week 4</td>
<td>17</td>
<td>32</td>
<td>13</td>
<td>3</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>Round 2</td>
<td>week 5</td>
<td>12</td>
<td>31</td>
<td>10</td>
<td>6</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>week 6</td>
<td>18</td>
<td>33</td>
<td>16</td>
<td>4</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>week 7</td>
<td>16</td>
<td>29</td>
<td>12</td>
<td>6</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>Round 3</td>
<td>week 8</td>
<td>13</td>
<td>36</td>
<td>13</td>
<td>3</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>week 9</td>
<td>24</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>39</td>
<td>55</td>
</tr>
</tbody>
</table>
With observation of the attendance data, the Figure 14 as follow presents the moving average of attendance on four options, which was the sign of dynamic actual behavior of students on class attending.

![Actual behavior of students on class attending](image)

**Figure 14.** Actual behavior of students on class attending.

The ranking order of actual behavior on attending ways stayed the same during whole process. They were *Attend exercise, Attend lecture, Attend both* and *Self-study* decreasingly. However, the descending ranking order of intended behavior of students were *Attend both, Attend exercise, Self-study*, and *Attend lecture*. Through comparing the ranking order of them, it is easy to see that the actual behavior and intended behavior was inconsistent.

The deliberation of decision maker under complex decision making environment is an abstract and complicated process. The comparison result of ranking order is a good evidence that the actual behavior decision making is not easy to be predicted by simple question.

### 7.3.2 Actual behavior versus predicted behavior

The preference states were calculated by collected data based on extended model. In this research, the preference states represent the predicted behavior. Then, the predicted behavior of model on class attending is depicted as follow Figure 15.
The purpose of this subchapter is to validate the prediction ability of extended model. Provided that the proposed model predict actual behavior accurately, the predicted behavior should be close to actual behavior of decision maker. If not, the prediction ability of model is poor.

It is clear to see that the ranking order of predicted behavior in three rounds were identical. The decent order were attending exercise, attend lecture, self-study and attend both, which was consistent with the ranking order of actual behavior.

In terms of attendance number, the dynamic trend of actual behavior were almost same as that of predicted behavior except for the behavior of Attend lecture. In specific, the predicted behavior of Attend exercise experienced slight raise and then dramatic fall. Similarly, actual behavior gradually increased first and decreased in last few weeks. Because the guideline about examination of the course was announced in week 8, it caused the difference between actual behavior and predicted behavior.

For the behavior of Attend both, the trend of actual behavior and predicted behavior were consistent in general, falling first and raising then. In the last week, there was no exercise, which influenced trend of actual behavior on Attend both. The number of students who chose Self-study in actual declined at first but rebounded slightly later on, which matched with the dynamic trend of respective predicted behavior.

Although there is some existing limitation, comparison results of actual behavior and predicted behavior in terms of ranking order and dynamic trend proved that the extended DFT model is able to predict dynamic behavior of decision making in the context of class attendance.
8. Discussion

Based on construction and evaluation of extended DFT model, the findings regarding to research questions were discussed in this chapter. Then, the contribution and limitation of this research were summarized in theory and in practice.

8.1 Findings about research question

The two main research questions of Can the practical application of DFT in existing research be used to solve the complex problems of decision making? and How to extend the DFT model that can be used to solve the complex problems of decision making? were proposed at the beginning of thesis.

The answer for first main research question was got through conducting systematic literature review. The result of SLR shown that there is no practical application of DFT in existing research can be used directly for complex problems of decision making. For the second research question, the answers for its three sub-questions are discussed as bellow.

- What additional feature does the original DFT model should have?

The original DFT model can’t work under complex dynamic environment, which was recognized as the limitation. The evaluation value in attributes and the attribute number are fixed in the original DFT model. However, the original DFT model can't adapt to complex dynamic environment because of fixed attribute matrix $M$. In the context of class attendance, students’ evaluation on these four attributes (time management, workload from other tasks, expectation for good grade and interest in subject) can’t be decided at one time. As getting know the course more, both of evaluation value and weight value on attributes are changing. That’s to say, the attribute matrix $M$ should be dynamic as well.

Therefore, general requirement of the extended model is that it should can adapt to complex environment. From the perspective of feature of extended model, two additional feature should be included: 1) Dynamic attribute matrix in terms of evaluation value and attribute number, 2) Dynamic weight matrix in terms of attribute number.
- How to merge the additional feature into the extended DFT model?

In order to merge the additional feature into extended model, the structure of AHP was studied because it is able to adopt to dynamic environment well. What's more important, the dynamic structure of AHP was adopted.

The dynamic AHP suggests that both number and evaluation value of attribute are dynamic to add, remove or modify, which just fit with two additional feature that extended model should have. Therefore, the extended DFT model was built by integrating with dynamic structure of AHP.

- How well does the extended DFT model suit to explaining and predicting the behavior of decision making?

The answer for this question was discovered by evaluation of extended model. In narrow sense, web survey was used to collect data for model quantification. In broad sense, it was a process of behavior prediction through deal with students’ answers in web survey.

The performance of extended model was analyzed in terms of explanation and prediction abilities. Through analyzing the value changes of model components, four relationships between options and attributes were found. They were able to explain the dynamic behavior of decision making. Moreover, the intended behavior, actual behavior and predicted behavior were collected. By comparing actual behavior and predicted behavior, the prediction ability of extended model was proved. In summary, the extended model performs well in terms of explanation and prediction abilities under complex dynamic environment.

8.2 Contribution

The contribution of this research was discussed in aspects of model construction, data collection method and student behavior learning.

8.2.1 Model construction

In theory, this research build an extended DFT model successfully under complex dynamic environment, which is the main contribution of this research. Apart from studying the principle of DFT theory, the dynamic structure of AHP is studied and adopted in order to improve the flexibility and adaptability of model under complex decision making environment. Merging original DFT theory with AHP theory is a novel and brave try. If the following researcher attempt to improve existing DFT model, using other theory as assistive technique as this research is a good choice. Of course, this research is also a good reference for them. In terms of application of model, this research confirms the possibility of adoption of DFT model under
complex dynamic environment. In addition, the analysis results prove that the extended model is able to explain and predict dynamic behavior of decision making. Therefore, another contribution in theory is that this research provides an extended DFT model with good performance under complex dynamic environment. In practice, it provides some suggestions for management of class attendance by analyzing the explanation ability of proposed model.

8.2.2 Data collection method

The web survey as data collection method in this research is a successful case. In existing research, time unit between two decision makings are designed in fixed value. However the duration of three rounds were different because deliberation time is becoming become shorter along with decision makers’ experience with similar decision occasion getting rich. As the collected data shown, the fluctuation on attribute weights of three rounds was gradual on the decline. In reality, decision making on certain situation tends to be stable when available information is rich. Therefore, differentiation in time unit of this research is reasonable. This change could be an example for following research.

In addition, students were required to participate in three repeated web surveys for same purpose. But it is stupid and boring to ask same question three times, which would cause participation decrease. To avoid the risk, the questions were designed flexibly by adding open-question, categorizing questions, and disordering questions in different rounds. Moreover, some questions were added for the sake of course management. As a result, the participated number of students in three rounds are 48, 48 and 38 out of 55 which is a decent participation rate in such condition. Therefore, the design of web survey in this research can be learnt and make contribution to future research.

8.2.3 Student behavior learning

Although it is not the main objective in this research, learning the students’ behavior give some suggestions for teaching management. Although much research explored the factors why student do or do not attend class ((Fleming, 1992; Hunter, 1999; Kottasz, 2005), there is no research focusing on what influence each factor have on students’ decision on class attending. Through analyzing explanation ability of extended model, the relationships between each options and each attributes were discovered. Specifically, they were (1) students’ evaluation for expectation for good grade (among five attributes) influence most on their decision on option Attend lecture. The increasing importance of good grade for students is supposed to raise the attendance rate of lecture. (2) Whether student attend exercise or not is affected by the attribute quality of lecture or exercise most obviously that other four attributes. The evaluation of students on this attribute make greatest contribution on exercise
participation. (3) For the option *Attend both of lecture and exercise*, attribute *time management* is the factor with strongest influence. It infers that the number of students attending both of lecture and exercise when they can manage time easily without any conflict. (4) Lastly, the attribute *workload from other tasks* is the top reason for why students’ amount of self-studying is up or down. In practical teaching issues, the four relationships may help teacher focus on major reason to manage and control the attendance rate of lecture or exercise.

### 8.3 Limitation

Apart from contribution, some limitation were recognized regarding to extended model, survey setting and results. First of all, the average time interval between two rounds of survey was three weeks which is different from the truth. In actual, deliberation of decision making is a continual process without any breaks. Hence, the time interval between two decision makings is considered very short no matter in micro level or macro level (Abad, 2014). The time interval was widen in this case, which may negatively influence performance of extended model. The future research need propose a better solution about valuing the time interval.

What’s more, the decision making normally repeat many times until final decision is made. Thus, it’s maybe a good solution to shorten time interval and increase the rounds of web survey. But the practical situation impose restriction to survey settings. Just as the explanation above, over frequent questions may make participant feel boring and weaken their interest in it. Whole web survey was divided into three rounds, which is an obvious limitation. In addition, the web survey was original planned to start at first lecture of course, but it was postponed to second lecture because some students enrolled course later. Consequently, the information collected in round 1 may doesn’t report students’ first impression on course completely and accurately. So, it is a remaining problem to design a web survey with rich and completed data.

Another limitation is related to the result. Four relationship between options and attributes were summarized, and they are referred as *Attend lecture* and *expectation for good grade*, *Attend exercise* and *quality of lecture or exercise*, *Attend both* and *time management*, and *Self-study* and *workload from other tasks*, for short. They summarized what main factor influence each of class attending way, but it failed to explain how the factor influence each of them. For example, it’s unknown the how that changes of workload from other tasks is related to ascent or descent of amount of students who select self-study way. It’s regarded as a limitation here, however, it indicates a new direction for future research.
9. Conclusion

In this research, an extended DFT model integrated with AHP structure was proposed for the complex problems of decision making. The results proved it’s possible to apply DFT theory under complex dynamic environment, and the extended model was able to explain and predict decision makers’ behavior.

In order to refine and simplify the research, the research questions and its sub-questions were identified based on goal of this research. And the research issues related to this study were summarized according to the process for model development research (Nunamaker et al., 1990). The guidelines (Hevner et al., 2004) were adopted to understand, execute and evaluate the DSR research.

At the very early stage of this research, a systematic literature review was conducted to explore the current situation of DFT theory. The primary studies suggested that DFT theory has been used wildly in every walk of life and includes several kinds of sub-theory, but no practical application of DFT research is able to be applied under complex dynamic environment. Hence, it necessary and valuable to do this research.

With the throughout theoretical knowledge, extended DFT-related model was constructed. Mainly based on the papers (Busemeyer et al., 2002; Abad et al., 2014; Qin et al., 2013), the basic components of original DFT theory were explained and defined firstly. Then, some limitation of original model were discussed. Next, the AHP structure was studied as a supplementary technique for extension. Lastly, DFT theory was merged with dynamic structure of AHP as extended model which provided better performance to explain and predict the behavior of dynamic decision making.

In addition to theoretical model construction, application context was defined. In fact, the phenomenon of class attendance decreasing has caused attention of educational fellows. According to the findings of Kottasz (2005), four main reasons affecting students do or do not attend class were selected as influence factors. They are time management, workload from other tasks, expectation for good grade and interest in subject, all of which build partial extended model.

With the theoretical and practical foundation, the data collection was undertaken in a bachelor-level course within 9 weeks. Four ways of class attending were identified: Attend lecture, Attend exercise, Attend both and Self-study. The participated students were required to give answer for certain questions. After analyzing the gathered data, the results shown the good performance of proposed model in terms of explanation and prediction abilities.
This research contribution were evaluated in three aspects. The extended DFT model was built by adopting dynamic structure of structure in order to adapt to complex dynamic environment, which can be considered as an innovation of this research. Moreover, the design of web survey in this research has some advantages that can be studied for reference by following researchers. In addition, the findings of relationships regarding to influence factors and attributes are assumed to be helpful for educator to concentrate on class attendance management. In summary, the extended DFT model integrated with AHP structure is pioneer in explaining and predicting for complex decision making problems.

Apart from the significant result, several limitations were demonstrated. From the perspective of web survey settings, the time interval of two rounds are not appropriately and the number of web survey round was supposed to be more. Both of these two settings were different from truth, which had bad impact on results. The analysis of survey result only suggested what factor of course influence the students’ decision on class attending way. It would be more significant practically if how certain factor influence each option are summarized.

For the future research, the space is open to design a more functional and accurate DFT-related model. The theory of DFT needs to be developed toward more area and applied in other context. Among the primary studies, only one-tenth of 612 papers focus on studying human supported decision making in specific context, which indicates lack of efforts in application of DFT. Therefore, following research can center resources on this direction. Although many educational fellows have explored factors affecting class attendance rate, hardly a research attempt to put forward method to manage or control the participation. Thus, it requires much study to make contribution to field of class attendance.

Importantly, this research success building an extended DFT model but it is just a first step, future research is expected to go further.
References


Appendix A. Web survey in round 1

**Part I Background information**

1. Age? *
   ________________________________________________________________________ years

2. Study year? *
   ○ 1
   ○ 2
   ○ 3
   ○ 4
   ○ 5
   ○ More than 5

3. How many study credits you have at the moment? *
   ________________________________________________________________________ credits

4. How many courses you are taking in this semester (Spring 2015)? *
   ________________________________________________________________________ courses

5. Are you working alongside of your studies during this semester? *
   ○ Yes
   ○ No

**Part II Study practices for BSDA course**

6. Which way do you prefer to study this course? *
   ○ Attendance lectures
   ○ Attendance exercises
   ○ Attendance both lectures and exercises
   ○ Self-study instead of attending lectures and exercises
Please indicate to what extent do you disagree or agree the following statements (1 = disagree strongly; 4 = neither disagree or agree; 7 = agree strongly)

7. Studying in following way helps me achieve better grade. *
   1 2 3 4 5 6 7
   Attending lectures 〇〇〇〇〇〇〇
   Attending exercises 〇〇〇〇〇〇〇
   Attending both lectures and exercises 〇〇〇〇〇〇〇
   Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇〇

8. Studying in following way makes my personal time management easier. *
   1 2 3 4 5 6 7
   Attending lectures 〇〇〇〇〇〇〇
   Attending exercises 〇〇〇〇〇〇〇
   Attending both lectures and exercises 〇〇〇〇〇〇〇
   Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇〇

9. Learning the subject in the following way is interesting to me. *
   1 2 3 4 5 6 7
   Attending lectures 〇〇〇〇〇〇〇
   Attending exercises 〇〇〇〇〇〇〇
   Attending both lectures and exercises 〇〇〇〇〇〇〇
   Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇〇

10. Workload from other tasks makes me willing to studying in the following way instead of the other ways. *
    1 2 3 4 5 6 7
    Attending lectures 〇〇〇〇〇〇〇
    Attending exercises 〇〇〇〇〇〇〇
    Attending both lectures and exercises 〇〇〇〇〇〇〇
    Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇〇

11. Please rate the items below in terms of how important they are for you when
you think about attending lectures/exercises or not. *
1 = least important; 5 = most important Note: Each value only can be selected only once!

<table>
<thead>
<tr>
<th></th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectation for good grade</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Time management</td>
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<td>☐</td>
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<tr>
<td>Interest in subject</td>
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<tr>
<td>Workload</td>
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<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

12. Besides the four attributes mentioned above, please select one or more attribute from list below that you feel important to your decision on attending lectures/exercises or not.

☐ Difficulty of content  ☐ Quality of lectures/exercises  ☐ Presentation of the lecturer
☐ Size of lecture/exercise group  ☐ Entertainment of lectures/exercise  ☐ Availability of materials in other ways

13. If you think you have other reasons, not present in the list above, that affect to your decision whether to attendance lectures/exercises or not, please write them here.

________________________________________________________________
________________________________________________________________
________________________________________________________________

Part III Weekly time usage

14. How many hours you are using weekly, on average, for the following activities? *

Studies __________________________________

Work ____________________________________

Physical exercises or sports ________________________

Social activities ________________________________

Entertainment usage of Internet ___________________

Part IV Expectations on Statistical Data Analysis and BSDA course
15. Perceptions on Statistical Data Analysis. *

*Please indicate to what extent do you disagree or agree the following statements (1 = disagree strongly; 4 = neither disagree or agree; 7 = agree strongly)*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical Data Analysis is useful to learn</td>
<td>○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>I might need Statistical Data Analysis in my future work</td>
<td>○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>Statistical Data Analysis is interesting</td>
<td>○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>Statistical Data Analysis is easy</td>
<td>○ ○ ○ ○ ○ ○ ○</td>
</tr>
</tbody>
</table>

16. What is your grade goal of BSDA course? *

<table>
<thead>
<tr>
<th>Grade</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○ ○ ○ ○ ○ ○</td>
</tr>
</tbody>
</table>

Thank you for your answers!
Appendix B. Web survey in round 2

Part I Study practices for BSDA course

1. Which way do you prefer to study this course? *
   ○ Attendance lectures
   ○ Attendance exercises
   ○ Attendance both lectures and exercises
   ○ Self-study instead of attending lectures and exercises

Please indicate to what extent do you disagree or agree the following statements (1 = disagree strongly; 4 = neither disagree or agree; 7 = agree strongly)

2. Studying in following way helps me achieve good grade. *

   1 2 3 4 5 6 7
   Attending lectures ○ ○ ○ ○ ○ ○ ○
   Attending exercises ○ ○ ○ ○ ○ ○ ○
   Attending both lectures and exercises ○ ○ ○ ○ ○ ○ ○
   Self-studying instead of attending lectures and exercises ○ ○ ○ ○ ○ ○ ○

3. Studying in following way makes my personal time management easier. *

   1 2 3 4 5 6 7
   Attending lectures ○ ○ ○ ○ ○ ○ ○
   Attending exercises ○ ○ ○ ○ ○ ○ ○
   Attending both lectures and exercises ○ ○ ○ ○ ○ ○ ○
   Self-studying instead of attending lectures and exercises ○ ○ ○ ○ ○ ○ ○

4. Learning the subject in the following way is interesting to me. *

   1 2 3 4 5 6 7
   Attending lectures ○ ○ ○ ○ ○ ○ ○
   Attending exercises ○ ○ ○ ○ ○ ○ ○
Attending both lectures and exercises 〇〇〇〇〇〇
Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇

5. Workload from other tasks makes me willing to studying in the following way instead of the other ways. *

Atending lectures 〇〇〇〇〇〇
Attending exercises 〇〇〇〇〇〇
Attending both lectures and exercises 〇〇〇〇〇〇
Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇

6. Quality of lectures/exercises makes me willing to studying in the following way instead of the other ways. *

Atending lectures 〇〇〇〇〇〇
Attending exercises 〇〇〇〇〇〇
Attending both lectures and exercises 〇〇〇〇〇〇
Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇

7. Please rate the items below in terms of how important they are for you when you think about attending lectures/exercises or not. *

(1 = least important; 7 = most important. Note: Each value can be selected only once!)

Expectation for good grade 〇〇〇〇〇
Time management 〇〇〇〇〇
Interest in subject 〇〇〇〇〇
Workload 〇〇〇〇〇
Quality of lectures/exercises 〇〇〇〇〇

8. Besides the five attributes mentioned above, please select one or more attribute from list below that you feel important to your decision on attending lectures/exercises or not.

☐ Possibility to ask  ☐ Difficulty of content  ☐ Presentation of the
9. If you think you have other reasons, not present in the list above, that affect your decision whether to attend lectures/exercises or not, please write them here.

________________________________________________________________
________________________________________________________________

Part II Weekly time usage

10. How many hours you are using weekly, on average, for the following activities? *

Studies

Work

Physical exercises or sports

Social activities

Entertainment usage of Internet

Part III Expectations on Statistical Data Analysis and BSDA course

11. Perceptions on Statistical Data Analysis. *

Please indicate to what extent do you disagree or agree the following statements (1 = disagree strongly; 4 = neither disagree or agree; 7 = agree strongly)

Statistical Data Analysis is useful to learn

I might need Statistical Data Analysis in my future work

Statistical Data Analysis is interesting

Statistical Data Analysis is easy
12. What is your grade goal of BSDA course? *
   1  2  3  4  5

Grade ○ ○ ○ ○ ○

Thank you for your answers!
Appendix C. Web survey in round 3

Part I Perceptions of BSDA course

1. Please rate the following aspects of the course *

   (1 = Poor; 3 = Average; 5 = Very Good)

   Contents of the lectures ○○○○○
   Contents of the exercises ○○○○○
   Lecture material ○○○○○
   Exercise material ○○○○○
   Interaction and communication in the lectures ○○○○○
   Interaction and communication in the exercises ○○○○○
   Teacher's activities in the lectures ○○○○○
   Teacher's activities in the exercises ○○○○○

2. Please evaluate your perceptions of the course *

   (1 = Low; 3 = Average; 5 = High)

   Your own learning ○○○○○
   Easyness of the contents of the course ○○○○○
   Sufficiency of your background knowledge for the course ○○○○○
   Easyness of the lectures ○○○○○
   Easyness of the exercises ○○○○○
   Your grade expectation of the course ○○○○○

3. What worked well and supported your learning in the course?

   ________________________________________________________________
   ________________________________________________________________
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4. What could have done better and would have improved your leaning in the course?

________________________________________________________________
________________________________________________________________
________________________________________________________________

5. How many hours you spent for studying for the course? *
Weekly, on average, for the lecture contents ("theory")
Weekly, on average, for the exercise contents (R)
For preparing yourself to the exercise (R) exam
For preparing yourself to the ("theory") exam

Part II Perceptions of Statistical Data Analysis

6. Your perceptions on Statistical Data Analysis after the course. *
Please indicate to what extent do you disagree or agree the following statements (1 = disagree strongly; 4 = neither disagree or agree; 7 = agree strongly)

1  2  3  4  5  6  7

Statistical Data Analysis is useful to learn
I might need Statistical Data Analysis in my future work
Statistical Data Analysis is interesting
Statistical Data Analysis is easy

Part III Study practices for BSDA course

7. Which way you studied this course? *
○ Attendance lectures
○ Attendance exercises
○ Attendance both lectures and exercises
○ Self-study instead of attending lectures and exercises
○ I did not finally participate the course at all

*Please indicate to what extent do you disagree or agree the following statements (1 = disagree strongly; 4 = neither disagree or agree; 7 = agree strongly)*

8. Studying in following way helped, or would have helped, me to achieve better grade.

   1 2 3 4 5 6 7
   Attending lectures ○ ○ ○ ○ ○ ○ ○
   Attending exercises ○ ○ ○ ○ ○ ○ ○
   Attending both lectures and exercises ○ ○ ○ ○ ○ ○ ○
   Self-studying instead of attending lectures and exercises ○ ○ ○ ○ ○ ○ ○

9. Studying in following way made, or would have made, my personal time management easier.

   1 2 3 4 5 6 7
   Attending lectures ○ ○ ○ ○ ○ ○ ○
   Attending exercises ○ ○ ○ ○ ○ ○ ○
   Attending both lectures and exercises ○ ○ ○ ○ ○ ○ ○
   Self-studying instead of attending lectures and exercises ○ ○ ○ ○ ○ ○ ○

10. Learning the subject in the following way was, or would have been, more interesting to me.

   1 2 3 4 5 6 7
   Attending lectures ○ ○ ○ ○ ○ ○ ○
   Attending exercises ○ ○ ○ ○ ○ ○ ○
   Attending both lectures and exercises ○ ○ ○ ○ ○ ○ ○
   Self-studying instead of attending lectures and exercises ○ ○ ○ ○ ○ ○ ○

11. Workload from other tasks made me study in the following way, instead of the other ways.

   1 2 3 4 5 6 7
Attending lectures 〇〇〇〇〇〇
Attending exercises 〇〇〇〇〇〇
Attending both lectures and exercises 〇〇〇〇〇〇
Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇

12. Quality of lectures/exercises made me to study in the following, way instead of the other ways. *

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Attending exercises 〇〇〇〇〇〇
Attending both lectures and exercises 〇〇〇〇〇〇
Self-studying instead of attending lectures and exercises 〇〇〇〇〇〇

13. Please rate the items below in terms of how important they were for you when you thought about attending lectures/exercises or not. *

(I = least important; 5 = most important. Note: Each value can be selected only once!)

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</tbody>
</table>
Expectation for good grade 〇〇〇〇〇〇
Time management 〇〇〇〇〇〇
Interest in subject 〇〇〇〇〇〇
Workload 〇〇〇〇〇〇
Quality of lectures/exercises 〇〇〇〇〇〇

14. If you think you have other reasons, not present in the list above, that affect to your decision whether to attendance lectures/exercises or not, please write them here.

________________________________________________________________________
________________________________________________________________________

Part IV Any other feedback?
15. If you have any other feedback, comments, or development ideas about the course in your mind, please feel free to share those.

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

Thank you for your answers!