TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS IN TAIWAN USING SCENARIO METHOD

Ming Chih CHUNG
Ph. D. Student
Dept. of Transportation & Communication Management
National Cheng Kung University
1, University Road, Tainan,
701 Taiwan
Fax: +886-6-275-3882
E-mail: r5887105@ccmail.ncku.edu.tw

Chien Hung WEI
Professor
Dept. of Transportation & Communication Management
National Cheng Kung University
1, University Road, Tainan,
701 Taiwan
Fax: +886-6-275-3882
E-mail: louiswei@mail.ncku.edu.tw

Abstract: This paper presents a scenario approach integrating with a grey statistics method for determining the developmental priorities of advanced public transportation systems technologies in Taiwan. The proposed approach executes grey statistics and formulates decisive scenario using key factors of technology selection based on the data collected from the survey respondents. In the process of scenario formulation, the identification of specific advanced public transportation systems technology is made when the decision-making group reaches the consensus. In addition to methodology exploration, a comprehensive questionnaire investigation to obtain the estimation of grey statistics samples used for scenario formulation is conducted to demonstrate the feasibility of scenario approach. Using the proposed approach, the authors indicate appropriate technology of advanced public transportation systems for Taiwan to develop. The significance of the results implies the scenario approach is an effective alternative for planning developmental strategies of advanced public transportation systems as well as other subsystems.

Key Words: Scenario, Grey statistics method, Advanced public transportation systems, Technology selection, Questionnaire investigation

1. INTRODUCTION

In today's world, many government agencies are forced to make difficult decisions about selecting the appropriate technologies for the country to develop. A technology selection decision means reflecting compatibility with innovative and other existing technologies and risk of successful implementation. A technology selection decision for intelligent transportation systems (ITS) such as advanced public transportation systems (APTS) is a new and complex decision process involving considerable cost and time uncertainty as well as uncertain political and economic situations in Taiwan. Owing to the deficiency of historical data for reference, this paper applies a scenario analysis method for ITS technology selection.

The scenario analysis is a method can be used for technology selection especially when government is in the face of increasing national concern about economic and technological development but decreasing budget. To meet this challenge it will be urgent to use the national resources effectively. Moreover, the scenario method is applicable to problems with larger future variability and with no historical data for reference. Based on the examination of prior literature and APTS-related technology selection problems in Taiwan [3,6,18], this

method is chosen as an appropriate method for selecting suitable APTS-related technology for Taiwan to develop. This paper indicates the development of the conceptual scenario model for APTS-related technology selection. The next section of the paper covers the literature review of technology selection. Then the methodology of this research is discovered. Then a typical analysis is demonstrated. The last section of this paper provides some concluding comments.

2. TECHNOLOGY SELECTION

There are numerous researches have described technology selection and development.

Jackson *et al*. (1999) explore the selection of technologies for landfill waste site remediation in American. The required attributes are found to be total cost and time. Zysman *et al*. (2000) investigate the mobile and personal communications development and selection. They reveal that technological and research ability and research organization are important factors. Schimmoller (2000) identifies the business strategies in fast-developed power generation project development and the factors influencing technology selection. He indicates environmental concerns such as emissions control could be the required factor in the selection decisions. From a mass transit service perspective, Cunningham and Young (2000) examine public transportation development and service quality from the American managerial viewpoint. In their conclusion, stockholders' opinions such as transportation officials and customers' opinions are all important determinants of a provider's selection. Zhang (1998) describes some required success factors of technology choice from questionnaire investigation and e-mail messages. She indicates fast-developed technology use in distance teaching of a graduate course. The critical success factors are effectiveness of user needs, user characteristics and availability of the technology. Zhang indicates evidence of effectiveness on distance technology choice, and describes important administrative support to distance instructional persons for choosing and utilizing advanced technologies.

Recently, previous research investigates technology planning and selection in West Virginia, U.S.A. in the research. The results of his research indicate the essential influencing factors to technology selection are: research infrastructure, specialized workforce, existing technology ability, strong research universities, dense networks of firms, supporting technology organizations, existing local sources of capital and technological characteristics [1].

The selection of critical factors for this paper is based on various attributes perceived from a transport perspective. After summarizing the review of prior literature and conducting personal interviews with more than five executives, fifteen factors corresponded to current economic and technological situations were chosen for analysis of technology selection for APTS in Taiwan.

3. METHODOLOGY

Cotter (2002) describes that scenario analysis offer much value for evaluating fast-developed e-marketing initiatives and plan appropriate systems and technologies effectively. The authors adopt a conceptual model with grey statistics method for objective scenario building of APTS-related technology selection. The scenario building process is better than subjective one adopted by prior researches [2,6,10]. The structure is shown in Figure 1.

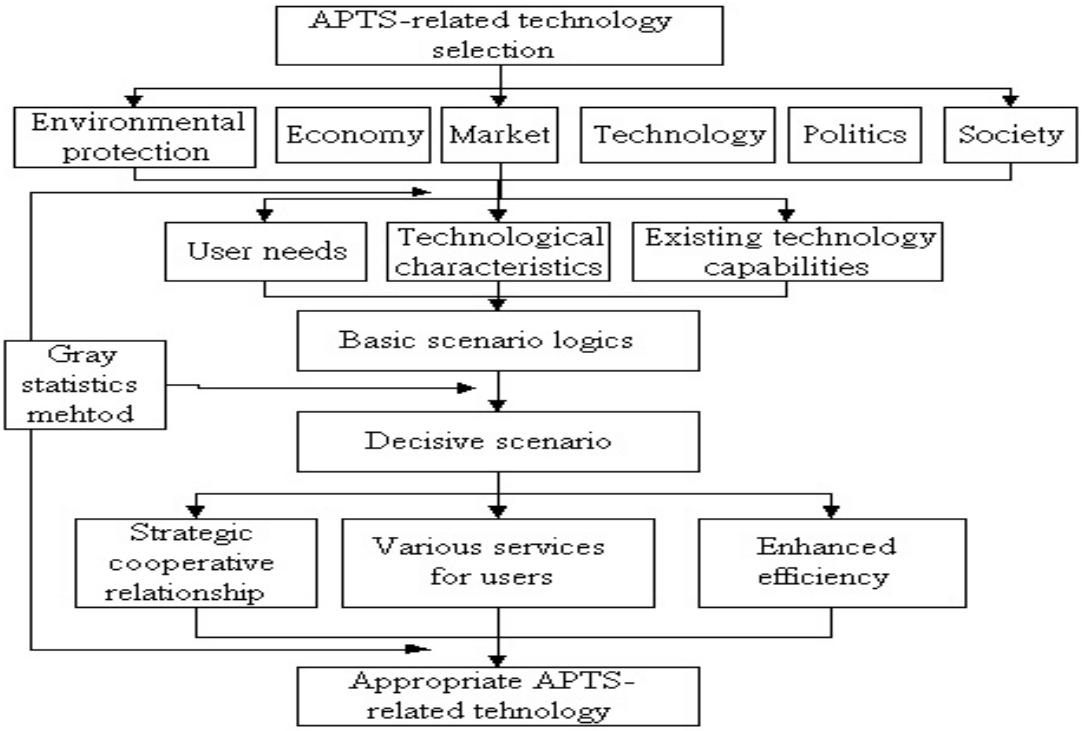

Figure 1. The Conceptual Model of Scenario Analysis

4. QUESTIONNAIRE DESIGN AND DATA PROCESS

In order to establish the APTS developmental plan, a comprehensive questionnaire mail survey is conducted. The contents of the questionnaire are designed based on the proposed method for determining the developmental priority of APTS-related technologies such that the proposed strategy can meet the needs of both supply and demand markets. Some sections are covered in the questionnaire survey, as described briefly below.

(1) Essential factors of selecting APTS-related technology for public sectors

This section identifies the comparative significance among the pre-specified key factors of selecting transportation technologies based on given literature. Survey respondents are asked to present their opinions about the key factors of selecting technology with transferred positive integer bounded by 1 and 5, corresponding to “strongly disagreeable” and “strongly agreeable”, respectively. The positive integer obtained here is referred to as the degree of comparative significance of factors.

(2) Formulation of basic scenario logics

The goal of this section is to formulate some types of basic scenarios for further use and select likely future scenario (it represents a structurally different but plausible scenario) and the developmental priority of APTS-related technology for public sectors. Given the scenario logics formulated by essential factors of choosing APTS-related technology, survey respondents are asked to denote the base case scenario, the optimistic scenario, the pessimistic scenario and the likely future scenario.

(3) Developmental priority of APTS-related technology

Questions obtained in the section are designed to investigate the potential usefulness of APTS-related technologies. In the section, six APTS-related technologies, either currently used or being developed, can be classified into several groups: (1) communications technology: short-range communications systems technology, (2) positioning technology: automatic vehicle location technology and (3) others: route guidance systems technology, automatic vehicle monitoring technology, combi card and contactless smart card technology. These groups are predetermined based on the consideration in the potentialities of APTS to the markets of passenger service and freight transportation [11,12,13,14,16,18,19]. Given the likely future scenario, survey respondents are asked to rate the technologies on a nine-point scale to denote numerically the developmental priority of transport technologies to the APTS-related technologies.

The comprehensive questionnaire mail survey is conducted at the October of 2002 in Taiwan. Considering the comprehensiveness of the samples to be surveyed, the authors included four groups in this survey. They are (1) researchers and professors in this field, (2) the government representatives, (3) the APTS-related hardware/software providers (the APTS technical supplier), (4) public transportation business operators (the APTS demander). The sample for this research is obtained based on the Directory of ITS of Taiwan Website renewed about half-year. These samples selected include air transport corporation, bus company, mass rapid transit corporation, Taiwan railway administration and electronic corporation. In this survey, a total of 66 samples are identified. There are 33 samples are valid. The effective questionnaire rate is 50%. The sample size of government representatives, professors and researchers, private operators are 14, 9 and 10, respectively. Sample characteristics in the aspect of sample familiarity with ITS and APTS is worth noting. They are summarized in Table 1. The information with respect to the respondents' familiarity with ITS may help to enhance the acceptability of these investigation results. It is notable as much as 94% and 88% of the respondents are familiar with ITS and APTS to a certain extent, respectively. More than 60% of *somewhat familiar or above* are classified either *assistant manager or above* or *first engineer/engineer*. They are in the position of *assistant manager or above* (28%), *first engineer/engineer* (24%), *professor/associate professor* (14%), *section chief* (24%) or *other* (10%).

Table 1. Sample Familiarity with ITS and APTS

Familiarity with ITS	**Number of respondents**	**Percentage %**
Very familiar	4	12
Familiar	14	43
Somewhat familiar	13	39
Slightly unfamiliar	2	6
Rather unfamiliar	0	0
Familiarity with APTS		
Very familiar	3	9
Familiar	13	39.5
Somewhat familiar	13	39.5
Slightly unfamiliar	4	12
Rather unfamiliar	0	0

The authors process the raw data and develop the scenarios utilizing these 33 experts' opinions. We first analyze experts' opinions with grey statistics method to process the unclear

characteristics contained within expert opinions. Chen (1997) explores that grey statistics approach defines the integration between experts' opinions is clear so that it gives the same weight to all experts in the analysis. The grey statistics approach uses grey numbers to classify influencing factors into different categories. Essential factors can be identified to construct the basic scenario logics and decisive scenario can be further identified. Moreover, the developmental priority of APTS-related technology can be identified. The process is described as follows.

4.1 Definition of the Ultimate Forces

We develop a new questionnaire survey method named "conditional infinite sequencing" in the section. In the questionnaire, we first ask experts to assess the factors affecting technology choice based on the potential importance. The rank number interval designed from 1 to 5. Nevertheless, the numbers can be designated unlimited rank after decimal point such as 1.10 or 2.112. Using this method can analyze generalized trapezoid grey number and special triangular grey number. The results would precisely represent experts' opinions. We convert the rank numbers into grey numbers (or sample values) from 9 to 1 so that Number 1 is converted to Value 9, Number 2 to Value 7, and so on. Namely, the higher value it is, the more importance it represents. The rankings are all identified by experts' professional background. We collect the sample values for analysis based on the five degrees of importance (or gray group). The details about data processing are described as follows.

A. Establishment of conversion scales

We categorize factor importance into five linguistic terms. The conversion scale of each linguistic term is shown in figure 2 [4,5,9].

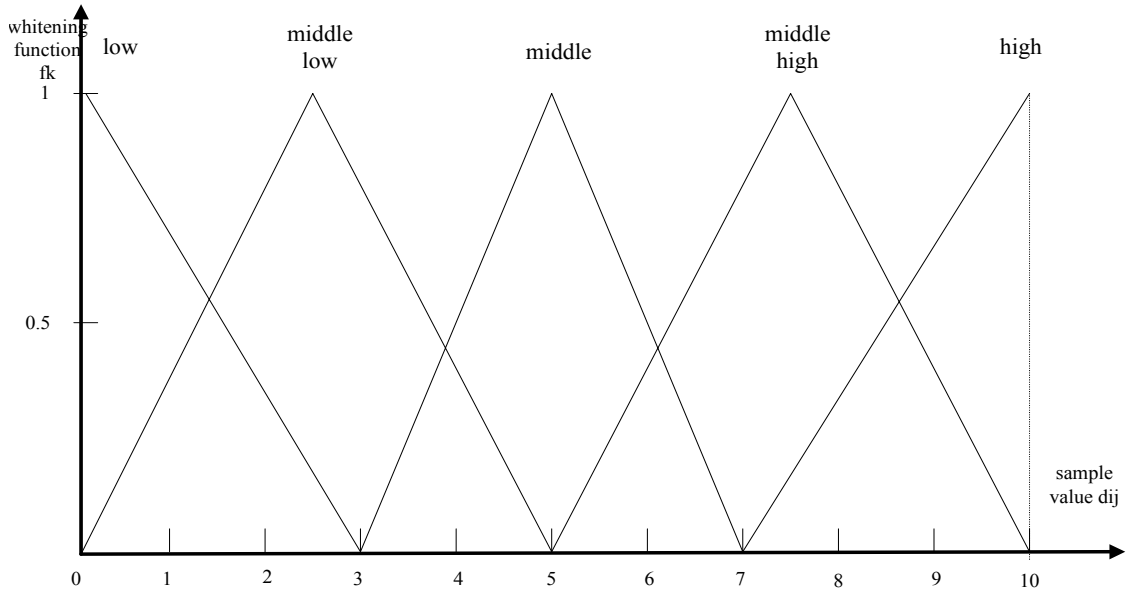

Figure 2. Conversion Scale of Linguistic Terms

B. Establishment of white value

In the data processing, the final goal is to calculate the values of APTS-related technology associated with each sample. The authors first obtain a specific element d_{ij} represented the

degree of comparative significance associated with the factor j and identified by survey respondent i. Then we obtain the element f_k to represent the whitening function of grey group k and σ_{jk} is the white value of the factor j belong to grey group k, the white value is given by $\sigma_{jk} = (\Sigma f_k \ d_{ij}) / (\Sigma^n_{k=1} \ \Sigma f_k \ d_{ij})$, $k \in \{1,2,\ldots,n\}$, $i \in \{1,2,\ldots,w\}$, $j \in \{1,2,\ldots,m\}$. For k, the grey statistics series of factor j is $\sigma_j = [\sigma_{j1}, \ldots, \sigma_{jk}]$. Moreover, the authors define factor j belong to gray group k*, then $\sigma_{jk*} = \max_k \sigma_{jk}$.

We take the factor "user needs" for example, its grey statistics series [high, middle-high, middle, middle-low, low] is [9.38,7.31,0,0,0]. According to the results, the authors categorize "user needs" into "high" conversion scale.

C. Establishment of grey group

We appoint each factor's grey statistics series as [high, middle-high, middle, middle-low, low]. Table 2 summarizes relative grey group of each factor.

Table 2. Relative Grey Group of Each Factor

Influencing factor	Grey statistics series	Grey group
User needs	[9.38,7.31, 0, 0,0]	High
Specific knowledge demand	[2.01,9.70,3.00,0.67,0]	Middle-high
Infrastructure	[8.04,9.32, 0, 0,0]	Middle-high
Local economic development	[4.02,8.68,3.00,0.67,0]	Middle-high
Dense networks of firms	[0.67,9.04,4.00,1.34,0]	Middle-high
Supporting organization	[2.68,10.03,2.00,0.67,0]	Middle-high
Local capital source	[2.01,9.70, 0, 0,0]	Middle-high
Stakeholders' opinions	[0.67,8.37,5.00,1.34,0]	Middle-high
Professional worker	[6.03,10.34, 0, 0,0]	Middle-high
Existing technical ability	[3.35,11.03,1.00, 0,0]	Middle-high
Human resources training	[3.35,9.69,4.00, 0,0]	Middle-high
Emissions	[1.34,9.37,5.00, 0,0]	Middle-high
Technological characteristics	[2.68,10.7,2.00, 0,0]	Middle-high
Setting cost	[6.03,9.67,1.00, 0,0]	Middle-high
Safety	[9.38,9.98, 0, 0,0]	Middle-high

According to the aforementioned analysis, the authors utilize factors belong to "high grey group" and "middle-high grey group with highest white value" in constructing basic scenario logics. However, these factors have uncertainties and, according to the literature [3], we must select the factors without interaction. Therefore, the independent factors (or ultimate forces) are selected: user needs, existing technology ability, and technological characteristics.

4.2 Creation of Decisive Scenario

The creation of scenario can first join two factors to construct some basic scenario logics, and

analyze the consistency. For example, one can first construct scenarios by two factors: user needs and technological characteristics shown in Figure 3.

		User needs	
		High	**Low**
Technological characteristics	**Simple**	Situation 1	Situation 3
	Complicated	Situation 2	Situation 4

Figure 3. Possible Situations for Technology Choice Scenario Structures (Part 1)

From Figure 3, we realize that Situations 1 to 4 are all possible situations, thus we retain them all. Then a third factor (Existing technology ability) is added to the matrix to form another figure as shown in Figure 4.

		User needs/Technological characteristics			
		High/Simple	**High/Complicated**	**Low/Simple**	**Low/Complicated**
Existing technology ability	**High**	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Low	Scenario 5	Scenario 6	Scenario 7	Scenario 8

Figure 4. Possible Situations for Technology Choice Scenario Structures (Part 2)

From Figure 4, we finally formulate eight reasonable scenario logics for public sectors. For example, Scenario 1 represents that under a slower economic development environment together with urgent user needs for efficient and safe transportation, the existing technology ability can be utilized for developing effective products. Government agencies pursue business and infrastructure with reasonable return for economic development and industrial advancement. On the other hand, the technological characteristics of APTS-related technology are fully utilized by manufactures. Thus, public sectors cooperate with private operators in the development of transport technology industry.

After formulating possible scenario logics of public sectors in Taiwan, the next round questionnaire survey is conducted to interview experts and ask them to rank each scenario by the possibility of its occurrence under strategic situation. As the replies come back, we analyze every scenario under “likely future” situation by grey statistics method to determine the final decisive scenario. Based on the aforementioned analysis, the structurally different but plausible scenario is Scenario 1, and the prior-developed technologies of APTS are short-range communications technology and contactless smart card technology. Table 3 and 4 summarize grey groups of each scenario and technology respectively.

Table 3. Grey Group of Each Scenario

Scenario	Grey statistics series	Grey group
Scenario 1	[9.71,6.40, 0, 0,0]	High
Scenario 2	[6.99,11.20,1.00, 0,0]	Middle-high
Scenario 3	[1.99,5.20,1.50,0.40,0]	Middle-high
Scenario 4	[1.32,2.40,4.50,1.20,0]	Middle
Scenario 5	[0.33,2.80,5.50, 0,0]	Middle
Scenario 6	[0.67,2.80,1.50,2.80,0]	Middle-high or Middle-low
Scenario 7	[0, 0,1.50,5.20,0.33]	Middle-low
Scenario 8	[0, 0, 0,4.02,1.65]	Middle-low

Table 4. Grey Group of Each Technology

Technology	Grey statistics series	Grey group
Short-range communications	[2.64,18.80,4.50,3.20,0]	Middle-high
Route guidance systems	[1.65,8.40,8.50,5.60,0]	Middle
Automatic vehicle location systems	[3.96,16.00,5.50,2.80,0]	Middle-high
Automatic vehicle monitoring systems	[0.66,10.00,9.50,3.20,0]	Middle-high
Contactless smart card	[3.30,17.20,8.00,2.00,0]	Middle-high
Combi card	[0.33,5.20,11.50,6.40,0]	Middle

5. RESULTS AND DISCUSSIONS

There are some generalizations indicated by this paper. First, contactless smart card technology will be the relative essential technology among other APTS-related technologies in the near future in Taiwan. Second, the route guidance systems are commonly agreed to be the important technologies in APTS, they draw less concern than we anticipated in this research. The reason would be the complication of systems and infrastructures needed.

The scenario analysis provides useful tool for exploring technology selection decisions. The model uses decisive scenario for survey experts to see the opportunity involved with future scenario and further select technologies. Therefore, this approach helps decision-makers better prepared to make a decision and execute their plans.

6. CONCLUSIONS

The objective of this paper is to develop a scenario model for exploring the selection of prior-developed APTS-related technologies for Taiwan public sectors. The model utilizes grey statistics method for analyzing questionnaire data and offers survey respondents a decisive scenario for developmental priority of APTS-related technology selection. The decision-makers will find it useful to utilize grey statistics process for objective scenario acquisition for decision-making.

The model described in the paper provides a framework to explore the selection of prior-developed APTS-related technologies over a decisive scenario. With the downsizing of development budgets, the need for increased effective decision-making approach on technology selection problems is undeniable.

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Appendix 1. Questionnaire 1: Factor Determination

Part 1. Critical Uncertainties

How important were the following critical uncertainties for selecting transportation technologies for Taiwan public sectors?

	Extremely Unimportant	Neutral	Extremely Important
1. User needs	1	3	5
2. Specific knowledge demand	1	3	5
3. Infrastructure	1	3	5
4. Local economic development	1	3	5
5. Dense networks of firms	1	3	5
6. Supporting organization	1	3	5
7. Local capital source	1	3	5
8. Stakeholders' opinion	1	3	5
9. Professional worker	1	3	5
10. Existing technical ability	1	3	5
11. Human resources training	1	3	5
12. Emissions	1	3	5
13. Technological characteristics	1	3	5
14. Setting cost	1	3	5
15. Safety	1	3	5

Part 2. Background Information

16. How long do you work in your company?_____(Year)
17. What is your title in your company?_____
18. What type of company do you work in?_____
19. How well do you understand the "intelligent transportation systems"? (Please check one)
    ___Very familiar ___Familiar ___Somewhat familiar ___Slightly unfamiliar ___Rather unfamiliar
20. How well do you understand the "advanced public transportation systems"? (Please check one)
    ___Very familiar ___Familiar ___Somewhat familiar ___Slightly unfamiliar ___Rather unfamiliar

Appendix 2. Questionnaire 2: Scenario Formulation

Part 1. The Likely Future Scenario

The basic scenario logics of selection for advanced public transportation systems-related technologies for Taiwan public sectors are shown as follows. They are formulated on the basis of three uncertain axes selected by the survey respondents.

		User needs/Technological characteristics			
		High/Simple	**High/Complicated**	**Low/Simple**	**Low/Complicated**
Existing technology ability	**High**	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Low	Scenario 5	Scenario 6	Scenario 7	Scenario 8

How probable were the following basic scenario logics for occurrence as a likely future scenario?

	Extremely Probable	Neutral	Extremely Improbable
1. Scenario 1	1	5	9
2. Scenario 2	1	5	9
3. Scenario 3	1	5	9
4. Scenario 4	1	5	9
5. Scenario 5	1	5	9
6. Scenario 6	1	5	9
7. Scenario 7	1	5	9
8. Scenario 8	1	5	9

Part 2. Background Information

9. How long do you work in your company?_____(Year)
10. What is your title in your company?_____
11. What type of company do you work in?_____
12. How well do you understand the "intelligent transportation systems"? (Please check one)
    ___Very familiar ___Familiar ___Somewhat familiar ___Slightly unfamiliar
    ___Rather unfamiliar
13. How well do you understand the "advanced public transportation systems"? (Please check one)
    ___Very familiar ___Familiar ___Somewhat familiar ___Slightly unfamiliar
    ___Rather unfamiliar

Appendix 3. Questionnaire 3: Technology Selection

Part 1. Developmental Priorities of Advanced Public Transportation Systems-Related Technologies

The candidate advanced public transportation systems-related technologies for Taiwan public sectors are shown as follows. They are selected based on the previous literature and the consideration in the potentialities of advanced public transportation systems to the markets. The likely future scenario is selected based on the grey statistics method and represents that *under a slower economic development environment together with urgent user needs for efficient and safe transportation, the existing technology ability can be utilized by APTS technical suppliers for developing effective transport products. Government agencies pursue business and infrastructure with reasonable return for economic development and industrial advancement. On the other hand, the technological characteristics of APTS-related technology are fully utilized by equipment manufactures. As such, public sectors cooperate with private operators in the development of transport technology industry.*

How prior were the following technologies for development of advanced public transportation systems under aforementioned scenario?

	Extremely Prior	Neutral	Extremely Posterior
1. Short range communications technology	1	5	9
2. Route guidance systems technology	1	5	9
3. Automatic vehicle location systems technology	1	5	9
4. Automatic vehicle monitoring systems technology	1	5	9
5. Contactless smart card technology	1	5	9
6. Combi card technology	1	5	9

Part 2. Background Information

7. How long do you work in your company?_____(Year)
8. What is your title in your company?_____
9. What type of company do you work in?_____
10. How well do you understand the “intelligent transportation systems”? (Please check one)
    ___Very familiar ___Familiar ___Somewhat familiar ___Slightly unfamiliar ___Rather unfamiliar
11. How well do you understand the “advanced public transportation systems”? (Please check one)
    ___Very familiar ___Familiar ___Somewhat familiar ___Slightly unfamiliar ___Rather unfamiliar