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Evaluating vehicle telematics system by using a novel MCDM techniques with dependence and feedback

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A R T I C L E   I N F O

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Vehicle **T**elematics **S**ystem (VTS)
Telematics service provider (TSP)
DEMATEL
ANP (Analytical Network Process)
TOPSIS
MCDM (multiple criteria decision-making)

A B S T R A C T

As the advanced integration of communications, information and vehicle technologies, **V**ehicle **T**elematics **S**ystems (VTS), have been initiated for satisfying consumers' needs with respect to automobile movement. Importantly, VTS enables a vehicle to become a multifunction mobile-services platform. Cars are now designed not only for transportation, but also to provide value-added services covering navigation, safety, security, information, communications and entertainment. Drivers or passengers can contact a call center via VTS to access aspired/desired services and information online. Therefore, VTS increases both the utility/functions and the safety of driving. Developing the optimal VTS that satisfies with consumers' needs has become the foremost concern of automobile producers. This study will attempt to identify the required VTS utilities between distinguishing characteristics/features of consumers and propose the ideal service combinations for the next e-era generation VTS. An evaluating model by six aspects to be considered/constructed, which encompasses 25 criteria, is built to identify consumers' needs for the next e-era generation VTS. In the paper, a Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique is used to construct the network relation-map (NRM) among the criteria of each aspect. These criteria are not mutually independent; instead, they have feedback mechanisms. The Analytical Network Process (ANP) based on NRM is used to determine the relative weightings among those criteria. Moreover, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to determine and improve the gaps among the distinguishing characteristics/features of consumers' desired utilities with respect to services/provide the decision-maker of Telemetics Service Provider (TSP) for improving existing functions or planning further utilities in the next-generation VTS. Based on above NRM those results can be served as a suggestion for the TSP to improve the existing functions or plan further utilities/functions for reducing the gaps and satisfying the users' needs in next e-era generation VTS.

1. Introduction

With the extensive traffic network and the changes in lifestyles, automobile users will no longer be pleased with just a pleasant driving experience and comfortable interior. Instead, people will expect their navigational device to change from a closed system into an open intellectual communications system, in which users can communicate or transmit information to and from external systems or other people in real-time via their car's vehicle telematics device. With the remarkable advances in consumer electronic and telecommunications technologies, development in the automobile industry has been progressed from the past era, in which driving mechanisms and comfortable equipments were emphasized to the telematics era, in which the interaction between users and various platforms is stressed. These trends not only push the automobile industry to extend its industrial value chain but also to represent the new definition of what the automobile should be.

Therefore, the development of the next-generation vehicle has extended from improving machine efficiency to providing communications and information services. In order to meet consumers' needs when they are on the move, VTS (**V**ehicle **T**elematics **S**ystems) should integrate existing communications, information and automobile technologies for various service utilities. VTS can change the car from a closed body into an open mobile-service platform. The car will not only be designed for transportation, but will also provide value-added services regarding navigation, safety, security, information, communications and entertainment.

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Drivers or passengers will be able to contact a call center via VTS to access desired services through information online. Therefore, VTS increases both the utility/function and the safety of driving. The high price of VTS hardware will be reduced with the innovation of communications technologies, information technologies and the popularization of system services by mass production, and will also enable suppliers to attain economies of scale in production and services. Once this is achieved, VTS will become standard equipment in the vehicle. Since problems of technology and costs will be resolved in the future, the biggest challenge for the development of VTS is to discover the services and applications that the consumers really want. Therefore, how to develop VTS in order to meet the user's needs has become the main topic of automobile producers and telematics service providers (TSPs). It will influence new car sales and the scale of derived value-added service markets.

Early in 1997, European studies had proposed a solution for evaluating traffic effects of a route guidance system by dynamic simulation of an advanced transport telematics technology for easing the problems induced by traffic. They pointed out that an efficient and safe infrastructure is an essential prerequisite for European economic and social cohesion. Those situations have urged the development of telematics technologies for route guidance systems to solve those traffic problems like traffic congestion. They also predicted traffic problems with the rapid development of telematics technologies it would become possible in the near future to make real-time information for real traffic situations (Chen & Stauss, 1997). The core of VTS is communications and information services. The transmission, reception, and communication of information need to be operated via various communications and information technologies, particularly wireless technologies. Accordingly, car users can get various kinds of real-time and precise information when they have different needs such as personal e-commerce (Anker & Arnold, 1998; Golob & Regan, 2001). With the advances in telecommunications technologies, consumers can search and download video, music, and other multimedia information in real-time, via the VTS (Golob & Regan, 2001).

Based on above literature reviews and expert discussions of our research group, this study would like to identify the required VTS utilities according to distinguishing characteristics of consumers and propose the most appropriate service combination for the next e-era generation VTS. These following six aspects (i.e. navigational and location services, safety and security services, communications and information services, audio–video and entertainment services, fee rate and payment methods, product image), encompassing 25 criteria, are constructed to identify and evaluate consumers' needs for the next e-era generation VTS. We propose a novel MCDM model which combines DEMATEL with ANP and TOPSIS. It is generally introduced and applied with real products to illustrate the VTS innovation/creation. VTSs are applied to four regions (i.e. North America, Western Europe, Japan and Taiwan) for empirical analyses. The DEMATEL technique is used to build the NRM among criteria of each aspect. Then, the ANP method is used to determine the relative weightings among those evaluation criteria based on NRM. Finally, the TOPSIS is used to determine and improve the gaps between consumers' negative (the worst levels) and positive ideal solutions (aspired/desired levels) among utilities of the existing VTSs and preferences of various consumers for improving the gaps in each criterion based on whole systems of NRM (Chen & Tzeng, 2004; Kuo, Tzeng, & Huang, 2007; Opricovic & Tzeng, 2004; Shih, Shyur, & Lee, 2007; Tzeng, Tsaur, Laiw, & Opricovic, 2002). The gaps between the consumers' most appropriate and most inappropriate service of the existing/developing VTS in each criterion are analyzed to achieve the aspired/desired level for satisfying the customers' needs. Those conclusions will serve/provide the decision-maker of TSP for improving existing gaps of functions or planning further utilities/functions for the next e-era generation VTS. Commercial VTSs of four regions (i.e. North America, Western Europe, Japan and Taiwan) are illustrated to use as empirical analyses. The result shows that user ages will influence the preference of desired utilities of VTS. Those comments can help automobile manufacturers develop new e-era generation VTS, modulize the service functions and satisfy target consumers' requirements for customized purposes. This paper recommends that TSPs improve the current utilities or initiate new utilities/functions on the basis of Japan's or Taiwan's existing VTSs in order to shorten the time to market.

The rest of this paper is organized as follows. In Section 2, telematics system markets based on consumers' requirements/needs of VTS are discussed. In Section 3, the evaluation model of the best VTS market for the next e-era generation VTS is proposed by combined the DEMATEL technique with ANP and TOPSIS methods. In Section 4, an empirical analysis of evaluation model of VTS market is proposed to apply to four empirical cases. Finally, conclusions and further planning strategies for the next e-era generation VTS are proposed in Section 5.

2. The development of vehicles telematics markets based on consumers' needs

The development experiences of VTSs in countries with advanced automobile industries (i.e. North America, Western Europe, and Japan) can be benchmarked by Taiwan's TSPs. In Europe, the United States and other advanced countries, car users care about and focus on the security and safety functions of automobiles. The law of strict/severe rules is also legislated regarding car safety. Accordingly, emergency services, automatic notification, stolen vehicle location assistance, security protection, vehicle diagnosis, and other safety and security-related services have been developed (Golob & Regan, 2001; Magnusson et al., 2002). In North America, many people work in cities but live in suburbs. Therefore, the car becomes people's main form of transportation and car users are interested in receiving correct traffic information and in driving safety. Those characteristics have influenced automobile producers and TSPs to initiate R&D plans regarding real-time traffic information, driving safety and security measures. Additionally, with increased time for enjoying leisure time, entertainment and location-based services (abbreviated LBS) have become the basic utilities for future VTSs. In the long history of Western Europe, under the circumstances of multiple languages and multiple cultures, the constructions and plans of routes are denser and more reticular than in North America, and the car density is higher than in North America. Like people in North America, the Western European consumers are also concerned about receiving correct traffic information and pursuing driving safety. The mainstream European TSPs are equipped with navigation, safety, security utilities and multi-language interfaces to meet the requirements/needs of consumers from different nations/countries. Western Europeans like to travel across different European nations/countries, and thus demands for entertainment and LBS services are becoming increasingly more important and popular.

In Japan, because of the small territory, extremely dense population, expensive real estate, heavy traffic, and complex streets, the Japanese government proposed the Intelligent Transport Systems (ITS) plan and boosted Advanced Safety Vehicles (ASV) plan. Generally, traffic jams have always happened in a megalopolis; therefore customers desire navigation products to save their driving time. Because of the flourishing development of the entertainment and electronics industry and various requirements from consumers, entertainment utilities of VTS are more stressed than those in the U.S. and Europe. In Japan, when a car breaks down, the possibility of helplessness is less than North America because of its small territory, high population density, and well-connected transport systems. Therefore, Japanese customers require fewer safety and security utilities than those in the US and European markets. From the development track of foreign VTSs regarding services and utilities, whether TSPs succeed or fail depends on the degree of satisfaction of consumers' needs. The U.S. and European TSPs focus on safety and security services, while the Japanese TSPs provide navigation and location services in the beginning, followed by communications and information services, and audio–video and entertainment services in recent years. The Taiwanese TSP first provides to adjust navigation and location utilities on the basis of Japan's technologies, and further provides safety and security utilities due to a high rate of car theft and frequent storage of stolen cars in Taiwan. As a result, consumers' requirements/needs for the VTS will differ by cultures and regions/countries. Thus, referring to the market trends of Europe, US and Japan's VTS industries and considering Taiwan consumer's preferences will be useful for Taiwan's TSPs to plan the product roadmap of VTS.

2.1. Navigation and location services

With the rapid growth of road networks and total numbers of cars on the road, traffic problems seem inevitable with urbanization. With the advanced development of information and communications technologies, people do not need to find roads via traditional maps, rather they just enter their desired destination into a navigation system, and the location services of the VTS will map the routes with vocal instructions to help people reach the desired place easily and conveniently. But in addition to the way to the destination, consumers are concerned about real-time traffic situations for route planning in order to avoid areas of congested traffic (Chen & Stauss, 1997). In this paper, four commercial VTS products by different telematics service providers (TSPs) i.e. Taiwan, the US, Europe, and Japan are analyzed and benchmarked to discuss the required utilities/functions and services of the next e-era generation VTS. The aspect of navigation and location services will be divided into three evaluation criteria; voice-guided navigation devices, traffic information and electronic map information to find out the required utilities/functions for the next e-era generation VTS regarding navigation and location services.

2.2. Safety and security services

The Europe, the United States and other advanced countries, with nationality behaviors, automobile users are concerned about security and safety utilities/functions. The laws of strict/severe rules regarding car safety are also legislated. Accordingly, emergency services, automatic notification, stolen vehicle location assistance, security protection, vehicle diagnosis, and other safety and security-related services are developed (Golob & Regan, 2001; Magnusson et al., 2002). In this paper, four commercial VTS products of different TSPs (i.e. Taiwan, U.S., Europe, and Japan) are analyzed and benchmarked to discuss the required utilities/ functions and services for the next e-era generation VTS. The aspect of safety and security services would be divided into five criteria; safety and emergency services, remote central control services, vehicle location services, car security services and vehicle diagnosis and maintenance services to find out the required utilities/functions for the next e-era generation VTS regarding safety and security services.

2.3. Communications and information services

The core of VTS is communications and information services. The transmission, reception, and communication of information need to be operated via various communications and information technologies, particularly wireless technologies. Accordingly, automobile users can get various kinds of real-time and precise information when they have different needs on moving such as personal e-commerce (Anker & Arnold, 1998; Golob & Regan, 2001). In this paper, four commercial VTS products from different TSPs (Taiwan, the US, Europe, and Japan) will be analyzed and benchmarked to discuss the required utilities/functions and services for the next e-era generation VTS. The aspect of communications and information services is divided into five evaluation criteria: mobile information services, user interfaces, platform integration services, information security protection and information update frequency to find out the required utilities/functions of the next e-era generation VTS regarding communications and information services.

2.4. Audio–video and entertainment services

Traditional automobile multimedia entertainment was a closed system; people could choose their favorite form of multimedia storage, and its corresponding hardware players, such as cassette tapes, compact discs, DVDs, MP3s. With the advances in development of technologies, the integrated player supporting different audio–video formats has been created. It eases the inconvenience of converting different systems, but it cannot satisfy the needs of fashion, real-time, and preference between people. With the advances in technologies, consumers can search and download video, music, and other multimedia information in real-time via the VTS (Golob & Regan, 2001). In this paper, four commercial VTS products from different TSPs (Taiwan, the US, Europe, and Japan) are analyzed and benchmarked to discuss the required utilities/functions and services for the next e-era generation VTS. The aspect of audio–video and entertainment services is divided into four evaluation criteria: real-time multimedia services, vehicle multimedia playing systems, game services, and personal platform services to find out the required utilities/functions for the next e-era generation VTS regarding audio–video and entertainment services. Six aspects based on the above four functions (navigational and location services, safety and security services, communications and information services, audio–video and entertainment services) with the cost consideration (fee rate and payment methods) and the image consideration (product image) use to construct the entire evaluation network of VTS systems.

3. Building an evaluation model for the best vehicle telematics system

In this Section the general concept of evaluation model is proposed to build a best vehicle telematics system model using MCDM techniques for evaluating and improving the existing vehicle-telematic products. The study is divided into four Subsections. Section 3.1 deals with the survey of VTS functions and consumers' preference. In Section 3.2, the DEMATEL method is used to build the value-created and influence network system. In Section 3.3, the ANP method will be introduced based on influence network system. In Section 3.4, the TOPSIS method for improving the gaps in each criterion will be described based on the whole system.

3.1. Survey for VTS functions and consumer preference

In this Subsection, consumers answer the questionnaires by considering the following six aspects: navigational and location services, safety and security services, communications and information services, audio–video and entertainment services, fee rate and payment methods, and product image that encompass 25 cri-

Table 1
Description of criteria and its codeword for evaluating VTS's functions.

Aspects/criteria	Descriptions
Navigation and location services (N)	
Voice-guided navigation services (N_1)	The more precise voice-guided navigation services improve the efficiency of driving and reduce driving time
Traffic information (N_2)	More correct traffic situation information and more driving time to save, helps user to realize the immediate road conditions, and comply with traffic signals
Electronic map information (N_3)	More accurate map information allows drivers to handle and estimate the distance to destination
Safety and security services (S)	
Safety and emergency services (S_1)	To prevent accidents and provide rescue assistance. Also clarifies the responsibilities for investigation after an accident
Remote central control services (S_2)	Remote door lock or unlock services to assure safety of passengers and car security
Vehicle location services (S_3)	To search and locate a stolen vehicle or a towed car
Car security services (S_4)	To prevent the vehicle from being stolen and provide prior warning
Vehicle diagnosis and maintenance services (S_5)	To handle the operating conditions of vehicle devices, and provide maintenance suggestions
Communications and information services (I)	
Mobile information services (I_1)	Enable consumers to manage e-commerce, get real-time information and access the internet while moving
User interface (I_2)	Friendlier and more numerous choices will increase the convenience of use
Platform integration services (I_3)	Integrating different platforms will increase compatibility of systems, and save replacement costs
Information security protection (I_4)	Stricter security protection, more safeguards for the privacy of personal data, to prevent the criminal use of personal data
Information update frequency (I_5)	More immediate and quick information updates to ensure more accuracy and precision
Audio–video and entertainment services (V)	
Real-time multimedia services (V_1)	More choices for real-time multimedia services, enabling more current access to fashion and entertainment
Vehicle multimedia playing system (V_2)	Larger screen size, support for various multimedia formats, and larger storage capacity enable consumers to enjoy more comfortable audio–video services
Game services (V_3)	Various choices of game services allow for more fun
Personal platform services (V_4)	Personalized set-up function of multimedia. Consumers can enjoy personalized services
Fee rate and payment method (C)	
Service fee rate (C_1)	The service fee rate and promotion term
Pricing (C_2)	The different pricing items and pricing methods which users prefer
Payment method (C_3)	Flexible payment methods can satisfy consumers with different spending habits
Payment channel (C_4)	More payment channels can enhance consumers' convenience
Product image (P)	
Product design (P_1)	More popular product design, more selective and easier to carry can stimulate the desire to buy the product
Brand image (P_2)	Better brand image, more confidence in the quality of the services provided
After-sales services (P_3)	More after-sales service locations and wider channels, consumers will feel confident about maintenance and warranty services
Privacy policy (P_4)	More stringent privacy protection policies can avoid the leakage of car and personal information for criminal use

teria to identify their real needs for the next e-era generation VTS. Descriptions of the contents of each criterion are shown in Table 1.

3.2. Building the DEMATEL model

The basic concept of DEMATEL technique was initiated for the Science and Human Affairs Program by Battelle Memorial Institute of Geneva between 1972 and 1976 to solve complex problems. This study uses the concept DEMATEL method to build the evaluation structure of network relation-map (NRM) for creating an e-era VTS. When making decisions, the decision-maker has to consider the criteria in detail and all the interrelations between them. What the decision-maker has to do is to find out the key criteria, modify them and then the whole performance of satisfaction will be enhanced. Therefore, when the decision-maker copes with lots of criteria being changed, the best solution is to determine the key criteria that most affect the other criteria and modify them. Eventually, the results of the evaluation will become more and more precise. Therefore, some recent studies considered the DEMATEL techniques for solving complex studies, such as user interface (Hori & Shimizu, 1999), reprioritization of failures in a system failure mode and effects analysis (Seyed-Hosseini, Safaei, & Asgharpour, 2006), developing global managers' competencies (Wu & Lee, 2007), evaluating performance in e-learning programs (Tzeng, Chiang, & Li, 2007), the innovation policy portfolios for Taiwan's SIP mall industry (Huang, Shyu, & Tzeng, 2007), airline safety measurement (Liou, Tzeng, & Chang, 2007), choice of knowledge management strategy (Wu, 2008), causal analytic method for group decision-making (Lin & Wu, 2008); safety management system of airlines (Liou, Yen, & Tzeng, 2008); selection management systems of SMEs (Tsai & Chou, 2009), the expectation model of service quality (Tseng, 2009a, 2009b), value-created system of science (technology) park (Lin & Tzeng, 2009), hotel service quality system (Tseng, 2009a, 2009b), importance-performance analysis model of the computer industry (Hu, Lee, Yen, & Tsai, 2009) and denotification of a threshold value for the DEMATEL method (Li & Tzeng, 2009). The steps of the DEMATEL method are described as follows: (1) calculating the original influence matrix by average of expert-respondents, (2) calculating the degree of direct influence matrix, (3) calculating the total degree of indirect influence matrix, (4) calculating the total degree of direct and indirect influence matrix, and (5) determining the NRM.

3.2.1. Calculating the original influence matrix by average of expert-respondents

Respondents were asked to indicate the influence that they believe each aspect exerts on each of the others according to a scoring scale ranging from 0 to 4 (going from "no influence (0)," to "extreme strong influence (4)"). A higher score from a respondent indicates a belief that insufficient involvement in the problem by aspect i exerts a stronger possible direct influence on the inability of aspects/criteria j, or, in positive terms, that greater improvement in i is required to improve j. From any group of direct matrices of respondents it is possible to derive a average influence matrix $\boldsymbol{A}$ (original), as shown in Table 2. Each aspect of this average matrix will be in this case the mean of the same aspects in the different direct matrices of the respondents. As the data shows in Table 2, the aspect of N is moderately affected by the aspect of I. Comparably the aspect of N is less affected by the aspect of V, as shown in Table 2.

3.2.2. Calculating the degree of direct influence matrix

As shown in Table 2, the average influence matrix $\boldsymbol{A}$ (original) is a matrix, which can be gained from following Eqs. (1) and (2). As

Table 2
The average influence matrix *A* (original).

Aspects	*N*	*S*	*I*	*V*	*C*	*P*	Total
Navigation and location services (*N*)	0.00	1.57	2.83	1.52	1.79	2.31	10.02
Safety and security services (*S*)	1.71	0.00	2.52	1.31	1.79	2.31	9.64
Communications and information services (*I*)	**2.98**	2.40	0.00	2.00	1.93	2.36	**11.67**
Audio–video and entertainment services (*V*)	**1.52**	1.31	2.12	0.00	2.00	2.31	9.26
Fee rate and payment method (*C*)	2.05	1.71	1.86	2.02	0.00	1.57	9.21
Product image (*P*)	2.26	2.05	1.98	1.95	1.52	0.00	9.76
Total	10.52	9.05	11.31	8.81	9.02	10.86	–

shown in Table 3, the matrix $\boldsymbol{X}$ of each element denotes the degree of direct influence value; these total row or column values are less than 1 and at least one row or column value equal 1 but not all. So calculating the each sum of columns and rows of matrix $\boldsymbol{A} = [a_{ij}]_{n\times n}$, then the direct influence matrix can be gained $\boldsymbol{X} = [x_{ij}]_{n\times n}$, as shown in Table 3. As data shown in Table 4, the degree of direct influence of the aspect of communication and information service (I) is the most important one. Comparably, the aspect of audio–video and entertainment service (V) is the lowest one.

$$\boldsymbol{X} = s\boldsymbol{A}, \quad s > 0 \tag{1}$$

where

$$s = \min_{i,j}\left[1\Big/\max_{1\leqslant i\leqslant n}\sum_{j=1}^{n} a_{ij}, 1\Big/\max_{1\leqslant j\leqslant n}\sum_{i=1}^{n} a_{ij}\right], \quad i,j = 1,2,\ldots,n \tag{2}$$

Table 3
The direct influence matrix *X*.

Aspects	*N*	*S*	*I*	*V*	*C*	*P*	Total
Navigation and location services (*N*)	0.00	0.13	0.24	0.13	0.15	0.20	0.86
Safety and security services (*S*)	0.15	0.00	0.22	0.11	0.15	0.20	0.83
Communications and information services (*I*)	0.26	0.21	0.00	0.17	0.17	0.20	**1.00**
Audio–video and entertainment services (*V*)	0.13	0.11	0.18	0.00	0.17	0.20	0.79
Fee rate and payment method (*C*)	0.18	0.15	0.16	0.17	0.00	0.13	0.79
Product image (*P*)	0.19	0.18	0.17	0.17	0.13	0.00	0.84
Total	0.90	0.78	0.97	0.76	0.77	0.93	–

Table 4
The degree of direct influence.

Aspects	Sum of columns	Sum of rows	Sum of columns + rows	#
Navigation and location services (*N*)	0.86	0.90	1.76	3
Safety and security services (*S*)	0.83	0.78	1.60	4
Communications and information services (*I*)	1.00	0.97	1.97	1
Audio–video and entertainment services (*V*)	0.79	0.76	1.55	6
Fee rate and payment method (*C*)	0.79	0.77	1.56	5
Product image (*P*)	0.84	0.93	1.77	2

and $\lim_{m\to\infty}\boldsymbol{X}^m = [0]_{n\times n}$, where $\boldsymbol{X} = [x_{ij}]_{n\times n}$, when $0 < \sum_{j=1}^{n} x_{ij}$ and $\sum_{i=1}^{n} x_{ij} \leqslant 1$ and at least one $\sum_{j=1}^{n} x_{ij}$ or $\sum_{i=1}^{n} x_{ij}$ equal one, but not all. We can guarantee $\lim_{m\to\infty}\boldsymbol{X}^m = [0]_{n\times n}$.

3.2.3. Calculating the indirect influence matrix

The indirect influence matrix $\boldsymbol{IT}$ can be gained from following Eq. (3), as shown in Table 5.

$$IT = \sum_{i=2}^{\infty}\boldsymbol{X}^i = \boldsymbol{X}^2(\boldsymbol{I}-\boldsymbol{X})^{-1} \tag{3}$$

[Proof]

$$\begin{aligned}\boldsymbol{IT} &= \sum_{i=2}^{\infty}\boldsymbol{X}^i = \boldsymbol{X}^2 + \boldsymbol{X}^3 + \cdots + \boldsymbol{X}^m \\ &= \boldsymbol{X}^2(I + \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^{m-2})(1-\boldsymbol{X})(1-\boldsymbol{X})^{-1} \\ &= \boldsymbol{X}^2(I-\boldsymbol{X}^{m-1})(I-\boldsymbol{X})^{-1} = \boldsymbol{X}^2(I-\boldsymbol{X})^{-1}, \\ &\quad \text{when } \lim_{m\to\infty}\boldsymbol{X}^{m-1} = [0]_{n\times n}\end{aligned}$$

3.2.4. Calculating the total (direct and indirect) influence matrix

The total (direct and indirect) influence matrix $\boldsymbol{T}$ as shown in Table 6 – the infinite series of direct and indirect effects of each aspect – can be obtained by the matrix operation of $\boldsymbol{X}$. The matrix $\boldsymbol{T}$ shows the final structure of aspects after the continuous process (see Eqs. (4)–(8)). Setting a threshold value, P, to filter the obvious effects can be denoted by the aspects of matrix $\boldsymbol{T}$, is necessary to explain the structure of the aspects. Based on the matrix $\boldsymbol{T} = [i_{ij}]_{n\times n}$, each aspect, $\boldsymbol{t}_{ij}$, of matrix $\boldsymbol{T}$ provides information about how aspect i influences aspect j. If all the information from matrix $\boldsymbol{T}$ converts to the NRM, the map will be too complex to show the necessary information for decision-making. To obtain an appropriate NRM, the decision-maker must set a threshold value for the influence level. Only some aspects, whose influence level in matrix $\boldsymbol{T}$ are higher than the threshold value, can be chosen and converted into the NRM for simplicity. The threshold value is determined by

Table 5
The indirect influence matrix.

Aspects	*N*	*S*	*I*	*V*	*C*	*P*
Navigation and location services (*N*)	0.94	0.81	0.93	0.77	0.78	0.91
Safety and security services (*S*)	0.90	0.80	0.92	0.76	0.76	0.89
Communications and information services (*I*)	1.02	0.90	1.12	0.87	0.89	1.05
Audio–video and entertainment services (*V*)	0.86	0.75	0.88	0.73	0.72	0.84
Fee rate and payment method (*C*)	0.84	0.74	0.88	0.70	0.74	0.86
Product image (*P*)	0.89	0.77	0.93	0.74	0.77	0.93

Table 6
The total direct and indirect influence matrix (*T*).

P = 1.04	*N*	*S*	*I*	*V*	*C*	*P*
Navigation and location services (*N*)	0.94	0.94	1.17*	0.90	0.93	1.11*
Safety and Security Services (S)	1.05*	0.80	1.14*	0.87	0.91	1.09*
Communications and information services (*I*)	1.28*	1.11*	1.12*	1.04*	1.06*	1.25*
Audio–video and entertainment services (*V*)	0.99	0.86	1.06*	0.73	0.89	1.04*
Fee rate and payment method (*C*)	1.02	0.89	1.04*	0.87	0.74	0.99
Product image (*P*)	1.08*	0.95	1.10*	0.91	0.90	0.93

* Means the value is ⩾ the threshold value (*P* = 1.04).

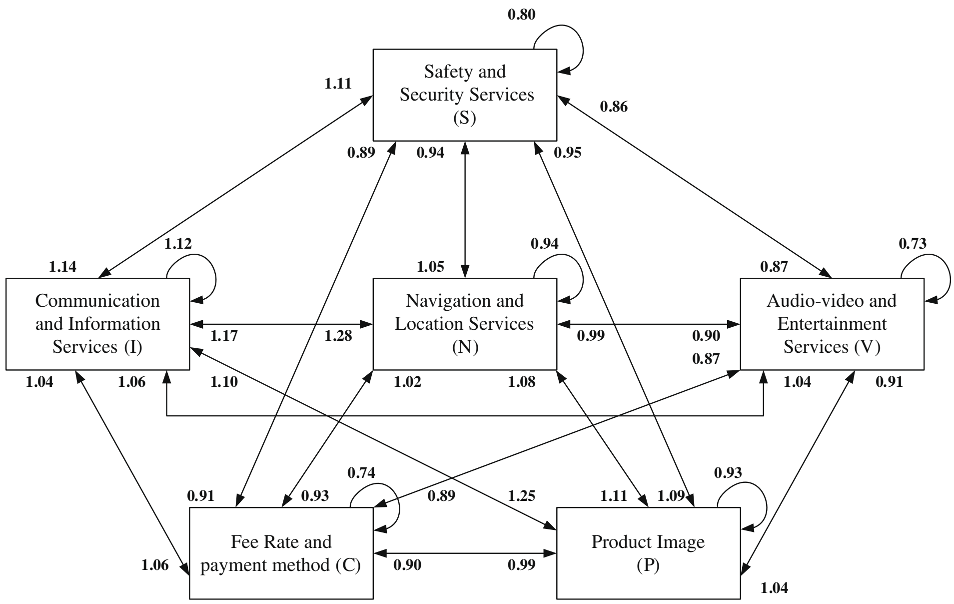

Fig. 1. Total influence NRM (no setting threshold).

the decision-maker or, in this paper, by experts through discussion in real case. Like matrix $\boldsymbol{X}$, contextual relationships among the aspects of matrix $\boldsymbol{T}$ can also be converted into a NRM. If the threshold value is too low, the map will be too complex to show the necessary information for decision-making as shown in Fig. 1. If the threshold value is too high, many aspects will be presented as independent aspects without showing the relationships with other aspects. Each time the threshold value increases, some aspects or relationships will be removed from the map. After the threshold value and relative impact-digraph-map are decided, the final influence result can be shown. For example, the NRM of a factor is the same as Figs. 2 and 3 and six aspects exist in this map. The total direct/indirect influence matrix ($\boldsymbol{T}$) can be gained as Eqs. (4)–(6). The higher the sum of column value plus row value $(d_i + r_i)$ is shown the stronger the influence of the aspect or criterion i to the others. The sum of column value minus row value $(d_i - r_i)$ shows the net influence relationship. If $d_i - r_i > 0$, it means the degree of affect on the others is stronger than the degree it is affected. This can be seen in Table 7.

$$\boldsymbol{T} = \boldsymbol{X} + \boldsymbol{IT} \tag{4}$$

$$\boldsymbol{T} = \sum_{i=1}^{\infty} \boldsymbol{D}^i = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1} \tag{5}$$

$$\boldsymbol{T} = [t_{ij}], \quad i,j = 1,2,\ldots,n \tag{6}$$

$$\boldsymbol{d} = \boldsymbol{d}_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = (d_1,\ldots,d_i,\ldots,d_n) \tag{7}$$

$$\boldsymbol{r} = \boldsymbol{r}_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = (r_1,\ldots,r_j,\ldots,r_n) \tag{8}$$

[Proof]

$$\begin{aligned}\boldsymbol{T} &= \boldsymbol{X} + \boldsymbol{IT} = \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^m \\ &= \boldsymbol{X}(I + \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^{m-1})(I - \boldsymbol{X})(I - \boldsymbol{X})^{-1} \\ &= \boldsymbol{X}(I - \boldsymbol{X}^m)(I - \boldsymbol{X})^{-1} = \boldsymbol{X}(I - \boldsymbol{X})^{-1}, \quad \text{when } \lim_{m\to\infty} \boldsymbol{X}^m = [0]_{n\times n}\end{aligned}$$

3.2.5. Determining the NRM

According to the defined aspects/criteria as shown in Table 1, some experts were invited to discuss the relationship and influence

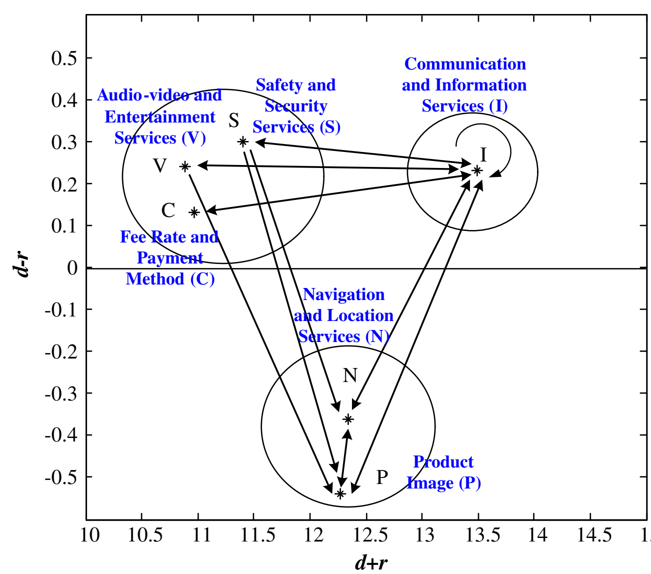

Fig. 2. Telematics system entwined criteria structure (threshold value = 1.04).

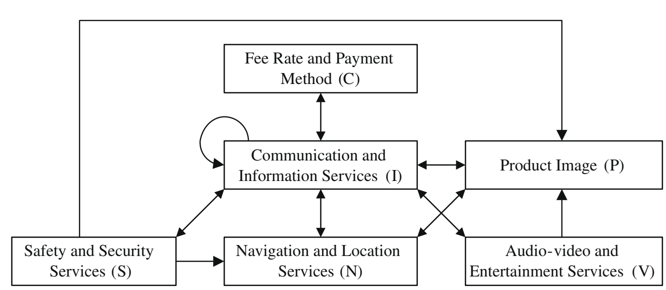

Fig. 3. The network relation-map of telematics system (threshold value = 1.04).

levels of criteria under the same aspects/criteria, and to score the relationship and influence among criteria based on the DEMATEL technique. Aspects/criteria were divided into different types, so the experts could answer the questionnaire in areas with which

Table 7
The degree of full influence.

Aspects	{d}	{r}	{d + r}	{d − r}
Navigation and location services (*N*)	5.99	6.35	12.34	−0.36
Safety and security services (*S*)	5.85	5.55	11.40	0.30
Communications and information services (*I*)	6.86	6.63	13.49	0.23
Audio–video and entertainment services (*V*)	5.56	5.32	10.89	0.24
Fee rate and payment method (*C*)	5.55	5.42	10.97	0.13
Product image (*P*)	5.86	6.40	12.27	−0.54

Note: {d} = sum vector of columns, {r} = sum vector of rows, {d + r} = sum vector of columns plus rows, {d − r} = sum vector of columns minus rows.

they were familiar. In order to limit information loss from the DEMATEL technique's results, threshold values ($P = 1.04$) were determined after discussions with these experts and an acceptable NRM was found as shown in Table 6 and Fig. 2. As shown in Fig. 2, safety and security services (*S*) is the main net influence aspect, product image (*P*) is the main be affected aspect, and communications and information services (*I*) is the main total influence aspect as shown in Figs. 2 and 3.

3.3. The analytical network procedure (ANP) model

The ANP method is expressed by a unidirectional hierarchical relationship among decision levels. The top element of the hierarchy is the overall goal for the decision model. The hierarchy decomposes to a more specific criterion until a level of manageable decision criteria is met (Meade & Presley, 2002). Under each criterion, sub-criteria elements relative to the criterion can be constructed. ANP was originally applied to uncertain problems with multiple criteria, and has been widely used in solving problems of ranking, selection, evaluation, optimization, and prediction decisions (Aragones-Beltran, Aznar, Ferris-Onate, & Garcia-Melon, 2008; Dagdeviren, Yuksel, & Kurt, 2008; Erdogmus, Kapanoglu, & Koc, 2005; Kahraman, Ertay, & Buyukozkan, 2006; Shyur, 2006; Shyur & Shih, 2006; Wu, 2008). The steps of the ANP method are described as follows: (1) clarifying the questions and constructing the structure of evaluating system, (2) designing the questionnaire and survey the effect, (3) pair-wise comparison to determine relative importance of aspects/criteria, (4) calculating the super-matrix, (5) calculating the synthesical index and improving the gaps of each criterion (Saaty, 2006; Shyur, 2006; Shyur & Shih, 2006).

3.3.1. Clarifying the questions and constructing the structure of evaluating system

The essentiality of the questions induces all possible elements affecting the decision-making as follows. The researchers should clarify and induce all information about the questions. The researchers should propose the result composed of goal, hierarchy, criteria and feasible solutions to the expert for reference, then use the brainstorming method to find out how the elements affects the decision-making. When constructing the evaluating system, the relations (including dependence and feedback) between different hierarchies should be connected as an arc, a one-way arrow or a two-way arrow, as shown in Fig. 4.

3.3.2. Designing the questionnaire and survey the effect

According to the evaluating system, the expert should make the judgment of the degree of the relative importance of aspects/criteria. The research should adapt the questionnaire method to produce the desired effect.

3.3.3. Pair-wise comparison to determine relative importance of aspects/criteria

ANP procedures to gain the weights are described as follows:

(1) Compare pair-wise the relative importance of factors and obtain a $n \times n$ pair-wise comparison matrix, in which n means the number of criteria. As the data shows in Table 8, a pair-wise comparison can be gained.
(2) Check the consistency of logical judgment using the consistency index (*C.I.*) and consistency ratio (*C.R.*). The *C.I.* value is defined as $C.I. = (\lambda_{\max} - n)/(n-1)$, and the $\lambda_{\max}$ is the largest eigenvalue of the pair-wise comparison matrix. The *C.R.* value is defined as *C.R.* = *C.I.*/*R.I.* (*R.I.*: random index). The *R.I.* value is decided by the value of n. In general, the values of *C.I.* and *C.R.* should be less than 0.1 or reasonably consistent (as shown in Table 9).
(3) Use the normalized eigenvector of the largest eigenvalue ($\lambda_{\max}$) as the factor weights, as shown in Table 10. The purpose of the ANP enquiry in this paper is to construct a hierarchical evaluation system.

Table 8
Pair-wise comparisons in aspect *P*.

Criteria	*P*1	*P*2	*P*3	*P*4
Product design (*P*1)	1 (1)	1	1/9 (3)	1/9
Brand image (*P*2)	1	1	1/2	1/2
After-sales services (*P*3)	9 (2)	2	1	1
Privacy policy (*P*4)	9	2	1	1

Note 1: the parenthetic value 1 means the criterion (*P*1) and criterion (*P*1) are equally important.
Note 2: the parenthetic value 9 means the criterion (*P*1) has 9-times the degree of importance as criterion (*P*3).
Note 3: the parenthetic value 1/9 means the criterion (*P*3) has 1/9 times the degree of importance as criterion (*P*1).

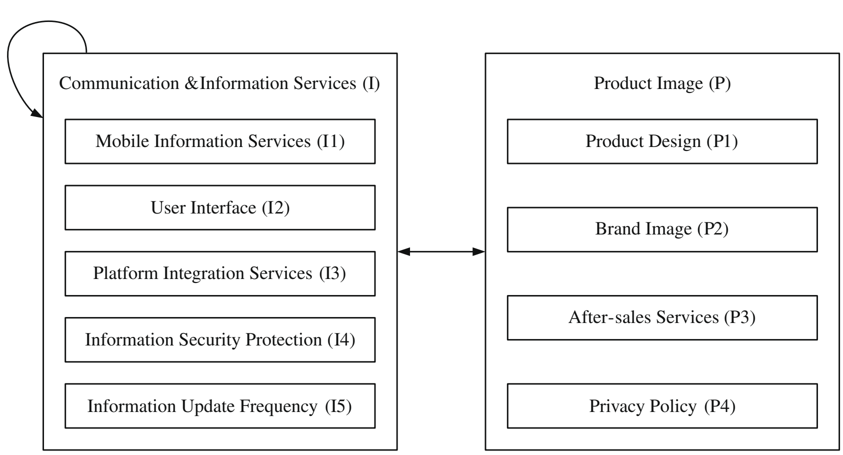

Fig. 4. Hierarchical relationship with dependence-feedback and self-relation.

Table 9
The testing of consistency (*C.I.* and *C.R.* testing).

$C.I. = (\lambda_{\max} - n)/(n-1);\ n = 4$	0.02	C.R. = C.I./R.I.	0.02
The threshold value	0.1	The threshold value	0.1

Note: Saaty suggested the values of *C.I.* and *C.R.* should be less than 0.1.

Table 10
The weights (pre- and post-normalization) in aspect *P*.

Criteria	Pre-normalization	Post-normalization (%)
Product design (*P*1)	0.06	0.04
Brand image (*P*2)	0.39	0.22
After-sales services (*P*3)	0.65	0.37
Privacy policy (*P*4)	0.65	0.37
Sum	1.75	1.00

Note: Pre-normalization means the largest eigenvalue as the factor weights; post-normalization means the sum of factor weights = 1.

3.3.4. Calculating the super-matrix

The super-matrix can be gained by $(\boldsymbol{T} \times \boldsymbol{T})^{2k+1}$, where k is determined by assumption. Based on the independent criteria obtained in Section 3.1 and the reduced criteria derived from Section 3.2, the ANP method could gain criteria weights and criteria, and then obtain the final effectiveness of the VTS (as shown in Tables 11–15).

3.3.5. Calculating the synthesical index and improving the gaps of each criterion

The synthesical index can be gained as DI calculated as shown in Eq. (9):

Table 11
Relative weighted relationship.

Aspects	Weight
Navigation and location services (*N*)	0.18
Safety and security services (*S*)	0.18
Communications and information services (*I*)	0.18
Audio–video and entertainment services (*V*)	0.09
Fee rate and payment method (*C*)	0.18
Product image (*P*)	0.18

Table 12
Relative weighted relationship.

Aspects	Proportion rate	Relative weighted coefficient (%)
Communications and information services (*I*)	$I/(P+I)$	0.5
Product image (*P*)	$P/(P+I)$	0.5

$$DI_k = \sum_{j=1}^{n} w_j r_{kj}, \quad k = 1, 2, \ldots, m \tag{9}$$

where w_j is the relative weight of criteria; r_{kj} is the fitness of the degree of satisfaction; the aspired/desired level is A^{Best}, A^{Best} = {r_j^* is an aspired/desired value of j criteria| $j = 1, 2, \ldots, n$}. The gap between r_{kj} and r_j^* should be improved in j criteria of alternative.

3.4. TOPSIS method

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is presented in Abo-Sinna and Abou-El-Enien (2006), Abo-Sinna and Amer (2005), Chen and Tzeng (2004), Deng, Yeh, and Willis (2000), Jahanshahloo, Lotfi, and Izadikhah (2006a, 2006b), Olson (2004), Shyur (2006), Shyur and Shih (2006), Tzeng, Lin, and Opricovic (2005), Wang and Chang (2007), Wang and Lee (2007), Yurdakul and Ic (2005). The basic principle is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution as shown in Fig. 5.

In this paper, four commercial VTS products of different TSPs (i.e. Taiwan, US, Europe, and Japan) as example are analyzed and benchmarked to discuss the required utilities and services of the next e-era generation VTS. The results using the TOPSIS method could determine which one is the most appropriate for consumers. The TOPSIS procedure consists of the following steps: (1) calculating the normalized decision matrix (Tables 16–18); (2) calculating the weighted normalized decision matrix (Table 19), (3) determining the positive ideal and negative-ideal solution; (4) calculating the distance of the utility value of each criterion between the positive and negative-ideal solution, (5) calculating the relative closeness to the ideal solution, and (6) improving the gaps in criteria.

3.4.1. Calculating the normalized decision matrix

The normalized value $r_{kj},\ r_{kj}$ is calculated as Eq. (10), as shown in Table 16.

$$r_{kj} = \frac{e_{kj} - e_{j,\min}}{e_{j,\max} - e_{j,\min}} \quad \text{or} \quad \frac{e_{kj} - e_{j,worst}}{e_{j,aspire} - e_{j,worst}}, \quad j = 1, 2, \ldots, n \tag{10}$$

In this research, let $e_{j,\max} = e_{j,aspire} = 10$ and $e_{j,\min} = e_{j,worst} = 0$.

3.4.2. Calculating the weighted normalized decision matrix

The weighted normalized value v_{kj} is calculated as Eq. (11)

$$v_{kj} = w_j \times r_{kj} \tag{11}$$

where w_j is the weight of the ith attribute or criterion.

Table 13
Original super-matrix.

Aspects/criteria		*I*					*P*			
		*I*1	*I*2	*I*3	*I*4	*I*5	*P*1	*P*2	*P*3	*P*4
Communications and information services (*I*)	*I*1	1.00	0.00	0.00	0.00	0.00	0.05	0.24	0.30	0.31
	*I*2	0.00	1.00	0.00	0.00	0.00	0.43	0.03	0.03	0.03
	*I*3	0.00	0.00	1.00	0.00	0.00	0.43	0.24	0.28	0.03
	*I*4	0.00	0.00	0.00	1.00	0.00	0.05	0.24	0.12	0.31
	*I*5	0.00	0.00	0.00	0.00	1.00	0.05	0.24	0.28	0.31
Product image (*P*)	*P*1	0.05	0.04	0.05	0.04	0.04	0.00	0.00	0.00	0.00
	*P*2	0.05	0.22	0.05	0.32	0.32	0.00	0.00	0.00	0.00
	*P*3	0.45	0.37	0.45	0.32	0.32	0.00	0.00	0.00	0.00
	*P*4	0.45	0.37	0.45	0.32	0.32	0.00	0.00	0.00	0.00

Note: Communications and information services (*I*) includes 5 criteria composed of *I*1 (mobile information services), *I*2 (user interface), *I*3 (platform integration services), *I*4 (information security protection) and *I*5 (information update frequency); product image (*P*) includes 4 criteria composed of *P*1 (product design), *P*2 (brand image), *P*3 (after-sales services) and *P*4 (privacy policy). The same definition is adopted in Tables 14 and 15.

Table 14
Weighted super-matrix.

Aspects/criteria		*I*					*P*			
		*I*1	*I*2	*I*3	*I*4	*I*5	*P*1	*P*2	*P*3	*P*4
Communications and information services (*I*)	*I*1	0.50	0.00	0.00	0.00	0.00	0.05	0.24	0.30	0.31
	*I*2	0.00	0.50	0.00	0.00	0.00	0.43	0.03	0.03	0.03
	*I*3	0.00	0.00	0.50	0.00	0.00	0.43	0.24	0.28	0.03
	*I*4	0.00	0.00	0.00	0.50	0.00	0.05	0.24	0.12	0.31
	*I*5	0.00	0.00	0.00	0.00	0.50	0.05	0.24	0.28	0.31
Product image (*P*)	*P*1	0.03	0.02	0.03	0.02	0.02	0.00	0.00	0.00	0.00
	*P*2	0.03	0.11	0.03	0.16	0.16	0.00	0.00	0.00	0.00
	*P*3	0.22	0.19	0.22	0.16	0.16	0.00	0.00	0.00	0.00
	*P*4	0.22	0.19	0.22	0.16	0.16	0.00	0.00	0.00	0.00

Table 15
Limited super-matrix.

Aspects/criteria		*I*					*P*			
		*I*1	*I*2	*I*3	*I*4	*I*5	*P*1	*P*2	*P*3	*P*4
Communications and information services (*I*)	*I*1	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
	*I*2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	*I*3	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	*I*4	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
	*I*5	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Product image (*P*)	*P*1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	*P*2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	*P*3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
	*P*4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

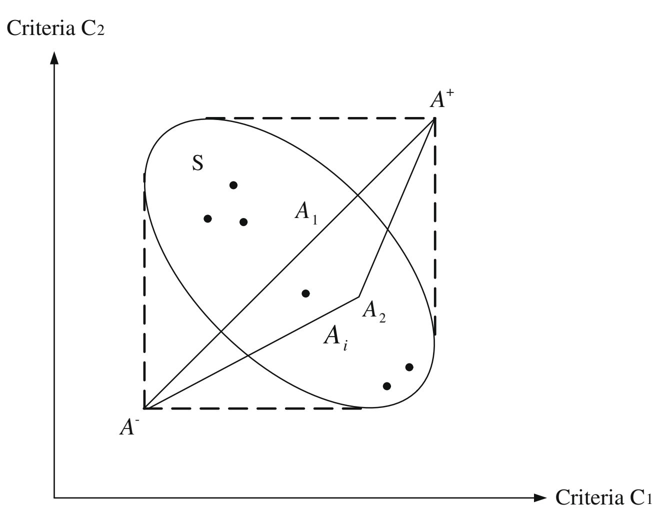

Fig. 5. The positive ideal and negative-ideal solution relationship.

3.4.3. Determining the positive ideal and negative-ideal solution

The ideal solution (A^+) and negative-ideal solution (A^-) is calculated as Eqs. (12) and (13)

$$A^+ = \left\{(\max_k v_{kj}|j \in I), (\min_k v_{kj}|j \in I'), k = 1,2,\ldots,m\right\} = \{v_1^+, v_2^+, \ldots, v_j^+, \ldots, v_n^+\} \quad (12)$$

$$A^- = \left\{(\min_k v_{kj}|i \in I), (\max_k v_{kj}|i \in I'), k = 1,2,\ldots,m\right\} = \{v_1^-, v_2^-, \ldots, v_j^-, \ldots, v_n^-\} \quad (13)$$

where I is associated with benefit criteria, and I' is associated with cost criteria.

3.4.4. Calculating the distance of the utility value of each criterion between the positive and negative-ideal solution

The separation of each alternative from the ideal solution is given as Eq. (14),

$$d_k^+ = \sqrt{\sum_{j=1}^{n} (v_{kj} - v_j^+)^2}, \quad k = 1,2,\ldots,m \quad (14)$$

Similarly, the separation from the negative-ideal solution is given as Eq. (15)

$$d_k^- = \sqrt{\sum_{j=1}^{n} (v_{kj} - v_j^-)^2}, \quad k = 1,2,\ldots,m \quad (15)$$

3.4.5. Calculating the relative closeness to the ideal solution

The relative closeness of the alternative A_k with respect to A^* is defined as Eq. (16)

$$C_k^* = \frac{d_k^-}{d_k^+ + d_k^-} = 1 - \frac{d_k^+}{d_k^+ + d_k^-}, \quad k = 1,2,\ldots,m \quad (16)$$

where $\frac{d_k^+}{d_k^+ + d_k^-}$ denotes the gap that should be improved in alternative k. Then we will improve this gap according to the NRM among criteria.

3.4.6. Improving the gaps in criteria

The largest value of $e_{j,aspire}$ is the best solution theoretically. If there have been gaps between e_{kj} and the best solution $e_{j,aspire}$ in all criteria j, there is still much levels for improving the performance of existing solutions to attain the aspired/desired level in consumers' minds.

Table 16
VTS value-created evaluation (navigation and location services).

Criterion	Items	Service items	T VTS			U VTS			E VTS			J VTS		
			OV	BV	AVE	OV	BV	AVE	OV	BV	AVE	OV	BV	AVE
Voice-guided navigation services (N_1)	Short route	Short-cut	7.28	8.10	7.77	0.00	8.10	7.03	0.00	8.10	7.03	7.28	8.10	7.03
		Best route	8.10			8.10			8.10			8.10		
		Alternative route	7.02			0.00			0.00			7.02		
		Turning navigation	5.30	7.43		5.30	5.96		5.30	5.96		5.30	5.96	
	On-driving	Route navigation	5.96			5.96			5.96			5.96		
		Route speed-limit	7.02			0.00			0.00			0.00		
		Speed limit alarm	7.43			0.00			0.00			0.00		

Note: OV and BV mean original value and the best value, AVE means average of service items.

Table 17
Original value of VTS service (*N*).

Aspect	C_j	Preference	VTS A_k				$e_{j,aspire}$	$e_{j,worst}$
			T	U	E	J		
Navigation and location services (*N*)	*N*1	MAX	7.77	7.03	7.03	7.03	10	0
	*N*2	MAX	4.57	2.84	2.84	2.84	10	0
	*N*3	MAX	6.89	6.85	6.86	6.97	10	0

Note: Navigation and location services (*N*) includes 3 criteria composed of *N*1 (voice-guided navigation services), *N*2 (traffic information), *N*3 (electronic map information). The same definition is adopted in Tables 18 and 19.

Table 18
The normalized value of VTS.

Aspect	C_j	VTS A_k			
		T	U	E	J
Navigation and location services (*N*)	*N*1	0.78	0.70	0.70	0.70
	*N*2	0.46	0.28	0.28	0.28
	*N*3	0.69	0.69	0.69	0.70

Table 19
The weighted normalized value of VTS (navigation and location).

Aspect		w_j	VTS A_k			
			T	U	E	J
Navigation and location services (*N*)	*N*1	0.060	0.047	0.042	0.042	0.042
	*N*2	0.064	0.029	0.018	0.018	0.018
	*N*3	0.081	0.056	0.055	0.055	0.056

Table 20
The degree of demand (by gender).

Gender	Male		Female	
Function	#	Priority	#	Priority
Navigation and location services (*N*)	3.96	1	4.09	1
Safety and security services (*S*)	3.19	2	3.45	2
Communications and information services (*I*)	2.59	4	2.27	4
Audio–video and entertainment services (*V*)	2.96	3	2.64	3

Note: # means the degree of demand.

4. The empirical analysis of evaluation model for VTS market

In this Section, the study is divided into five subsections. Section 4.1 deals with the survey of consumer preference for VTS functions. Section 4.2 uses the decision-making trial and evaluation laboratory (DEMATEL) method for analysis of empirical cases. Section 4.3 uses the analytic network process (ANP) method for analysis of empirical cases. Section 4.4 uses the technique for order preference by similarity to ideal solution (TOPSIS) method for analysis of empirical cases. Section 4.5 is the discussion.

4.1. Finding the consumer preference for VTS functions

The priority of needs of males and females is the same (as shown in Table 20). The utility value from the best aspect to the last is *N*, *S*, *I*, *V*. As shown in Table 21, the priority of demand of the 21–30 year-old group and the 31–40 year-old group is the same. The utility value from the best to the last is *N*, *S*, *I*, *V*. The priority of demand of the 41–50 year-old group, the utility value from the best to the last one is *S*, *N*, *I*, *V*. As a result, the priority of need of services of VTS will differ by age group. TSPs could take the age factor into consideration for modulizing the VTS services. The 41–50 year-old group put stress on safety and security services, perhaps due to their wealth and concern for family members.

4.2. Finding the degree of importance and satisfaction for VTS functions

As shown in Fig. 6 and Table 22, the analysis the degree of importance and satisfaction of criteria is conducted and the surveyed data is normalized into equal measuring scales. According to the results of surveyed data, the criteria is divided into four categories as follows: The first category is a high degree of satisfaction with a high degree of importance shown by the symbol $\circ(+,+)$. The second category of criteria is a high degree of satisfaction with a low degree of importance shown by the symbol $\bullet(+,-)$, and the third category of criteria is a low degree of satisfaction with a low degree of importance shown by the symbol $\blacktriangle(-,-)$. The fourth category of criteria is a low degree of satisfaction with a high degree of importance shown by the symbol X(−,+). In this study, the strategies of the value-created system of VTS are proposed as follows; First, to improve those criteria (i.e. *I*5, *C*3) falling into the fourth category [X(−,+)]; the next immediate step is to improve those criteria (i.e. *S*4, *S*5, *I*1, *I*3, *I*4, *V*1, *V*2, *V*3, *V*4, *P*1) falling into the third category [$\blacktriangle(-,-)$]. The fourth category criteria [X (-, +)] are key factors that affect the whole satisfaction degree of VTS. About the

Table 21
The degree of demand (by age).

Age	21–30 years old		31–40 years old		41–50 years old	
Function	#	Priority	#	Priority	#	Priority
Navigation and location services (*N*)	4.00	1	4.25	1	3.25	2
Safety and security services (*S*)	3.55	2	2.58	2	3.75	1
Communications and information services (*I*)	2.73	4	2.08	4	2.50	4
Audio–video and entertainment services (*V*)	3.14	3	2.25	3	3.25	2

Note: # means the degree of demand.

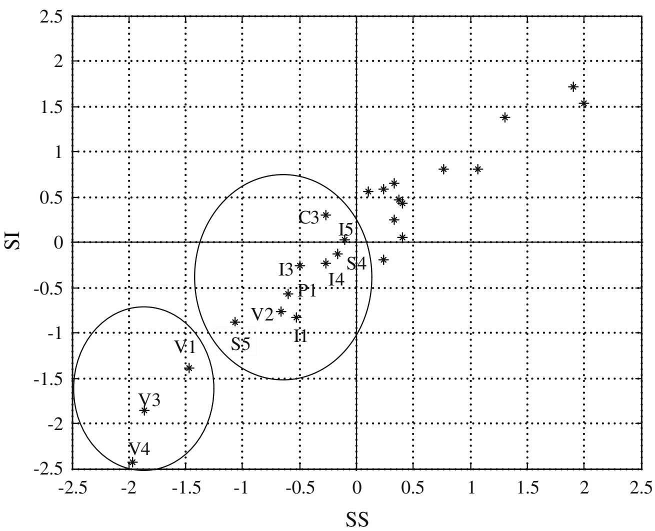

Fig. 6. Improvement strategies of satisfaction and important degree of VTS.

third category criteria [▲(−, −)], a higher degree of importance would affect the whole satisfaction degree of VTS in the short run (as shown in Fig. 6 and Table 22).

4.3. The empirical analysis using ANP method

The criteria weights can be gained by using the ANP method. In the process of limitation, multiples of the super-matrix *M* for 13 squares and the weights can be obtained. The results are shown in Table 23. In this paragraph, the parenthetic value means the weight of aspect or criterion. The largest value of factor weights of the criterion is *I*5 (11.4%), the next is *I*1 (11.0%), *P*3 (8.8%), *I*4 (8.7%), *N*3 (8.1%), *P*2 (7.4%). From the view of aspects, the aspect of *I* (39.8%) is the most important weighted value, followed by *P* (21.7%), *N* (20.5%), *S* (7.2%), *C* (7.2%), and *V* (3.6%). With the results of using the ANP method, the key decision-making consideration factor affects the consumer's purchasing of VTS is *I*. Among the criteria of the aspect, *I*5 (11.4%), *I*1 (11.0%), *I*4 (8.7%) are the main influencing factors. Regarding the *P* aspect (21.7%), *P*3 (8.8%) and

Table 22
Satisfaction and important degree of VTS.

Aspects/criteria		MI	SI	MS	SS	(IS, SS)
Navigation and location services (*N*)	Voice-guided navigation services (N_1)	8.881	1.720	7.929	1.902	○(+, +)
	Traffic information (N_2)	8.619	1.374	7.500	1.302	○(+, +)
	Electronic map information (N_3)	8.738	1.531	8.000	2.002	○(+, +)
Safety and security services (*S*)	Safety and emergency services (S_1)	7.905	0.431	6.857	0.401	○(+, +)
	Remote central control services (S_2)	7.762	0.243	6.810	0.335	○(+, +)
	Vehicle location services (S_3)	8.024	0.588	6.738	0.235	○(+, +)
	Car security services (S_4)	7.476	−0.135	6.452	−0.165	▲(−, −)
	Vehicle diagnosis and maintenance services (S_5)	6.905	−0.889	5.810	−1.066	▲(−, −)
Communications and information services (*I*)	Mobile information services (I_1)	6.952	−0.826	6.190	−0.532	▲(−, −)
	User interface (I_2)	7.619	0.054	6.857	0.401	○(+, +)
	Platform integration services (I_3)	7.381	−0.260	6.214	−0.499	▲(−, −)
	Information security protection (I_4)	7.405	−0.229	6.381	−0.265	▲(−, −)
	Information update frequency (I_5)	7.595	0.023	6.500	−0.099	X (+, −)
Audio–video and entertainment services (*V*)	Real-time multimedia services (V_1)	6.524	−1.392	5.524	−1.466	▲(−, −)
	Vehicle multimedia playing system (V_2)	7.000	−0.763	6.095	−0.666	▲(−, −)
	Game services (V_3)	6.167	−1.863	5.238	−1.866	▲(−, −)
	Personal platform services (V_4)	5.738	−2.429	5.167	−1.966	▲(−, −)
Fee rate and payment method (*C*)	Service fee rate (C_1)	8.000	0.557	6.643	0.101	○(+, +)
	Pricing (C_2)	8.071	0.651	6.810	0.335	○(+, +)
	Payment method (C_3)	7.810	0.305	6.381	−0.265	X (+, −)
	Payment channel (C_4)	7.929	0.463	6.833	0.368	○(+, +)
Product image (*P*)	Product design (P_1)	7.143	−0.574	6.143	−0.599	▲(−, −)
	Brand image (P_2)	7.429	−0.197	6.738	0.235	●(−, +)
	After-sales services (P_3)	8.190	0.808	7.333	1.068	○(+, +)
	Privacy policy (P_4)	8.190	0.808	7.119	0.768	○(+, +)
	Average	7.578	0.000	6.570	0.000	
	Standard deviation	0.758	1.000	0.714	1.000	
	Maximum	8.881	1.720	8.000	2.002	
	Minimum	5.738	−2.429	5.167	−1.966	

Note 1: ○(+, +) is the criteria of a high degree of satisfaction and a high degree of importance; ●(+, −) is the criteria of a high degree of satisfaction but a low degree of importance; ▲(−, −) is the criteria of a low degree of satisfaction and a low degree of importance; X(−,+) is the criteria of a low degree of satisfaction but a high degree of importance.

Note 2: MS, SS, MI, SI, respectively, stand for satisfaction value, standardized satisfaction value, importance value, standardized importance value.

Table 23
The weights of evaluation criteria.

Aspects	W	Criteria	w_j
Navigation and location services (N)	0.205	Voice-guided navigation services (N_1)	0.060
		Traffic information (N_2)	0.064
		Electronic map information (N_3)	0.081
Safety and security services (S)	0.072	Safety and emergency services (S_1)	0.010
		Remote central control services (S_2)	0.014
		Vehicle location services (S_3)	0.019
		Car security services (S_4)	0.015
		Vehicle diagnosis and maintenance services (S_5)	0.014
Communications and information services (I)	0.398	Mobile information services (I_1)	0.110
		User interface (I_2)	0.026
		Platform integration services (I_3)	0.062
		Information security protection (I_4)	0.087
		Information update frequency (I_5)	0.114
Audio–video and entertainment services (V)	0.036	Real-time multimedia services (V_1)	0.013
		Vehicle multimedia playing system (V_2)	0.006
		Game services (V_3)	0.008
		Personal platform services (V_4)	0.010
Fee rate and payment method (C)	0.072	Service fee rate (C_1)	0.019
		Pricing (C_2)	0.016
		Payment method (C_3)	0.016
		Payment channel (C_4)	0.021
Product image (P)	0.217	Product design (P_1)	0.010
		Brand image (P_2)	0.074
		After-sales services (P_3)	0.088
		Privacy policy (P_4)	0.045
		Total	1.000

Note 1: W, w_j which separatly means the weight of aspect, the weight of criterion.

$P2$ (7.4%) play the key roles. About the N aspect (20.5%), $N3$ (8.1%), $N2$ (6.4%), and $N1$ (6.0%) are the main influencing factors.

4.4. Using the TOPSIS method for improving the performance of the existing VTS

The TOPSIS procedure consists of the following steps: (1) calculates the normalized decision matrix; (2) calculating the weighted normalized decision matrix, (3) determining the ideal and negative-ideal solution, (4) calculating the distance of the utility value of each criterion between the positive ideal solution (aspired levels) and negative solution (the worst levels); (5) calculating the relative closeness to the ideal solution for improvement. In this paper, four commercial VTS products of different TSPs (i.e. Taiwan, US, Europe, and Japan) are analyzed and benchmarked to discuss the required utilities and services of the next e-era generation VTS. The results by using the TOPSIS method can determine which one is the most appropriate for Taiwan's consumers as shown in Tables 24–29.

(1) Calculates the normalized decision matrix.
(2) Calculating the weighted normalized decision matrix.
(3) Determining the ideal and negative-ideal solution.
(4) Calculating the distance of the utility value of each criterion between the positive ideal solution (aspired levels) and negative solution (the worst levels) (as shown in Table 28).
(5) Calculating the relative closeness to the ideal solution for improvement.

Calculate the relative closeness to the ideal solution and rank the priority. In this paragraph, the parenthetic value means the value of C_{k^*}. As shown in Table 29, sorts C_{k^*} in sequence, the Taiwan's T VTS (0.743) is the better one; the next ones are the Japan's J VTS (0.688), the US's U VTS (0.665), and Europe's E VTS (0.588) (gap ratio 0.412, i.e. 41.2% should be improved). As a result, Taiwan's T VTS seems be the most appropriate one for Taiwan's consumers. However, there are still gaps in the criteria between the T VTS and the consumers' ideal VTS (25.7% should be improved). There is still much ratio to improve the performance of existing solutions for satisfying customers' needs. TSP should pay efforts to improving the gap 25.7% to attain the real ideal solution shown by consumers' needs.

4.5. Discussions

The analyzed results of consumer demand of VTS are as follows: the priority of demands by males and females are the same. The utility values from the best to the last, are navigation and location services (N), safety and security services (S), audio–video and entertainment services (V) and communications and information services (I), There is no difference in demand for VTS between males and females. The priority of demand of the 21–30 year-old group and the 31–40 year-old group is the same. The utility values from the best to the last are navigation and location services (N), safety and security services (S), audio–video and entertainment services (V) and communications and information services (I). The priority of demand of the 41–50 year-old group is different

Table 24
Original value of VTS service.

Aspects	C_j	Preference	VTS A_k				$e_{j,aspire}$	$e_{j,worst}$	Aspects	C_j	Preference	VTS A_k				$e_{j,aspire}$	$e_{j,worst}$
			T	U	E	J						T	U	E	J		
N	$N1$	MAX	7.77	7.03	7.03	7.03	10.00	0.00	V	$V1$	MAX	6.20	6.50	6.20	6.62	10.00	0.00
	$N2$	MAX	4.57	2.84	2.84	2.84	10.00	0.00		$V2$	MAX	1.24	1.24	1.24	5.04	10.00	0.00
	$N3$	MAX	6.89	6.85	6.86	6.97	10.00	0.00		$V3$	MAX	0.00	0.00	0.00	3.42	10.00	0.00
S	$S1$	MAX	6.00	6.81	6.07	6.00	10.00	0.00		$V4$	MAX	5.19	4.75	5.19	5.19	10.00	0.00
	$S2$	MAX	2.48	4.02	4.02	4.36	10.00	0.00	C	$C1$	MAX	4.74	5.26	5.26	5.26	10.00	0.00
	$S3$	MAX	7.24	4.23	4.63	4.23	10.00	0.00		$C2$	MAX	4.75	5.59	5.59	5.72	10.00	0.00
	$S4$	MAX	4.51	1.55	4.51	4.51	10.00	0.00		$C3$	MAX	5.43	6.64	6.64	6.64	10.00	0.00
	$S5$	MAX	3.46	5.55	4.41	4.41	10.00	0.00		$C4$	MAX	6.08	2.20	2.20	4.35	10.00	0.00
I	$I1$	MAX	5.74	5.36	4.04	5.74	10.00	0.00	P	$P1$	MAX	7.94	7.94	7.94	7.94	10.00	0.00
	$I2$	MAX	7.72	3.68	3.68	3.95	10.00	0.00		$P2$	MAX	6.48	6.48	6.48	6.48	10.00	0.00
	$I3$	MAX	4.39	5.26	5.59	5.56	10.00	0.00		$P3$	MAX	8.03	8.03	8.03	8.03	10.00	0.00
	$I4$	MAX	7.51	7.51	7.51	7.51	10.00	0.00		$P4$	MAX	7.89	7.89	7.89	7.89	10.00	0.00
	$I5$	MAX	5.14	5.14	5.14	5.14	10.00	0.00									

Table 25
The normalized value of VTS (r_{kj}).

Aspects	C_j	VTS A_k				Aspects	C_j	VTS A_k				Aspects	C_j	VTS A_k			
		T	U	E	J			T	U	E	J			T	U	E	J
N	*N*1	0.78	0.70	0.70	0.70	*I*	*I*1	0.57	0.54	0.40	0.57	*C*	*C*1	0.47	0.53	0.53	0.53
	*N*2	0.46	0.28	0.28	0.28		*I*2	0.77	0.37	0.37	0.40		*C*2	0.48	0.56	0.56	0.57
	*N*3	0.69	0.69	0.69	0.70		*I*3	0.44	0.53	0.56	0.56		*C*3	0.54	0.66	0.66	0.66
S	*S*1	0.60	0.68	0.61	0.60		*I*4	0.75	0.75	0.75	0.75		*C*4	0.61	0.22	0.22	0.43
	*S*2	0.25	0.40	0.40	0.44		*I*5	0.51	0.51	0.51	0.51	*P*	*P*1	0.79	0.79	0.79	0.79
	*S*3	0.72	0.42	0.46	0.42	*V*	*V*1	0.62	0.65	0.62	0.66		*P*2	0.65	0.65	0.65	0.65
	*S*4	0.45	0.15	0.45	0.45		*V*2	0.12	0.12	0.12	0.50		*P*3	0.80	0.80	0.80	0.80
	*S*5	0.35	0.56	0.44	0.44		*V*3	0.00	0.00	0.00	0.34		*P*4	0.79	0.79	0.79	0.79
							*V*4	0.52	0.48	0.52	0.52						

Table 26
The weighted normalized value of VTS (V_{kj}).

Aspects/Criteria		VTS A_k				Aspects/Criteria		VTS A_k				Aspects/Criteria		VTS A_k			
		T	U	E	J			T	U	E	J			T	U	E	J
N	*N*1	0.047	0.042	0.042	0.042	*I*	*I*1	0.063	0.059	0.044	0.063	*C*	*C*1	0.009	0.010	0.010	0.010
	*N*2	0.029	0.018	0.018	0.018		*I*2	0.020	0.009	0.009	0.010		*C*2	0.008	0.009	0.009	0.009
	*N*3	0.056	0.055	0.055	0.056		*I*3	0.027	0.032	0.035	0.034		*C*3	0.009	0.011	0.011	0.011
S	*S*1	0.006	0.007	0.006	0.006		*I*4	0.065	0.065	0.065	0.065		*C*4	0.013	0.005	0.005	0.009
	*S*2	0.004	0.006	0.006	0.006		*I*5	0.058	0.058	0.058	0.058	*P*	*P*1	0.008	0.008	0.008	0.000
	*S*3	0.014	0.008	0.009	0.008	*V*	*V*1	0.008	0.008	0.008	0.008		*P*2	0.048	0.048	0.048	0.048
	*S*4	0.007	0.002	0.007	0.007		*V*2	0.001	0.001	0.003	0.000		*P*3	0.071	0.071	0.071	0.071
	*S*5	0.005	0.008	0.006	0.006		*V*3	0.000	0.000	0.000	0.003		*P*4	0.035	0.035	0.035	0.035
							*V*4	0.005	0.005	0.005	0.005						

Table 27
The ideal and negative-ideal solution of VTS.

Items		A^+	A^-	Items		A^+	A^-	Items		A^+	A^-
N	*N*1	0.047	0.042	*I*	*I*1	0.063	0.044	*C*	*C*1	0.010	0.009
	*N*2	0.029	0.018		*I*2	0.020	0.009		*C*2	0.009	0.008
	*N*3	0.056	0.055		*I*3	0.035	0.027		*C*3	0.011	0.009
S	*S*1	0.007	0.006		*I*4	0.065	0.065		*C*4	0.013	0.005
	*S*2	0.006	0.004		*I*5	0.058	0.058	*P*	*P*1	0.008	0.000
	*S*3	0.014	0.008	*V*	*V*1	0.008	0.008		*P*2	0.048	0.048
	*S*4	0.007	0.002		*V*2	0.003	0.000		*P*3	0.071	0.071
	*S*5	0.008	0.005		*V*3	0.003	0.000		*P*4	0.035	0.035
					*V*4	0.005	0.005				

Table 28
The distance to ideal and negative-ideal solution of VTS.

Distance	VTS A_k			
	T	U	E	J
S_k^*	0.010	0.020	0.026	0.019
S_k^-	0.028	0.040	0.038	0.041

Table 29
The relative closeness to the ideal solution.

Item	VTS A_k			
	T	U	E	J
C_{k^*}	0.743	0.665	0.588	0.688
Gap	0.257	0.335	0.412	0.312

from the 21–30 and 31–40 year-old groups, in which the utility values from the best to the last are safety and security services (*S*), navigation and location services (*N*), communications and information services (*I*), audio–video and entertainment services (*V*). As a result, the priority of need of services of VTS will differ by age group. It means that as age and wealth increases, people will care more about their family's safety and will have the ability to afford higher prices for safety and security services (*S*). In this paper, four VTS products belong to four different TSPs of Taiwan, the US, Europe, and Japan are adopted to discuss the function and services options of the VTS. The results using TOPSIS method can determine which one is the most appropriate for Taiwan's consumers. As a result, Taiwan's T VTS may be the most appropriate for Taiwan's consumers. It is obvious that Taiwan's TSP has adjusted the VTS according to Taiwan consumer preference when transferring a new system. However, it still cannot satisfy all the functions desired by Taiwan's consumers. New TSPs should refer to specifications of the existing system and improve it via enhancing those existing criteria that do not attain the S_j^+. Then a most ideal VTS for Taiwan's consumer will be initiated.

5. Conclusions

The VTS industry consists of hardware suppliers, software suppliers; telematics service providers, content suppliers and telecommunications suppliers. TSP integrates the system and provides kinds of services via telecommunications networks, playing the key role. Referring to successful cases of foreign VTSs regarding services and utilities, TSPs who will succeed or fail in the market depend on the achievement of a degree of satisfaction of consumers' needs. US and European TSPs focus on safety and security services, while the Japanese TSPs first provided navigation and location services, and have added communications and information services and audio–video and entertainment services in recent years. The Taiwanese TSP first provided adjusted navigation and location utilities on the basis of Japan's technologies, and has recently begun providing safety and security utilities due to a high rate of car theft and frequent stowaway execution in Taiwan. As a result, consumers' needs for the VTS would vary across cultures and regions. Commercial VTSs in four regions (i.e. North America, Western Europe, Japan and Taiwan) were applied for empirical analysis. The results demonstrate that different ages of consumers will influence the preference of desired utilities for the VTS. Those comments can help automotive manufacturers in developing new e-era generation VTS, and in modulizing the service functions and spec-in target consumers' requirements for customized purposes. This paper suggests that TSPs could improve the current utilities or initiate new utilities on the basis of Japan's or Taiwan's existing VTSs to shorten the time to market.

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