Identification of new added value services on intelligent transportation systems

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The evolution of electronics and the growing capabilities of in-vehicle and public infrastructure equipment make feasible the development of new value-added services in the field of intelligent transportation systems (ITS). However, initiatives in this sense frequently failed due to the lack of agreement or coordination among service providers, public authorities and final users. This article proposes a scientific method based on concept mapping techniques to extract these value-added services. The main benefit of the proposed methodology is its ability to take into account the different points of view of the main actors involved in the transportation field. Obtained results will provide the general guidelines for future ITS services.

Keywords: ITS services; concept mapping; multi-dimensional scaling; cluster analysis

1. Introduction

Intelligent transportation systems (ITS) is a worldwide initiative 'concerned with the application of electronic information and control in improving transport' (Slinn *et al.* 2005). ITS should be considered as a multi-disciplinary area of research due to the variety of factors involved and the diversity of its applications. Today, ITS can offer a variety of technological solutions to the growing transportation problems being experienced by more and more cities in the world, alleviating congestion and increasing road capacities (Toral *et al.* 2009a). But, ITS also has important implications on safety and citizens' life quality. Modern information and communication technologies make possible offering new value-added services beyond the typical scope of transport. For instance, ITS equipment spread over the city can be on the basis of a future urban ambient intelligence, allowing interactions among citizens, vehicles and public infrastructure (Toral *et al.* 2010). Creating intelligent systems to enhance travelling is at the heart of ITS. Six types of components broadly define ITS technologies: ATIS (advanced traveller information systems), AVCS (advanced vehicle control systems), CVO (commercial vehicle operations), ATMS (advanced traffic management systems), ARTS (advanced rural transportation systems) and APTS (advanced public transportation systems) (Adler and Blue 1998, Kanninen 1996, Ng *et al.* 1995, Hameri and Paatela 2005). Currently, ITS activities are in various stages of research, development, operational testing and deployment. For instance, the third generation of ITS, intelligent traveller information systems (ITIS), has appeared as a result of the integration of artificial intelligence (AI) with ATIS. ITIS is drawn upon to create systems capable of providing travellers with more personalised planning assistance. This 'will be more competitive and successful if it is customer-oriented and smart enough to be customer specific' (Adler and Blue 1998, p. 164, Toral *et al.* 2009b). Therefore, ITS must be considered as a transversal problem with implications in many areas, and investments in any ITS technologies must take into account the full range of social impacts of these technologies (Kanninen 1996, p. 2).

In accordance with the findings of Adler and Blue (1998), the most available and common specific ITS benefits can be grouped into five sets of abilities, which are implicit in the application of ITS:

(1) recognising, election, communication and learning with the driver;
(2) reduction congestion or traffic flow improvement;
(3) decreasing of air polluting emissions and positive effect on the environment;
(4) enhancement of productivity; and
(5) increasing safety.

Furthermore, ITS will not solve all of our transportation problems and might exacerbate some, especially environmental costs (Goldman and Gorham

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2006). Consequently, an overall transportation policy mix that addresses both system and economic-social inefficiencies must be comprehensively thought (Kanninen 1996, pp. 8–9). All these previous considerations suggest the necessity of tacking ITS necessities with a broader scope. Typically, the most common methodologies in socio-economic assessments are cost-benefit analyses, cost effective analyses, and multi-criteria appraisals, such as data envelopment analyses (Zhang *et al.* 1996). However, the problem of these methodologies is that results are often difficult to compare as the different projects have often adopted different guidelines and cost and benefit evaluation methods (Zhicai *et al.* 2006). Besides, ITS initiatives frequently fail due to the lack of agreement among manufacturers, developers, users and public authorities. This article tries to fill this gap by proposing a scientific methodology known as concept mapping for the identification of new value added services with the participation of the main actors involved. Concept mapping is a conceptualisation technique intended for reaching a consensus among participants though the application of several statistical techniques. The obtained results will show the common ideas and sensibilities of the target group in the form of maps.

The rest of the article is organised as follows. The next section details the proposed methodology based on concept mapping techniques. Then, the case study based on ITS services is presented, including the state of art of ITS technologies as well as the main assessment methodologies considered in the literature. Concept mapping is applied to the identification of new added value ITS services in Section 4. Finally, discussion of results and conclusions are shown.

2. Methodology

A concept map is a form of structured conceptualisation that can be used by groups to develop the conceptual framework to guide an evaluation, an exercise, a plan, etc. (Toral *et al.* 2007). In this article, the method proposed by Trochim (1989) will be followed. This method considers a scientific procedure defined by a sequence of steps, and taking into account both quantitative and qualitative features, such us numerical ratings and participants' previous experiences, respectively. This form of concept mapping is different from others like the one proposed by Novak and Gowin (1984), which develops an informal drawing-based approach designed to help individuals representing their ideas, and it is not specifically designed to work with groups, has no mechanism for aggregating ideas across individuals, nor utilises any statistical analytic methods. As a difference, concept-mapping as defined by Trochim shows the main

categories of mathematically determined ideas derived from the participants' input. Each subset of ideas is represented on the map in cluster form. Those clusters that are closer to each other are said to be more directly linked. The maps represent the opinion of the participants. This procedure relies on expert opinions but with a statistical treatment of the compiled data to guarantee that conclusions are the result of the whole group conceptualisation (Toral *et al.* 2006).

The considered concept mapping technique is laid out in the following steps (Kolb and Shepherd 1997):

(1) selection and preparation of participants
(2) generation of statements (concepts) that deal with the topic matter
(3) structuration and rating of generated statements
(4) representation of those items on a concept map (using a multi-dimensional scaling and clusters analysis)
(5) interpretation of maps

Figure 1 details the concept mapping flow diagram. The first step consists of the selection and preparation of participants. The selection of participants is one of the most important tasks of the process. In general, the conceptualisation will be best if a wide variety of
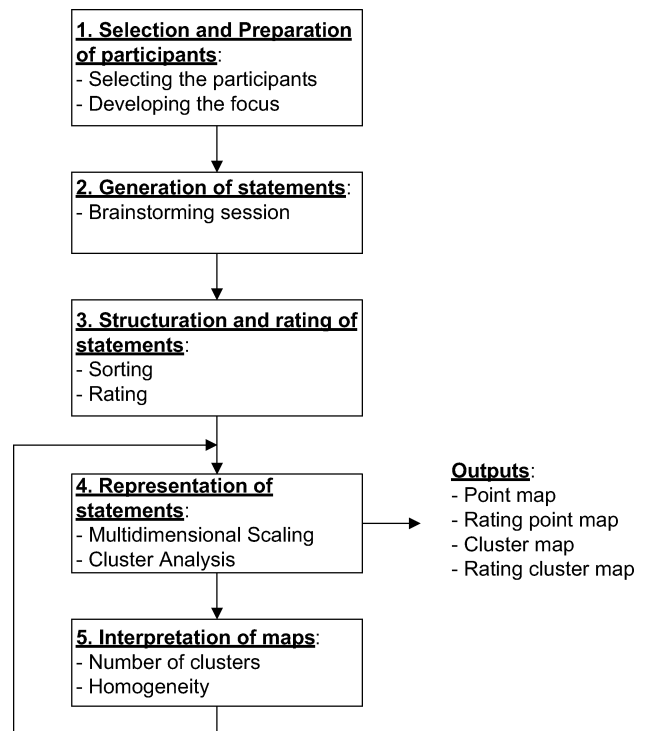

Figure 1.   Concept mapping flow diagram.

relevant people is included. Then, the focus or domain of the conceptualisation should be defined.

The second step consists of a brainstorming session where participants generate information in the form of statements related to the focus of conceptualisation previously defined. Once a final set of statements has been generated, it is valuable for the group to examine the statements for editing considerations. Sometimes the wording of statements generated in a brainstorming session is awkward or technical jargon is not clear. In general, each statement should be consistent with what was called for in the brainstorming prompt and should be detailed enough so that every member of the group can understand the essential meaning of the statement.

Once the final set of statements is obtained, participants must provide information about how these statements are related to each other, and they must also rate the statements according to their contribution to the focus of conceptualisation. Both of these tasks constitute the structuring of the conceptual domain (step 3 of Figure 1). Participants must sort the generated statements into homogeneous groups by applying their previous experience, and finally they must rate each statement using a Likert scale. Participants must be encouraged to be imaginative, i.e. not to include all items in a group or form as many groups as items.

Next, data are analysed using a double statistical analysis. The first one is a multi-dimensional scaling, which aggregates the sorted data across all participants and develops the basic point map. If n represents the number of statements, an $S_{n \times n}$ similarity matrix is obtained for each participant as a result of the sorting task. The (i,j) value of $S_{n \times n}$ is set to 1 if the ith and jth items are grouped together; otherwise, it is set to 0 (it is assumed that each item can only be placed in one group). The total similarity matrix $T_{n \times n}$ is obtained by adding all the similarity matrices. The multi-dimensional scaling is a multi-variate statistic technique that considers the total similarity matrix $T_{n \times n}$ and represents the distance of the matrix items in a p-dimensional space ($p < n + 1$). The distances in the p-dimensional space must be similar to the distances in the original n-dimensional space (Fahrmeir and Hamerle 1984). The most common approach to determine the coordinates of the map points is an iterative process usually referred to as the Shepard-Krustal algorithm (Fahrmeir and Hamerle 1984). The multi-dimensional scaling generates a map with the set of items (statements) selected in the brainstorming stage, and based on the similarity matrix obtained from the classification task. The multi-dimensional scale gives the analyst a specific number p of dimensions that represent the set of points. If a one-dimensional solution is required, all the points will form one line. A two-dimensional solution will place the set of points on a plane. Interpretation of solutions with more than three dimensions is difficult. Therefore, two-dimensional graphs is preferable when using concept maps. The result of multi-dimensional scaling is a (rated) point map where each statement is a point, and statements that were piled together by more people are located closer to each other.

The second statistical analysis is a cluster analysis. It organises the information coming from the multi-dimensional scaling, not from the similarity matrix (Everitt 1993), and its objective is classifying items in homogeneous groups. There are essentially two types of clustering methods: hierarchical algorithms and partitioning algorithms. The hierarchical algorithms can be divided into agglomerative and splitting procedures. The first type of hierarchical clustering starts with the coarsest partition possible: one cluster contains all of the observations. It proceeds by splitting the single cluster up into smaller-sized clusters. The partitioning algorithms start from a given group definition and proceed by exchanging elements between groups until a certain score is optimised. The main difference between the two clustering techniques is that in hierarchical clustering, once groups are found and elements are assigned to the groups, this assignment cannot be changed. In partitioning techniques, on the other hand, the assignment of objects into groups may change during the algorithm application (Basu *et al.* 2009).

As concept maps are usually intended for exploratory analysis where prior knowledge is scarce, an agglomerative hierarchical solution like Ward's algorithm is chosen to perform the cluster map (Ward 1963). The algorithm consists of the following steps:

If two objects or groups, say P and Q, are united, the distance between this new group

1. *Construct the finest partition*
2. *Compute the distance matrix D.*

   DO

3. *Find the two clusters with the closest distance.*
4. *Put those two clusters into one cluster.*
5. *Compute the distance between the new groups and obtain a reduced distance matrix D.*

   UNTIL all clusters are agglomerated into the starting data matrix X

$P + Q$ and group R is computed using the following distance function:

$$d(R,\, P + Q) = \delta_1 d(R,\, P) + \delta_2 d(R,\, Q) + \delta_3 d(P,\, Q)$$
$$+ \; \delta_4 |d(R,\, P) - d(R,\, Q)| \qquad (1)$$

where δ_js are weighting factors that lead to different agglomerative algorithms. In the case of Ward algorithm, they are defined as:

$$\delta_1 = \frac{n_R + n_P}{n_R + n_P + n_Q}, \quad \delta_2 = \frac{n_R + n_Q}{n_R + n_P + n_Q},$$
$$\delta_3 = -\frac{n_R}{n_R + n_P + n_Q}, \; \delta_4 = 0 \qquad (2)$$

Here, $n_P = \sum_{i=1}^{n} I(x_i \in P)$ is the number of objects in group P. The values of n_Q and n_R are defined analogously.

The Ward clustering algorithm computes the distance between groups according to the formula in Equation (1). The main difference between this algorithm and other agglomerative procedures is in the unification procedure. The Ward algorithm does not put together groups with smallest distance. Instead, it joins groups that do not increase a given measure of heterogeneity. The aim of the Ward procedure is to unify groups such that the variation inside these groups does not increase too drastically: the resulting groups are as homogeneous as possible.

The heterogeneity of group R is measured by the inertia inside the group. This inertia is defined as follows:

$$I_R = \frac{1}{n_R} \sum_{i=1}^{n_R} d^2(x_i, \bar{x}_R)$$

where $\bar{x}_R$ is the centre of gravity (mean) over the groups. I_R clearly provides a scalar measure of the dispersion of the group around its centre of gravity. If the usual Euclidean distance is used, then I_R represents the sum of the variances of the p components of x_i inside group R.

When two objects or groups P and Q are joined, the new group $P + Q$ has a larger inertia I_{P+Q}. It can be shown that the corresponding increase of inertia is given by

$$\Delta(P,\, Q) = \frac{n_P n_Q}{n_P + n_Q} d^2(P,\, Q)$$

The Ward algorithm is defined as an algorithm that joins the groups that give the smallest increase in $\Delta(P,Q)$. So, the Ward algorithm is related to the centroid algorithm, but with an inertial distance Δ rather than the geometric distance d^2. The result of cluster analysis is a (rated) cluster map where homogeneous statements are grouped together.

The last step of concept mapping is the interpretation of the obtained maps. This is an iterative process in which the analyst must decide the number of clusters leading to interpretable maps.

3. Case study: ITS services

A great number of future ITS applications have been studied in demonstration projects and field trials. These projects have involved a variety of ITS functions supporting e.g. vehicle control (lane departure warning, headway control and speed control), driver control (alcohol, drowsiness, illness) or flow control (fully automated systems on dedicated lanes) (Abe and Richardson 2006). All these results gave an appropriate prediction of the effects of using ITS applications in real traffic (De Moraes 2002, Jagtman et al. 2006). Efficiency has stemmed from specialisation and cost efficiency in individual value adding operations, generating constantly new business opportunities (Hameri and Paatela 2005). The rapid increase of road traffic congestion in recent years has contributed to promote ITS applications.

In fact, a major research effort on the part of the EU was initiated in 1988 with the main objective to assist in the application of new technologies in the field of transport (road transport in the very beginning) for safety and efficiency. Almost at the same time, similar research started in the United States and Japan. In the following years, a rigorous development of such prototype technologies and systems, and also of their applications in the field of transport, was appreciated. Notions such as the 'intelligent vehicle', the 'intelligent highway', or 'smart real time traffic monitoring and control', were introduced for the first time to express the increasing 'intelligence' and dynamic nature of the systems (Ward and Hirst 1997, Giannopoulos 2004).

Works on traveller information systems were focused on using visual displays to provide drivers with traffic condition and diverse information (Weinberg et al. 1966, Burnett et al. 2004). With the advancement of more powerful computers and other technologies, a centralised coordination of highway systems through real-time traffic surveillance and control strategies was believed to be useful to improve operations. In the 1970s, several traffic surveillance and control projects were fully implemented around the world (Nenzi and Anglisant 1974). Interest in human factors issues increased as it became important to improve the design of visual displays used to provide both real-time traffic information as well as diversion information at key intersections and ramps within large urban areas (Dudek 1970, Dudek and Jones 1971, Pretty et al. 1971). Efforts to develop in-vehicle route guidance systems were also initiated. The starting

objective was to improve information dissemination and driver compliance by bringing the information right to the driver (Rosen *et al.* 1970). Driver's route choice and switching behaviour were the main issues in ITS literature. In the 1980s, advances in computer and communication technologies reached such a threshold that effort to build and implement traveller information systems started. A considerable number of empirical studies on route choice behaviour indicated that drivers use numerous criteria in formulating a route, i.e. travel cost, travel time and its reliability, traffic safety, track comfort, roadway characteristics, utility, information supply, driver's habits, driver's experience, cognitive limits, socio-economic and demographic characteristics, and other behavioural considerations (see Jackson 1994, Ng *et al.* 1995, Kanninen 1996, Adler and Blue 1998, Yang 1998, Yang and Meng 2001, Chen and Ting 2007). However, the most widely used route-selection criterion has been the minimisation of travel time, as proposed by Wardrop (1952). Since route choice was the basis of traffic assignment, the results began to have a tremendous effect on traffic volume in traffic network (Chen *et al.* 2001). By the end of the 1980s, several in vehicle route guidance systems (IVRGS) were tested across the globe, particularly in Japan (Kobayashi 1979, Nakashita *et al.* 1988, Shibano *et al.* 1989), Europe (Jeffery *et al.* 1987, Karlsson 1988, Watling and Van Viren 1993) and the United States (Rillings 1991).

Parallel to the previous line of research arose other ones, such as traffic management systems, or safety road. The first one appeared in both urban areas and on freeways to analyse traffic congestion (Chang 1997, Chen *et al.* 2001). Traffic management systems should react to the different states of traffic flow in the controlled network (Jayakrishnan *et al.* 1994, Jha *et al.* 1998). In the early systems, the approach was based on a library of signal plans applied on-line in different predefined situations according to some time-based criteria (fixed-time systems) or to the traffic data collected by roadside sensors (traffic actuated systems). However, this pre-calculated-plan approach usually lacked the conceptual granularity required by the system to be adaptive enough in time and space to the variety of situations that might occur in the network (Cuenca *et al.* 1995). Later, more adaptive systems such as SCOOT, SCATS, OPAC, PRODY or UTOPIA were introduced as an evaluation step of local analysis at the level of single junctions together with a more general view evaluating a sequence of junctions (Cuenca *et al.* 1995).

The problem of traffic congestion links with the problem of road safety. Many researches thought that using advanced technologies to improve highway capacity could provide an effective solution to increase and guarantee road safety (Rodier *et al.* 1998, Sheu 2002, Giannopoulos 2004). A possible outgrowth of today's ITS technologies is the Automated Highway System (AHS), a concept that uses information and control technologies to create 'hands-off and feet-off' freeway driving (Carbaugh *et al.* 1998). Studies from Chang (1997) into the possible benefits of applying communication and control technologies to our highways forced to get gains in safety and efficiency. Driver behaviour under car-following became essential in ITS technology development as another important topic in the study of vehicular traffic flow (see Edie 1974 or Herman 1992). Various models of car-following behaviour were developed (Chandler *et al.* 1958, Herman *et al.* 1959, Gazis *et al.* 1961, Pipes 1967, Rockwell *et al.* 1968, between others) to collect data with sophisticated electronic instruments on driver behaviour on regular roadways, as opposed to previous test tracks (Chakroborty and Kikuchi 1999). However, studies into the feasible benefits of an AHS were not conclusive. Some studies warn that an AHS could exacerbate urban congestion, even under ideal conditions (Castillo *et al.* 1997), and safety benefits from such a system remain unproven. Furthermore, Chakroborty and Kikuchi (1999) consider that the literature is unclear as to the utility of an AHS, and certainly, work is needed to determine how the application of these technologies can enhance highway networks.

The links between new transport technologies and transport theories have grown strongly over time. Mainly, ITS literature efforts focus on the application of computer and communications technologies to solving transportation problems: to collect detailed travel survey information by monitoring the locations and movements; to consider driver route choice and the impacts of risk taking behaviours; dynamic route and schedule of freight vehicles in congested urban areas using real-time traffic information systems; to monitor the usage of multi-modal urban transit services, or to operate on traffic control systems, such as traffic signals, using automated driving technologies to enhance intersection efficiency and throughput.

Finally, it should be emphasised that knowledge on ITS technologies refers not only to the capacity of assessing the effectiveness of ITS. Researches on driver information technologies have evolved over the past 40 years as part of great efforts in creating urban traffic surveillance and control systems. Although technologies have advanced, the primary goal for providing travellers with information is still the same, that is, better management of traffic flow, enhancing driving operations, and improving traveller safety (Adler and Blue 1998, Taylor 2004). It is necessary to design beneficial information supply strategies (Bonsall and

Parry 1991, Vaughn *et al.* 1993, Koutsopoulos *et al.* 1994, Mahmassani and Liu 1999). The technological environment development, such as wireless telecommunications, cellular phones sector or mobile commerce (M-commerce), and the increase of traffic congestion, dangerous driver or traffic accident, makes ITS of significant interest. ITS is envisioned to be very serviceable and adaptable to individual users' needs and behaviours and it might be developed in many ways, varying in the capabilities and features that reach the marketplace (Adler and Blue 1998). Furthermore, as the employ of the technologies of ITS gets matured, they will be easily available, so they will not be considered as a luxury, becoming as part of every day life, as another type of technology (Hameri and Paatela 2005).

Unfortunately, ITS technologies are new and untested, and there are researchers that consider it impossible to make a reliable quantitative assessment of the economic and environmental impacts of ITS (Kanninen 1996). In accordance with Zhicai *et al.* (2006) and Polk (2000), ITS projects should include technical assessments, user acceptance assessments, traffic impact assessments, environmental impact assessments and socio-economic assessments (Martínez-Torres *et al.* 2008).

In general, during the last years, a general review of the socio-economic impact of ITS has been presented in transport literature. Cost-benefit analyses are still the dominant method for evaluating ITS. Socio-economic assessments are particularly important for government policy decisions with a considerable amount of work, now and in the past, being conducted to develop suitable evaluation guidelines in Europe and the United States for ITS projects (Madanat 1993, Fitzgerald *et al.* 2000, Kuo and Chen 2006). However, most guidelines do not detail how the impacts should be measured or valued with many benefits being inherently difficult to measure or even define in an agreed manner (Zhang *et al.* 1996). Considerable efforts have been made to identify the range of potential benefits with less emphasis on the costs. However, as different projects have often adopted different guidelines from cost and benefit evaluation methods, the results are sometimes difficult to compare (Zhicai *et al.* 2006). Moreover, Bristow *et al.* (1997) reviewed various appraisal procedures used to evaluate ITS projects and suggested that they need to have the same form, level of sophistication and consistency as appraisals of conventional transport infrastructure investments. Unfortunately, appropriate methods have not been established yet. In turn, it poses a number of challenging questions, since current socio-economic evaluation procedures are not directly suitable for either measuring or evaluating

many of the impacts that ITS schemes are planned to achieve.

All these previous elements have originated a substantial interest in the behaviour modelling of ITS and benefit evaluation of components of ITS (the six above-mentioned types broadly define ITS technologies: ATIS, AVCS, CVO, ATMS, ARTS and APTS) to determine the feasibility, benefits and risks of such technologies (Yang and Meng 2001). The methodology described in the previous section has been used to model future added value services that can be derived from ITS technologies.

4. Results

The concept-mapping technique has been applied to identify the added value services that ITS could offer. The general procedure is based on the five steps outlined earlier.

4.1. Selection and preparation of the participants

Experience show that conceptualisation is better when the process includes a wide range of experts (Martínez-Torres *et al.* 2005). A broad, heterogeneous participation helps to ensure that the different points of view will be considered, thus encouraging 'constructing' the right conceptual framework.

For this study, 16 participants with contrasted working experience in ITS have been selected (i.e. experts in ITS, researchers, users, designers, centres staff of control of traffic, public authorities, etc.). This number of people is within the adequate limits, between 10 and 20 (Trochim 1989).

4.2. Generation of statements

The next stage consisted of identifying a list of items related to added value services ITS could offer. Using the brainstorming technique, the workgroup identified a list of 72 items, listed in Table 1.

4.3. Structuration and rating of the statements

Once the set of statements that describes the conceptual domain of the given topic is established, the structuration and rating of these statements begins.

The first task of the working group consisted of classifying the 72 statements in several groups based on their affinity with respect to some common concept related to ITS added value services. Each of the participants applies his or her personal experience to define the number of groups and their components. A similarity matrix, defined as $S_{n \times n}$ with $n=72$, is obtained as follows: the value of (i,j) element is equal

Table 1. List of identified items.

1. Payment management in public vehicles
2. Route management in goods and people transport systems
3. Route management for emergency vehicles
4. Vehicle location and anti-theft alarm
5. Panic button against robbery, kidnappings
6. Automatic assistance request
7. Intelligence services for Mobile, PDAs, Laptops
8. Optimum route identification using traffic information
9. Collision avoidance warning (in movement)
10. Object detection (e.g. in parking)
11. Electronic payment in tolls/parking
12. Average speed control
13. Roadway sign guidance information
14. Driver information about nearby parkings (price and distance)
15. Driver information about road pavement conditions
16. Traveller information about potential hazards or route changes
17. Automatic speed limitation in dangerous areas
18. Electronic identification of vehicles in restricted areas
19. Automatic traffic light management for prioritising emergency vehicles
20. Used capacity use detection and information in public vehicles
21. Information services for handicapped groups
22. Access to routes information for handicapped persons
23. Information for no motorised vehicles
24. Location of nearest emergency services
25. Taxi request with automatic petition location
26. Automatic vehicles lighting
27. Automatic management of public lighting
28. Automatic management traffic queues in traffic lights
29. Incident detection and management
30. Public events intelligent management system
31. Tourist information system
32. Local citizen information system
33. Vehicle maintenance warnings
34. Streets pollution levels
35. Contaminant vehicle emissions detection
36. Commercial vehicles electronic trace
37. Special vehicles electronic trace
38. Warning of sleepiness
39. Automatic traffic signs detection
40. Dynamic management of reversible lanes
41. Surveillance systems for automatic vehicle and pedestrians detection
42. Intelligent traffic lights management for prioritising public transport vehicles
43. Intelligent traffic lights management depending on the traffic conditions
44. Speed limits management in urban or inter-city routes, depending on traffic conditions and rush hour
45. Traffic lights management depending on people or cyclist presence
46. Variable public transport price depending on the day hour.
47. Automatic detection of vehicles running red lights
48. Automatic detection of vehicle stop signs
49. Driver information about visibility conditions (fog and rains)
50. Automatic lighting in scarce visibility conditions
51. Black box rewarding of vehicle indicators
52. Authentication of authorised staff for vehicle driving
53. Remote monitoring of routes and locations of commercial vehicles.

(continued)

Table 1. (Continued)

54. Automatic planning of commercial vehicle routes
55. Monitoring of load state and its environmental conditions
56. Automatic stability control of vehicles.
57. Aid systems for commercial vehicles coupling
58. Driver information about distances
59. Night vision system
60. Collision avoidance warning in crossroads
61. Lane-change warning system
62. Trip planning
63. Multimode travel coordination and planning
64. Information about services
65. Information on attractions
66. Appointment request service
67. Road condition information
68. Improves of human sensory capacities
69. Hospitals and emergency medical services information
70. Real-time congestion information
71. Dynamic route selection
72. Services information directory

to 1 if the ith and jth items are grouped together, and is equal to 0 otherwise. The total similarity matrix, defined as $T_{n \times n}$, is obtained as the addition of all the similarity matrixes.

The second task consisted of rating each item according to the added value of the described service. The scoring options are defined as a Likert scale form, with a range of 1–5, considering 1, 'little contribution'; 5, 'a lot of contribution', and the numbers in between referred to intermediate contributions. A 'zero-contribution' score was not possible, since the brainstorming stage specifically asked for those ideas that contributed to offering the value-added services. Therefore, for greater or little, all had some contribution.

4.4. Representation of the statements

A double analysis was performed using information about the following statistical analysis: a multi-dimensional scaling and a cluster analysis.

In the case studied, the multi-dimensional scaling provides the point map shown in Figure 2. Each point represents each of the 72 items from Table 1. The distance between points indicates the affinity of the two items/points. Closer items are more closely related to each other, while further points show a high level of dissimilarity.

Figure 3 shows the rating point map that includes the items' scoring made by the participants. Consequently, Figure 3 exposes the relative importance of each item with regard to its contribution as an ITS-added value service.

Once the two-dimensional representation of the 72 items has been obtained, it is necessary to classify the items in homogeneous groups to categorise clusters of

Figure 2. Point map.

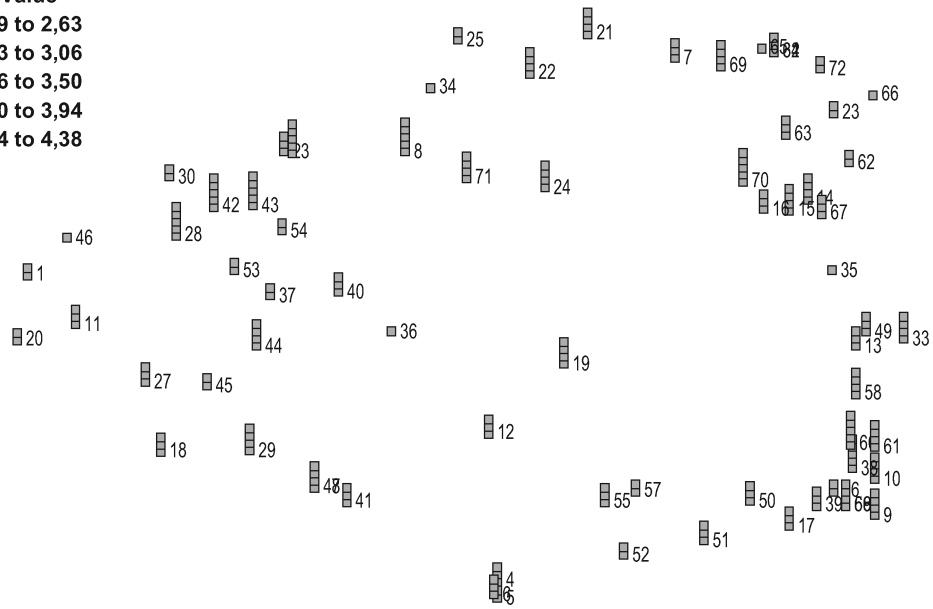| Layer	Value
1	2,19 to 2,63
2	2,63 to 3,06
3	3,06 to 3,50
4	3,50 to 3,94
5	3,94 to 4,38

Figure 3. Rating point map.

the value-added services. At first, the cluster analysis considers each item as its own cluster, thus obtaining a solution of N clusters, in this case 72, corresponding to the number of identified items. For each level of analysis, Ward's algorithm combines two clusters until finally all the items are combined into just one cluster. Determination of the number of clusters to be used in the final solution is important. Subsequently, discretion is required when examining the different types of possible cluster solutions to decide which ones make

sense. As a rule of thumb, the number of clusters that errs by excess, rather than by defect, is used; in other words, a larger number of clusters is preferred to having a cluster containing heterogeneous concepts.

The obtained result is shown in Figure 4 that includes the different groups highlighted by the cluster analysis. These clusters will define the resulting value-added services that ITS could offer.

The final analysis requires an average score for each participant and for each cluster, generating a
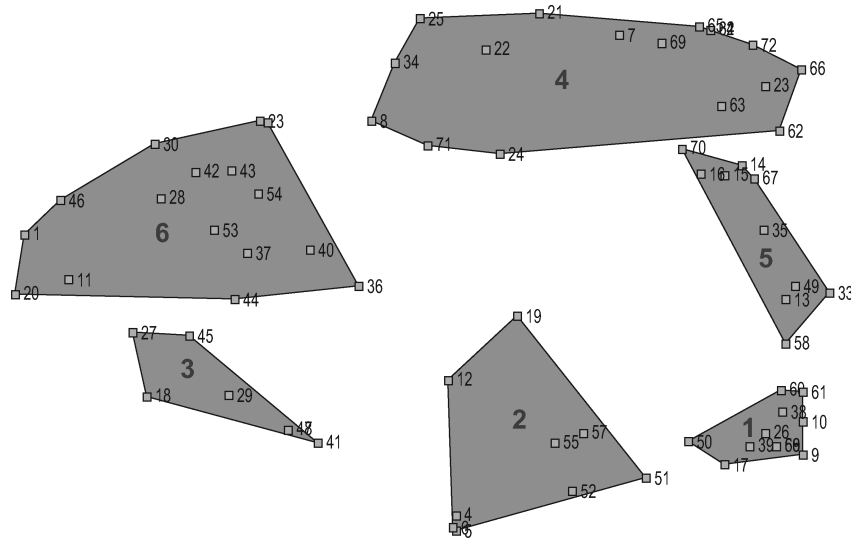
Figure 4.   Cluster map.

Layer   Value
1   3,19 to 3,29
2   3,29 to 3,38
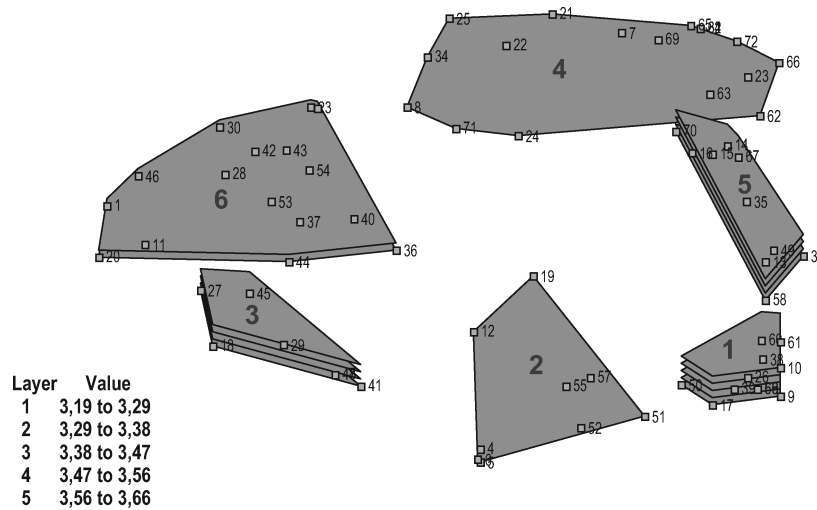3   3,38 to 3,47
4   3,47 to 3,56
5   3,56 to 3,66

Figure 5.   Rating cluster map.

rating cluster map. In the case studied, the inclusion of the scores for each cluster leads to the representation of Figure 5.

4.5.   *Interpretation of the maps*

A final workgroup was organised to achieve a better interpretation of maps. Generally, the results derived from the cluster analysis are more difficult to interpret than those from the multi-dimensional scale. At times, one would like to 'visually arrange' the clusters into sensitive parts so that the multi-dimensional space could be interpreted more easily. The key is to maintain the integrity of the multi-dimensional scale results by achieving a solution that will not allow the

clusters to overlap. A consensus of the names given to the different clusters must be reached, using as a starting point those names given to the groups by the participants.

Analysing the map from Figure 5, three big regions can be estimated, highlighted in Figure 6 and Table 2.

The first region, placed in the bottom part of Figure 6, refers to those tools designed to guarantee the security, not only to prevent drivers from accident or theft but also to ask for aid without needing to locate a phone, to know the appropriate phone number or even to know the current location. It will be named in a generic way 'safety and security', and comprises the clusters shown in Table 2.
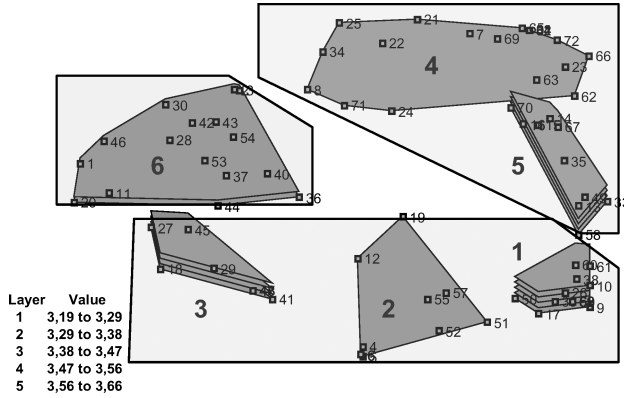
Figure 6.   Regions in the cluster map.

Table 2.   Cluster and region names.

Region	Cluster	Denomination
Region 1: safety and security	Cluster 1	In-vehicle safety
	Cluster 2	In-vehicle security systems
	Cluster 3	Third party vehicle safety
Region 2: information services	Cluster 4	Routes and services information management
	Cluster 5	Traffic information
Region 3: ITS management	Cluster 6	Intelligent management of public infrastructures

The second region placed in the top part of Figure 6 refers to those tools which enable drivers to access information about traffic, routes or services, to make efficient their journeys. This region is generically named 'information' and is formed by two clusters, as shown in Table 2.

The last region is placed in the low left part of Figure 6. It refers to those tools which could help the authorities to manage traffic and public transport services. This region is called 'ITS management' and it is formed by one cluster (see Table 2).

Finally, from the cluster rating map of Figure 5, it can be obtained the relative weight of the different matters that shape the ITS services. In the low left corner of this figure, the meaning of each layer is shown. The lower values correspond to cluster 2, 'security systems on board', and cluster 4, 'information on point of interest'. The rest of the clusters are highly valued respect to the previous ones. That is because these refer to safety and preventing accidents. The relative weight of each cluster can be used as a starting point when deciding the added value services to invest in.

4.6. Reliability analysis

A reliability analysis was accomplished to guarantee the obtained results. Traditional reliability theory used in social science research does not properly fit the concept maps because it assumes a correct answer for each test item that is known a priori. Therefore, the individual results for each item are classified as right or wrong. However, this procedure does not apply to concept maps where the answer for an item cannot be considered in simple terms (correct or incorrect). Because of this, the data matrix structure is inverted (compared to traditional theory) for the reliability assessment, i.e. the participants are placed in columns and the items (or pair of items) are located in rows. The reliability assessment focuses on consistency via the group of theoretically homogeneous participants. From this approach, it becomes useful to consider the reliability of the similarity matrix or map instead of the individual statement reliability (Trochim 1993). The key product of the Concept Mapping Technique is the two-dimensional concept map; consequently, the reliability assessment efforts are focused on the central stages of the analysis: development and representation. In the study published by Trochim (1993), the concept-map reliability was tested by six coefficients that can be estimated from the available data on any concept map project. These coefficients were defined and estimated for 38 concept map projects. The results show that a concept map process can be considered reliable according to standards generally recognised for acceptance reliability levels.

All the reliability indicators used by Trochim (1993) are considered for our study and were compared to the results obtained in Trochim's research (see Table 3).

It can be observed that a high degree of reliability is found in the proposed concept map since all indicators are included inside usual ranges:

(1) The individual-to-individual sort reliability, r_{II}, which correlates each participant's binary sort matrix $S_{n \times n}$ for each pair of individuals and explains how the sorts are correlated for the different participants in the development of the concept map, is identified by calculating the average of the correlations and by applying the Spearman–Brown Prophecy formula (Nunnally 1978):

$$r_{kk} = \frac{k \bar{r}_{ij}}{1 + (k - 1)\bar{r}_{ij}}$$

where r_{ij}, correlation estimated from data; $K = N/n$, being N the total sample size and n the sample size on which r_{ij} is based; r_{kk},

reliability estimated according to the Spearman–Brown Prophecy formula. This coefficient presents a value of 0.82274, which is below the mean value of Table 3 but above the minimum value of 0.6704. Consequently, the obtained individual-to-individual sort reliability is acceptable.

(2) The individual-to-total matrix reliability, r_{IT}, which correlates each participant's binary sort matrix $S_{n \times n}$ with the total matrix $T_{n \times n}$ and determines how the sorts carried out by each participant correlates with all sorts, is evaluated averaging these correlations and applying the Spearman–Brown Prophecy formula. The obtained value for this coefficient is 0.94437. This value is above the mean value of Table 3, indicating satisfactory results for this type of reliability.

(3) The individual-to-map reliability, r_{IM}, which correlates each participant's binary sort $S_{n \times n}$ with the Euclidean matrix distances $D_{n \times n}$, is obtained taking the average of these correlations and applying the Spearman–Brown Prophecy formula. Table 3 shows a value of 0.91103 for this type of reliability. It can be considered a satisfactory result since it is between the acceptable range and above the mean value (0.86371) shown in the same table.

(4) The average intersort reliability, r_{RR}, which calculates the correlation among the scores of each pair of participants, is obtained using the average of the correlation and the Spearman–Brown Prophecy formula, leading to a value of 0.72774. Consequently, the concept map scores are reliable since this value is close to the mean value.

(5) Finally, the split-half reliabilities, r_{SHT} and r_{SHM}, were also evaluated. The sort from each project is divided into two halves, calculating the concept maps for each group. The total matrices T_A and T_B are correlated, and the Spearman–Brown Prophecy formula is applied to obtain r_{SHM}. The Euclidean distances were correlated between all pairs of points on the two maps DA and DB, and the Spearman–Brown correction was applied to achieve r_{SHM}. The similarity matrix result (r_{SHM}) and the distance matrix result (r_{SHM}) are 0.96231 and 0.90764, respectively. Both values are significantly above the mean values (0.83330 and 0.55172, respectively), indicating acceptable values.

To sum up, a high level of reliability was found in our maps. That is, the results fall between the established maximum and minimum values; the indicators were found to be valid and within the standards shown by Trochim.

5. Discussion and implications

The obtained results summarise the main trends in transportation systems research and applications. Three wide regions have been identified. Although the first one refers to safety and security, its two highest scored clusters are related to safety. In particular, one of them is focused on in-vehicle safety issues and the other one in third-party vehicle safety. Traditionally, a great deal of research has been dedicated to improve in-vehicle safety systems in issues like vision enhancement, vehicle stability, driver condition monitoring or safety impacting (Bertozzi *et al*. 2002). This interest in safety is justified by reports like the ones published by World Health Organization about road traffic injury prevention (World Health Organization 2004). These reports underscore the concern that unsafe road traffic systems are seriously harming global public health and development, and contend that the level of road traffic injury is unacceptable and largely avoidable. For instance, the economic cost of road crashes and injuries is estimated to be 1% of gross national product in low-income countries, 1.5% in middle-income countries and 2% in high-income countries, being US\$ 518 billion per year the estimated global cost. By contrast, these reports emphasise that very little money is invested in research and development funding for preventing road traffic

Table 3. Descriptive statistics for reliability estimates.

	r_{II}	r_{IT}	r_{IM}	r_{RR}	r_{SHT}	r_{SHM}
Number of projects	33	33	33	37	33	33
Mean	0.81507	0.92965	0.86371	0.78374	0.83330	0.55172
Median	0.82060	0.93070	0.86280	0.82120	0.84888	0.55881
Minimum	0.67040	0.88230	0.74030	0.42700	0.72493	0.25948
Maximum	0.93400	0.97370	0.95490	0.93540	0.93269	0.90722
Standard deviation	0.07016	0.02207	0.04771	0.12125	0.05485	0.15579
Our map	0.82274	0.94437	0.91103	0.72774	0.96231	0.90764

incidents, and deduce that more attention must be paid in road traffic security research area. In this sense, new research lines are currently shifting the sensing capability from onboard sensors to inter-vehicle communications (Li *et al.* 2005). This technology is known as vehicle-to-vehicle (V2V) communication, and in the case of safety refers to the exchange of data over a wireless network that provides critical information which allows each vehicle to perform calculations and issue driver alerts, or driver advisories, or take pre-emptive actions to avoid and mitigate crashes (Yang *et al.* 2004).

The second identified area corresponds to information services, and, in this case, the most valued cluster is about traffic information. This issue can be included in the ATIS ITS technologies. In this case, the challenge for the automotive industry is the in-vehicle integration of nomadic devices. Nomadic devices refer to all portable devices that the driver brings into the vehicle and uses while driving, e.g. mobile phone, PDA (Amditis *et al.* 2006, Barrero *et al.* 2008).

Finally, the last identified area is related to public infrastructures, which can play an important role in modern ITS. Today, traffic equipment is spread over the city and connected with traffic control centres through urban data networks. From traffic regulators to surveillance cameras, all this equipment is provided with enough computing power to interact with the environment. In particular, it can interact with vehicles leading to the so-called vehicle to infrastructure technology (V2I), (Wu *et al.* 2005). The V2I architecture allows vehicles to communicate with some urban and roadway infrastructure offering new services like intelligent traffic signalling, speed warnings, traffic information services, etc. (Miller 2008).

The common base of the three identified areas relies on the idea of a smart urban environment or intelligent cities. A smart environment denotes a region of the real world extensively equipped with smart objects like sensors and actuators that, combined with computing components, provide 'a small world where all kinds of smart devices are continuously working to make inhabitants' lives more comfortable (Cook and Das 2004). The development of V2V, V2I and information services technologies will definitely contribute to the emergence of this idea in urban environments, moving the concept of a city from a collection of static buildings and infrastructures to dynamic and evolving smart ecosystems (Yovanof and Hazapis 2009).

6. Conclusion

This article refers to the development of a scientific method to identify the added value services that ITS could offer. This methodology guarantees that different points of view are reflected in the final result. It is true because people belonging to different areas (academic, drivers, traffic systems designers, etc.) have taken part in the development of the maps. Moreover, these people know the reality of the environment, so they are able to proportionate solutions to concrete situations.

With all this in mind, the added value services that ITS can offer have been obtained. The final result brings six added value services which can be grouped into three areas: safety and security, information and ITS management. It has also been identified that those services referring to improving safety and to accessing to information on traffic are more valuable than those referring to security or information on points of interest. This result coincides with Adler and Blue (1998). Finally, the reliability of our results has been tested.

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