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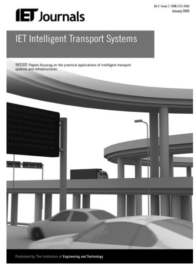

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# How to infer impacts of ITS services in different user cases

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**Abstract:** Despite the widely acknowledged potential of intelligent transport systems and services (ITS), the deployment of ITS has generally been scattered and slow. One of the main reasons for this is that people deciding on investments in the road and public transport sector often lack knowledge of the feasibility, cost-effectiveness, impacts and user acceptance of ITS solutions to their own transport related problems. One solution is to build up an intelligent ITS toolkit, which would propose to the decision maker the most viable ITS solutions in relation to his problems in his context. The study describes how such a toolkit has been designed and developed, including the knowledge base and inference engine providing the intelligence to that toolkit. The study is focusing on how to infer the most likely impacts and benefit/cost matching the user input on the basis of existing ITS evaluations studies and the available assessment expertise in the specific user contexts.

## 1 Introduction

One of the most important intelligent transport systems and services (ITS) deployment-related challenges is to facilitate decision making based on best available knowledge on the feasibility, impacts, user acceptance and profitability of different ITS solutions in relation to the problems of the decision maker. As lack of easy and efficient access to such ITS knowledge during decision making is recognised as a key factor [1, 2] for slow deployment of ITS and low willingness to invest on ITS especially in the road operator and public sector, a single entry approach for a new ITS toolkit for better decision making seems like an appropriate solution. This was also identified in the European ITS action plan [3], which identified such a toolkit as one of its key actions. The ambition of the 2DECIDE project, co-funded by the European Commission, is to support both EU ITS policy goals as well as national European ITS deployments strategies to gain the utmost benefit of ITS deployment and the related investments for a sustainable road and public transportation system.

Some attempts for comprehensive toolkits have already been made. The US [4] and UK [5] toolkits have been available for some time as well as some toolkits dedicated to some selected ITS applications such as intelligent vehicle safety systems [6]. These are available via the internet, while some ITS evaluation experiences have been compiled to book form, for example, by Federal Highway Administration [7] and PIARC [8]. The added element of 2DECIDE is to build a toolkit with additional intelligence with the help of an inference engine and a knowledge base.

The purpose of the inference engine is to provide the most appropriate output to the user of the toolkit based on the user input, that is, search criteria as well as the contents of the current database. The objective of the knowledge base and inference engine development in 2DECIDE were to compile and assess the selected ITS applications with regard to their impacts, socio-economic profitability, user acceptance as well as technical, legal, institutional and financial feasibility and on the basis of these, to build up the knowledge base that feeds the 2DECIDE toolkit and to describe at the same time the general requirements set by the deployment of different ITS services and applications.

This paper focuses on describing the design and development of the inference engine and especially the inference of the impacts of ITS services according to user input.

## 2 Knowledge base and inference engine

Fig. 1 provides an overview of the architecture of the 2DECIDE toolkit. According to the specific user needs, the user provides information on his context and objectives or problem or ITS service to be assessed. Through the use of an extensive knowledge base and an intelligent inference engine, the ITS toolkit provides a list of proposed ITS services that match or partially match the user input, together with the rationale, expected impacts and typical

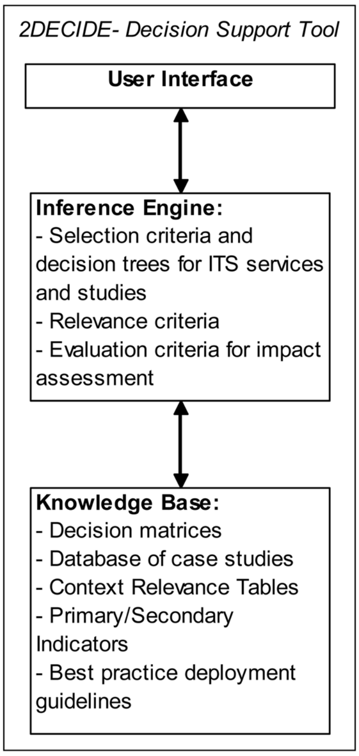


**Fig. 1** *Overview of 2DECIDE toolkit Architecture [9, 10]*

requirements for each proposed service. In addition, the toolkit provides detailed information in English on the relevant evaluation studies and reports that match the user input, that are stored in the knowledge base, ranked by relevance.

As seen in Fig. 1, the knowledge core of the toolkit contains two main components: the **inference engine** and the **knowledge base**. The **inference engine** contains the process and rules by which the output of the toolkit is produced on the basis of the user input. The inference engine was developed on the basis of the accumulated knowledge and expertise of the 2DECIDE experts and also of the basis on a thorough European survey of ITS stakeholder needs and requirements done in the project [11]. The inference engine contains the selection criteria and decision trees for matching the user inputs with the parameters of the ITS Services and studies stored in the Knowledge Base. Furthermore, the inference engine contains rules for estimating degrees of relevance of the studies to the user-defined context and inputs. Specific rules were developed to estimate average assessment impacts on the basis of the outputs of the various relevant studies in the database of studies and on the basis of a best-practice database of ITS services.

The **knowledge base** of the ITS toolkit contains basic knowledge and data used by the inference engine and is structured in terms of several sub-databases developed on the basis of expert judgment and assimilation of ITS deployment and evaluation knowledge from a large variety of sources across Europe and the world. On the first level, a comprehensive database of studies, is developed with each study stored and classified according to parameters, such as for example: type of study, relevant problems tackled, objectives, context of the study, summary and impact assessment area indicators reported. These studies are collected from a variety of mainly European sources and contain the knowledge of selected ITS evaluation reports and case studies covering a wide spectrum of ITS services and application contexts. The current database has been built up with more than 300 studies and reports during the 2DECIDE project, including an extensive scope of ITS ex-post evaluation studies reported in Europe. A plan has been proposed to the EC to expand and maintain the database of studies after the 2DECIDE project has ended. Each study is labelled in the database on the basis of the ITS service(s) assessed in the study. The ITS services were classified based on the ITS services listed in the PIARC ITS handbook [8] with some adaptation to include classification of new services as cooperative systems based upon the recently developed E-FRAME approach [12]. PIARC-based classification of ITS services was adopted since it follows a deployment-based (bottom-up) structure following closely those of the ISO TIC's classification scheme [13] and is adopted world-wide by road authorities that are viewed as key end users of the toolkit.

In a second level, relevance tables covering the degree of relevance between the various context parameters and the degree of relevance between various problems and objectives were developed as part of the knowledge base. Such relevance tables, together with specific rules, are used for each of the inferred studies in order to estimate its degree of relevance to the user-defined input, for example, the relevance of studies made in context of motorways to user's problems in rural roads.

In a third level, the knowledge base contains relations between general indicators, primary indicators and secondary indicators indexed according to the assessment area on hand. Relations between the indicators are developed in the knowledge base on the basis of expert opinion on the correlation between the various primary and secondary indicators in order to estimate a most probable estimate of primary indicators for each study and to account for the fact that not all studies in the database have the same type and number of indicators. Finally, the knowledge base contains an extensive database of best practice elements, deployment guidelines, expected impacts based upon expert opinion and typical implementation requirements and standards for each ITS service. Such a best practice database is useful to provide to the user to complement the specific data of relevant studies in case they are not found and to enhance a common view of ITS services.

The above knowledge core and inference process used in the 2DECIDE toolkit represents an intelligent evolution from the 'search and match' process used in the current databases for ITS services and deployment benefit and costs used in the UK and USA [4, 5, 7]. The search and match process in the toolkit is taken a higher level by providing ITS services and reports that are also partially relevant to the user input with a ranking according to their degree of relevance. In addition, the toolkit provides estimates of most likely values of the primary indicators for different impact assessment areas.

As an output of the toolkit inference engine, the user is provided with the relevant ITS services by order of priority, studies ranked by degree of relevance of their matching or partially matching the user input, average calculated or typical assessment indicators indexed according to area of impact assessment and ITS service and details on best practice elements and studies as an option for the user to access.

Fig. 2 provides an outline of the inference steps involved in the 2DECIDE toolkit design. Details of each inference steps are described in the following sections.




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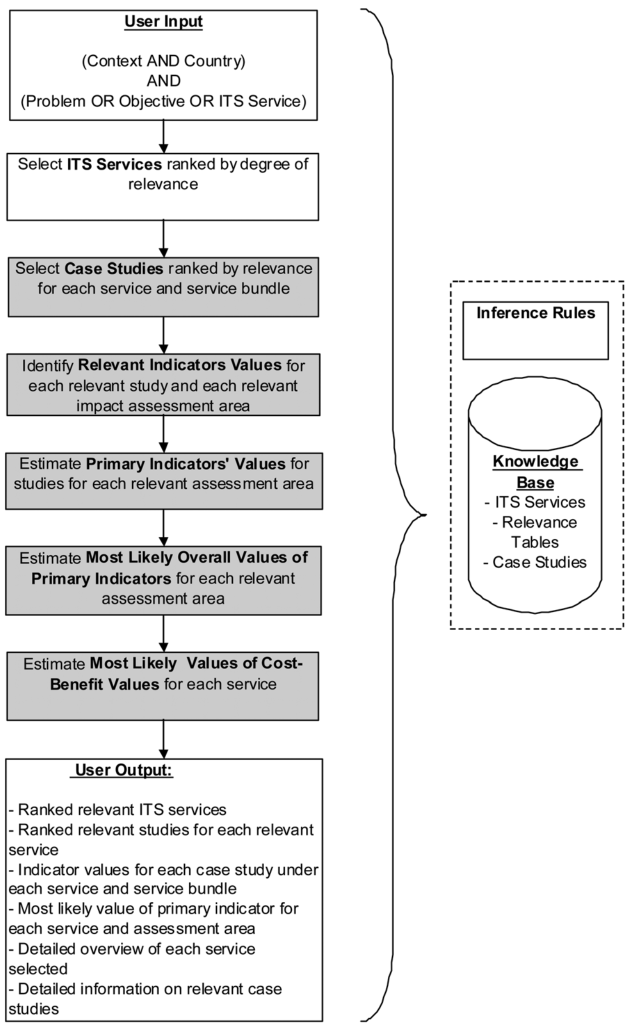


**Fig. 2** *Inference process in 2DECIDE toolkit*

## 3 Determining relevance of studies for use cases

On the basis of user needs assessment and extensive testing of the toolkit by the users, the toolkit was designed to allow the user to select one of the following items as input: objective(s), problem(s), or ITS-service(s). On the basis of pre-defined lists, the user can enter the toolkit according to a specific problem at hand requiring ITS measures or in a more general sense according to objectives as 'improve road safety' or 'improve traffic efficiency'. In the first case, the user requires a specific ITS solution to a particular problem as congestion incidents or unreliable incident detection, while in the second case of objective entry, the user can scan through possible ITS solutions that match the objective (s) entered. Another option would be to enter a specific ITS service that the user needs further knowledge on. In all cases, the user needs to set the context of his/her search, including both the area of transportation, for example, road transport/motorways and expressways and the geographical area, that is, country/countries the user is interested in. If the user has not selected any specific ITS service for assessment, the toolkit includes all ITS services that are relevant and considers the specific problem(s) or objective (s) and user context in judging the relevance of different information in the knowledge base. The links between different objectives to the appropriate ITS services, have also been identified on the basis of expert knowledge and are used in the inference engine. In addition, the links between the problems and objectives have been identified and are used in the inference engine calculations. If the user has input the ITS service or countries, only the studies dealing with the selected service or countries are considered for relevance. For the user context, that is, the geographical area and area of transport and selected system(s) or the user context and objective(s) or problem(s), all relevant studies from the database matching partly or totally the user input are used.

For each of the studies found, user context relevance values for the geographical area ($R_{GA}$) and area of transport ($R_{AT}$), respectively (see Fig. 3 for example of relevance tables), are obtained from the relevance tables stored in the knowledge base. Note that these relevance values differ according to assessment area: various impact assessment areas, benefit/cost, user acceptance and feasibility.

The total user context relevance value for an assessment area '$a$' $R_{UC(a)}$ is then calculated as the average of $R_{GA(a)}$ and $R_{AT(a)}$, that is, $R_{UC(a)} = (R_{GA(a)} + R_{AT(a)})/2$. For each of the relevant studies, according to user input, also an objective-related relevance value $R_O$ or a problem-related relevance value $R_P$ is estimated, on the basis of the degree of matching or partial matching between the use case input objective (Fig. 4) and/or problem parameter values on one hand and the respective parameters stored in the database for that study on the other hand. A composite relevance factor is estimated, $R_{OP}$, to account for all user entry scenarios (objective or problem or both). Studies in the knowledge base that have more matches in parameters to the user-specified problems/objectives have a higher $R_{OP}$ value. A full match between the objective and/or problem allocated to the study in the knowledge base and that specified by the user gives the value $R_{OP} = 1$. If the study has a partially matching objective, then $R_{OP}$ is calculated according to look-up relevance tables developed on the basis of expert knowledge. If the user has specified both the objective and the problem, $R_{OP}$ is calculated as the average of $R_O$ and $R_P$. If the user has specified only the objective, $R_{OP} = R_O$ and if only the problem $R_{OP} = R_P$. If the user has specified more than one goal/objective and/or problem or if the study has more than one goal/objective and/or problem, the total $R_{OP}$ of a study is determined as the average of all $R_{OP}$ combinations related to the user input and the particular study information. Example if the user objective is 'improve public transport service' and a study in the knowledge base has a stored objective of 'reduce greenhouse gases from transport', then the relevance value $R_O$ deduced from the relevance table of objectives is 0.3. In case the user has specified no additional problem or objective, then the composite relevance factor ($R_{OP}$) for the afore-mentioned study is = 0.3.

Finally, the relevance of the study with regard to quality of the study is determined. On the basis of careful assessment of the method and outputs for each of studies in terms of completeness and credibility, quality scores were given by the 2DECIDE experts for each of the studies $R_Q$ matching the following values: normal = 0.5, good = 0.8 and very good/excellent = 1. To ensure the quality of the 2DECIDE-output, it was decided that only the studies with $R_Q = 0.5$ or above will be included into the database.

The overall relevance of the study in relation to the user query is determined by the product: $R(a) = R_{UC}(a) \times R_{OP} \times R_Q$ for the assessment area 'a'. If $R = 0$, the study is excluded from the inference process.


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| | Road Transport (People) | Motorways and expressways (TERN) | Major, secondary and rural roads | City streets | All roads | Public Transport (People) | Train services (heavy rail) | Metro/Subway, Tram/Trolley | Regional or intercity and local bus | Demand-responsive/Special-needs public transport | All public transport |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Road Transport (People) | 1 | | | | | | | | | | |
| Motorways and expressways (TERN) | 0.7 | 1 | | | | | | | | | |
| Major, secondary and rural roads | 0.8 | 0.9 | 1 | | | | | | | | |
| City streets | 0.5 | 0.5 | 0.5 | 1 | | | | | | | |
| All roads | 1 | 1 | 1 | 1 | 1 | | | | | | |
| Public Transport (People) | | | | | | 1 | | | | | |
| Train services (heavy rail) | | | | | | 0.3 | 1 | | | | |
| Metro/Subway, Tram/Trolley | | | | | | 0.3 | 0.7 | 1 | | | |
| Regional or intercity and local bus | | | | | | 0.3 | 0.3 | 0.3 | 1 | | |
| Demand-responsive/Special-needs public transport | | | | | | 0.3 | 0.3 | 0.3 | 0.9 | 1 | |
| All public transport | | | | | | 1 | 1 | 1 | 1 | 1 | 1 |

**Fig. 3** *Examples of the relevance values for safety/area of transport*

| 2DECIDE GOALS AND OBJECTIVES | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Improve Travel Efficiency | reduce congestion | improve traveller information | travel time | routing | accident warning | congestion | special events | reduce travel time | improve travel time reliability | improve mobility options | improve travel comfort and confidence | Improve Road Safety | reduce accidents | number of accidents | severity of accidents (injuries/fatalities) |
| TE | Improve Travel Efficiency | | TE1 | | | | | | | | | | | | | | |
| 1 | reduce congestion | | 1 | TE2 | | | | | | | | | | | | | |
| 2 | improve traveller information | | 0.7 | 1 | TE2.1 | | | | | | | | | | | | |
| 2.1 | travel time | | 0.7 | 1 | 1 | TE2.2 | | | | | | | | | | | |
| 2.2 | routing | | 0.7 | 1 | 0.8 | 1 | TE2.3 | | | | | | | | | | |
| 2.3 | accident warning | | 0.7 | 1 | 0.6 | 0.7 | 1 | TE2.4 | | | | | | | | | |
| 2.4 | congestion | | 0.8 | 1 | 0.8 | 0.8 | 0.8 | 1 | TE2.5 | | | | | | | | |
| 2.5 | special events | | 0.7 | 1 | 0.8 | 0.7 | 0.6 | 0.8 | 1 | TE3 | | | | | | | |
| 3 | reduce travel time | | 0.8 | 0.3 | 0.3 | 0.5 | 0.3 | 0.3 | 0.3 | 1 | TE4 | | | | | | |
| 4 | improve travel time reliability | | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 1 | TE5 | | | | | |
| 5 | improve mobility options | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.5 | 1 | TE6 | | | | |
| 6 | improve travel comfort and confidence | | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.5 | 1 | | | | |
| RS | Improve Road Safety | | 0.1 | 0.1 | | | 0.5 | 0.1 | 0.1 | | | | | | RS1 | | |
| 1 | reduce accidents | | 0.1 | 0.1 | | | 0.5 | 0.1 | 0.1 | | | | | | 1 | RS1.1 | |
| 1.1 | number of accidents | | | | | | | | | | | | | | 1 | 1 | RS1.2 |

**Fig. 4** *Examples of the relevance values for goals and objectives per impact area*




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## 4 Assessing most likely impacts

The database includes information on the following impacts – named as impact assessment areas [11]: travel efficiency, road safety, public transport service, freight management, freight/fleet management, security, environmental impacts, road traffic planning/operations, revenue generation and traffic violations. For each of these areas, a number of primary and secondary indicators were identified. In addition, a number of general indicators relevant for various impact areas were identified. These general indicators usually describe changes in amount of travel and speeds. The impacts are to be estimated as values for the primary indicators. The unit of the value is usually %, as the impacts are measured as per cent change in the primary indicator either from before implementation of the ITS service to after its implementation, or from the situation without the service to the situation with the service.

In some cases, the primary indicators are category variables in the ordinal scale. In such cases, the most likely value is the value most frequently found among the relevant studies, with the frequency weighted by the relevance value $R(a)$ of the study.

These values are calculated either directly, in cases when the specific primary indicator is available in the relevant ($R > 0$) studies, or indirectly through the relevant secondary or general indicators available in the relevant studies.

Each value of secondary or general indicator is considered for the purpose of deducing the likely value of the primary indicator(s) linked to the secondary/general indicator in question. These deduced likely values is used to judge the plausibility of the values of the primary indicators, or if there are no or very few values of the primary indicators, to estimate the value category for the primary indicator. The most likely value categories of < −10%/ −10% … −3%/ −3 … −0.5%/ −0.5 … +0.5%/0.5% … + 3%/ + 3% … +10%/ > +10% are used in the 2DECIDE toolkit and are assessed instead of the calculated most likely value.

To utilise the secondary and general indicators, the toolkit contains impact area specific tables describing the relationships between the primary and secondary as well as general indicators (Table 1).

*Example:* User query proves two studies to be relevant ($R(a) > 0$) for the safety effect estimation. In one, the change in person kilometer travelled was −10% and in the other, the number of conflicts has decreased from 650 to 600 and average travel speed has changed by −2%. No values are available for the primary indicators for safety. To deduce the approximate effect on the number of traffic accident injuries, we use the afore-mentioned table for safety. The table gives the relationship of number of traffic accident injuries with the number of conflicts as '1', with person kilometer travelled as '0.95' and with the average spot speed as '2'. The estimates for the primary indicator can be calculated in the following manner (utilising the safety relationships of different factors based on the traffic safety handbook) [14]:

– from person kilometer travelled: −10% leads to change factor 0.90; $0.9^{0.95} = 0.905$ that is, −9.5%
– from conflicts: change factor 600/650 = 0,923 that is, −7.7%
– from average speed: −2% means a change factor of 0.98; $0.98^2 = 0.960$ that is, −4%

Note that these values are only used to estimate the value category of the primary indicator and not the actual value.

During the inference process, the studies are grouped by ITS service and for each service, according to the other services listed in the study, that is, in 'service bundles'. For instance, if the user is interested in public transport information (service = traveller information, area of transport = public transport), studies having only traveller information are dealt with separately from studies dealing with public transport information combined with public transport/public transport management or some other service.

The most likely value of a primary indicator is calculated as a weighted average of the values in the service bundle in question, using the overall relevance value of the study as the weight.

In the case of no values found in the relevant studies in the database, the descriptions of most likely impacts, feasibility and user acceptance given in the assessment experience database for the particular ITS service or ITS service bundle are used. This assessment experience database is an essential part of the toolkit knowledge base storing generic information and expert judgement on the various ITS services to be used to complement inferred impact values, particularly, in case of ITS measures that have little deployment and evaluation case data.

This database was built up by assigning experts on specific services as well as specific impact types to fill in the knowledge that they had on the basis of existing studies as well as their own experiences about the impacts, socio-economy, acceptance and implementation issues related to each ITS service. This database should be regularly updated as new information not already in the database is being made available. As for most services there are usually at most a few actual evaluation studies available,

**Table 1** Description of the relationship between the primary and secondary/ general indicators in the 2DECIDE toolkit

| Table cell | Description |
|---|---|
| number, special cases below | approximate exponent for the secondary indicator |
| 1 | full proportionality, for example, change in number of road injuries is approximately the same as for number of injury accidents; |
| 2 | proportionality to the square of secondary indicators; for example, the change in injuries is approximately proportional the change in average speed squared, that is, an average speed change of 10% means an injury change of 21% (1.10 × 1.10 = 1.21); |
| 0 | there is no linear or near linear relationship between the indicators |
| −1 | inverse proportionality, that is, a change in secondary indicator is approximately the inverse of the change in primary indicator; that is, a 10% increase in secondary indicator means a ca. 9% decrease in primary indicator (1/1.1 = 0.91) |
| text 'POS' | positive (changes tend to be in the same direction, but can not be quantified) |
| text 'NEG' | negative (changes tend to be in the opposite direction, but can not be quantified) |
| text 'WPOS' | weak positive (usually same direction but not always) |
| text 'WNEG' | weak negative (usually opposite direction but not always) |


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the information about impacts of many ITS services is solely based on the assessment experience database. For this reason it is essential to maintain and update the database regularly.

## 5 Assessing most likely benefit-cost

Cost and benefits in the 2DECIDE toolkit [11] concerns three types of information:

1. cost information;
2. benefit information;
3. cost-benefit results.

For each type of information the way to assess the most likely value can be different and are described per category below.

### 5.1 Cost information

During the data collection phase of the project only limited cost information was available in the studies which were examined and entered into the 2DECIDE database. Hence, additional sources like the USA ITS cost database RITA [15] have been examined to collect additional cost data. The collected information items have been and are entered into the 2DECIDE database for the main cost indicators (investment/implementation costs; maintenance costs; operational costs). Then all the costs are calculated in euro of the same year, for example the year 2010, using an inflation table. This table provides a factor to calculate the value in euro of the current year instead of year from the study year, for example 2005. Finally a most likely value in euro can be calculated for each main cost indicator. The costs are presented as unit costs (for example costs per kilometer) and not as absolute costs. In this way the user can use the cost data as input for his own situation and calculate for example the costs related to the kilometer of road of his own specific situation. In case of the unit costs changing considerably in time, only the most current information is retained in the database and obsolete information is removed.

### 5.2 Benefit information

In the data collection phase also limited information about monetary benefits has been found. Therefore impact information about benefits in non-monetary values like saved lives, is used as a basis to calculate monetary values of benefits. First the values of non-monetary impacts per primary indicator are looked up in the 2DECIDE database. Then a European unit value is used to transfer the non-monetary benefit into a monetary benefit. In the case of safety benefits related to saved lives, the value of statistical life (VOSL) is used to calculate the monetary benefit. Finally the European value is transferred into euro for the current year using the afore-mentioned inflation table. This is illustrated by the following example:

Non-monetary benefit: reduction of 10 fatal accidents per year on a motorway.
European unit value used: VOSL, around 1.0 million Euro per person for 2005 [16].
Inflation figure to be used, to transfer 2005 euros to 2010 euros: 12%
Monetary safety benefit (2010) = 10 * 1.0 million Euro *1.12 = 11.2 million Euro.

The European unit values are provided to the user. However, the user can also decide to use his own specific national unit value instead of the provided European value, because this national value is usually more appropriate for his specific situation.

### 5.3 Cost benefit results

Cost benefit results have also been collected, for example [17]: benefit cost ratio (BCR), internal rate of return or net present value. In case of BCR, values for BCR are examined in the 2DECIDE database for the specific ITS service that is investigated by the user. Then the most likely value for the BCR is calculated, based on the weighted average of all relevant BCR values. To the user, categories of BCR are presented instead of presenting the precise calculated value. In this way the user gets a good indication of the size of the benefits compared with the costs. The following categories are used: $<0.5/0.5 \ldots 1/1 \ldots 2/2 \ldots 4/>4$.

The user can also use the costs results and benefit results of the 2DECIDE toolkit as inputs for his own CBA calculation. Together with his own specific CBA assumptions, like year for re-investments, economic lifetime of ITS system etc. the user can carry out his own CBA calculations.

## 6 Problems encountered and solutions

A number of problems have been encountered when estimating the most likely impacts. The most relevant ones are presented below.

1. Indicator values in studies are provided for a bundle of ITS services deployed according to each relevant study instead of for one specific ITS service requested by the user.
• Solution: the most likely values for the specific ITS service, as indicated by the user, are shown for each specific bundle containing the service indicated. The first bundle is the indicated service provided on its own without any other services bundled together with it;
2. No relevant primary indicator values can be found in the 2DECIDE database.
• Solution 1: values of secondary indicators (in case they are available) are used in estimating the values of primary indicators. In that case, the range category of the estimated values of primary indicators is shown to the user;
• Solution 2: if solution 1 does not work because the available indicators do not have a numerical relationship (see Table 1), we also devised a method for describing the direction of the change in the primary indicator value (positive, weak positive, weak negative, negative). Unfortunately this solution was not realised in the database, although the algorithm was found satisfactory;
• Solution 3: an assessment database with typical estimates has been set-up, which can be used in case no relevant values for primary indicators are found in the 2DECIDE database;
3. Calculation of the average value can be highly influenced by one extreme value among the set of values used for the calculation of the most likely value.
• Solution: the extreme value is excluded from the calculation. This is done by comparing the average of all values to the averages, where one of the values has been excluded. These one-value-excluded-averages are divided with the all-values-average and those producing a ratio with



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the highest relative deviation from one are excluded, if the ratio is $>2$ or $<0.5$;

4. Many studies lack any quantitative results.

• Solution: the qualitative description of results in the database is also enabled and the users have access to these descriptions in the study summaries even if no quantitative values of impacts are available;

5. Extremely few studies include cost information.

• Solution: a cost database was set up, largely based on a similar US solution [15].

6. Difficulty to quantify in a generic way the transferability of results from one country to another.

• Solution: the user may include the countries he/she wishes into the analysis including the estimation of the most likely impact, thereby enabling the user to judge himself/herself the transferability of the results. In addition, any transferability references made in the original studies were to be stored in the database under transferability heading to make them also available to the users in the study summaries;

7. Proper assessment of the before or control situation is lacking in many assessments only focusing on the 'after situation', making the veracity of the impact estimates questionable.

• Solution: as the consortium did not want nor had the resources to take over the role of a judge over the appropriateness of the experimental designs of individual studies, we can only promote proper evaluation study designs within our own work and in cooperation with European ITS research funding bodies;

8. In various studies, impact indicators were provided in various forms: discrete values, ranges or subjective information.

• Solution: if the study was carried out in several locations, each having its own results reported the study was included in the database as a number of studies, one per location. In this way, the inference engine would benefit from one observation per study. In case of a range of results being given only instead of specific values per location, the average was used as the value of the quantitative indicator, but the range was given in the qualitative description;

9. Users would like to rank the selected services and studies according to specific impact area or relevance criteria

• Solution: the toolkit accepts various user specified selection queries on the output of the inference engine. Services and services selected are ranked according to user criteria;

### *6.1 Advantages compared with existing its toolkits*

The 2DECIDE ITS toolkit has the following advantages compared with existing ITS toolkits, like RITA (US), Dft ITS toolkit (UK) etc:

• 2DECIDE contains a database with ITS evaluations studies and case studies from the whole of Europe, while existing toolkits mainly provide studies for one specific country, or one specific region. 2DECIDE provides a single access point to all these ITS studies in Europe.

• 2DECIDE provides ITS decision makers in Europe at all levels: local, regional, national and European, the possibility to quickly find relevant material for taking decisions about ITS investments.

• 2DECIDE not only provides a summary of the contents of selected studies, but in addition provides an estimation of the most likely impacts, based on the available studies in the database.

• 2DECIDE uses relevance tables, which makes it possible to find more relevant studies than the ones completely matching the user's input.

• Even if no studies are found for a specific ITS service searched by a user, 2DECIDE always provides best practice deployment guidelines and typical impacts.

• If no values for the primary indicators are available, 2DECIDE can use the available secondary indicators to estimate value categories for these primary indicators.

• The 2DECIDE toolkit HMI is not only available in English, but also in German, French and Italian.

## 7 Conclusions

The 2DECIDE ITS toolkit is the first comprehensive attempt to provide the user, for example, road network operator, the most optimal ITS solutions to the existing problem by utilising a synthesis of the most current knowledge of the feasibility, acceptance, impacts and cost-effectiveness of different ITS solutions relevant to the user's context and objectives. We have shown that an inference engine and knowledge base to facilitate such a toolkit can be built on the basis of the experience of ITS assessment experts.

Although the toolkit with all its intelligent inferencing rules exists, many problems still exist. First, the inference engine works with primary indicators for each impact assessment area. Based on the ca 1000 evaluation studies identified in 2DECIDE, very few studies use the same primary or secondary indicators to describe the impacts of ITS and hence only a selection of those were integrated into the current database. To improve the usability of evaluation results, efforts to harmonise the evaluations of ITS deployments in this respect should be promoted.

Second, the current rules in the inference engine to determine the relevance of each study and thereby the transferability of its results to the user's context are *ad-hoc* and are based on the 2DECIDE consortium member expertise. Specific research is needed to explore the transferability of ITS evaluation results between different contexts and to verify the relevance factors used.

Third, the relationships between different indicators should also be verified by further research. The most essential relationships here are the ones between driving and travelling behaviour indicators and the actual impacts. This is important as most actual impacts on safety, environment, efficiency etc. are resulting from changes in driver and traveller behaviour and to understand ITS effects we need to understand these relationships.

It should be stressed that the level and type of outputs of the 2DECIDE toolkit do not eliminate the need for detailed level assessment, planning and design required to be done prior to deployment of an ITS service and application.

The toolkit has been tested and validated by European users coming from both the public and private sectors. A high degree of satisfaction with the interface and performance of toolkit was reported. Results of the validation tests, resulting refinements and options for future maintenance of the toolkit are reported in other papers [18].

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