REGRET THEORY-BASED SCENARIO BUILDING USING AN INTERACTIVE PROCESS

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ABSTRACT

Identifying transport demand management (TDM) measures in a sustainable transport system is a complex task and it involves a high degree of uncertainty due to the long-term planning horizon. The immense complexity necessitates the use of new tools (i.e., scenario building, transport models and evaluation methods).

For this purpose, this paper is an introduction of the regret theory-based scenario building approach combining with a modified Delphi method that uses an interactive process to design and assess four different TDM measures (i.e., cordon toll, parking charge, increased bus frequency and decreased bus fare). The case study of Madrid is used to present the analysis and provide policy recommendations. The new scenario building approach incorporates expert judgement and transport models in an interactive process. It consists of a two-round modified Delphi survey, which was answeared by a group of Spanish transport experts who were the participants of the Transport Engineering Congress (CIT 2012), and an integrated land-use and transport model (LUTI) for Madrid that is called MARS (Metropolitan Activity Relocation Simulator).

The new approach of scenario building involving regret theory shows that (i) an interactive process with a feedback loop between expert judgement and transport modelling is useful, (ii) regret-based ranking has similar mean but larger variance than utility-based ranking, (iii) the least-regret scenario forms a compromise between the desired and the expected scenarios.

1. INTRODUCTION

Planning sustainable transportation systems is a complex task involving a high degree of uncertainty due to the long-term planning horizon, the wide spectrum of potential policy packages, the need for effective and efficient implementation, the large geographic scale, the necessity to consider economic, social, and environmental goals, and the travelers' response to the various action courses and their political acceptability (Shiftan et al., 2003). The immense complexity necessitates the use of new tools (i.e., scenario building, transport models and evaluation methods).

Scenario building, transport models and MCA were combined to analyze scenarios via several macro-simulation tools for modeling energy, transport, and externalities (Fedra, 2004), to examine scenarios for representing economics, transport, and environment (Lopez et al., 2012), and to construct policy packages via expert-based methods within a regional study. According to the existing practices of the scenario approach (Shiftan et al., 2003; Chatterjee & Gordon, 2006; Turcksin et al, 2011;), a scenario can be built in many valid ways from the methodological point of view, such as intuitive logics, trend impact analysis, morphological analysis and cross impact analysis (Ratcliffe, 2000; Ram, 2011). The main limitation of the existing approaches is that they are all utility-based. Scenario building largely incorporates the concepts of desirability or deliverability (e.g., Shiftan et al., 2003; Hickman et al., 2012).A cavity of the utility-based approach is that it disregards the feeling of regret due to a comparison between the chosen and the foregone alternatives. People experience regret when a choice outcome does not fulfill their expectations and the expected outcome of a foregone alternative is perceived to be better than the outcome of the chosen alternative. Regret is plausible in policy-making decisions because it is associated with important and complex decisions since it is associated with high-order cognitive processes such as contra-factual comparisons (e.g., Zeelenberg & Pieters, 2007).

This study chooses to assemble the scenarios from a regret minimization point of view based on the knowledge of a group of transport professionals. Chorus et al. (*2011*) established regret-based decisions as plausible and more likely in the context of transport planning involving road pricing. The conditions underlying regret-based decisions, namely complex and important decisions for which decision-makers feel accountable, readily apply to policy decisions in transport. Moreover, the regret-based discrete choice model for politicians' choice of road pricing outperformed the utility-based model (Chorus et la., 2011). In the context of integrated planning for sustainable transport, economic, social and environmental goals are combined. These policy goals are often conflicting and thus there are not clear 'no regret' policy options. Such decisions often require compromise solutions, which are associated with regret minimization (Chorus & Bierlaire, 2013). Moreover, the decision-making process in this study involves a group decision, in which the consensus alternative is attained through compromise and does not always comply with the views of all the policy-makers involved (Iverson, 2012). Regret has been recently suggested as an alternative approach for ex-post analysis of choices among transport policies (Chorus et la., 2011) and performing MCA in other policy decision contexts (Kujawski, 2005). This study is the first to embed regret both ex-ante and ex-post in the integrated transport planning framework. Moreover, the current study is the first to employ the generalized utility function combining utility and regret for scenario building and transport policy appraisal. The generalized utility combining utility and regret was proposed by Inman et al. (Inman et al., 1997) and applied to discrete choice models by Chorus et al. (Chorus et al., 2013). The combined utility-regret mechanism is theoretically preferable compared to models based on utility or regret as sole decision paradigms because of its generality (Loomes and Sugden, 1982))

The method to build TDM scenario is a two-round survey in agreement with the modified Delphi survey guidelines by Sackman (1974) and the approach proposed by Shiftan et al, (2003). The proposed framework was applied to the case-study of the future implementation of travel demand management (TDM) measures in Madrid, the third largest metropolitan area in Europe. Decision-makers were requested to construct TDM policy scenarios. The TDM measures included cordon toll, parking fees, and bus frequency increase. Expert judgement was elicited regarding which measures are desired or expected, their timeframe and geographic scale. The integrated framework consisted of a combination of a two-round Delphi survey with the integrated land-use and transport model (LUTI) MARS for Madrid.

The remainder of the paper is organized as follows. The next section provides the case-study context, followed by the description of the proposed approach embedding regret. Then, the results of the analysis are presented and discussed. Last, concluding remarks are offered.

2. REGRET-BASED APPROACH

Regret is a common word to describe the human emotion experience when one or more non-chosen alternative performs better than the chosen one in terms of one or more criteria (Von Neumann and Morgenstern, 1947). From the psychological perspective, any selection people made automatically evokes the experience of regret or rejoicing, in relation to what could or might have been (Gilovich & Melvec, 1994). Regret theory contains these two key points: 1) the fact that regret is commonly experienced and 2) people try to anticipate and avoid the experience of future regret (Loomes and Sugden, 1982).

Through a literature review of the regret theory, the existing practices are diverse. For example, the research by Savage (1951), Loomes and Sugden (1982) proposed a proper regret theory for rational decision-making under uncertainty. Eldar (2004) and Wang (2011) adopted mini-max regret criterion for decision making with incomplete utility information or with bounded data uncertainties. The work of Coricelli (2005, 2007) sheds light on the experience of regret from the neuropsychological and neuroimaging point of view. Kujaswski (2005) and Chorus (2010) developed their mathematical model on the basis of regret theory and created a regret function that incorporated regret element in a similar manner as the expected utility function to aid the decision-making process.

Thus the many violations of the axioms of von Neumann and Morgenstern (1947) expected utility theory might, in principle, be explained by the influence of anticipated regret. A decision maker under such influences might incur a sub-optimal choice to avoid future regrettable situations. It was also found that the existing expected utility theory appears to fail because the single outcome is not sufficient (Kahneman and Tversky, 1979). These authors found that the failure was neither small scale nor randomly distributed, but because some important factors like regret was not involved that, indeed, would affect choices by people that were specified by the conventional theory (Ibid). Thus, regret could be an important factor in resolving the apparent failure of utility theory to reflect observed behaviour.

Moreover, regret aversion has recently been associated with policy-makers' decisions on issues of climate change (Bulkeley, 2001) and transportation (Chorus, 2011). Choices based on anticipated-regret are essentially different from utility-based choices since regret-aversion tends to favor compromised or 'balanced' solutions rather than unbalanced 'optimal' solutions (Chorus & Bierlaire, 2013). Consequently, embedding regret in the integrated approach for scenario building is beneficial for increasing the robustness and the flexibility of the analysis.

Incorporating regret theory with a modified Dephi method to construct TDM scenarios is mainly because of two reasons. Firstly, sustainable transport involves economic, social and environmental goals that are often conflicting and thus there are not clear ¨no regret¨ policy options. Such decisions often require compromise solutions, which are associated with regret minimization (Chorus & Bierlaire, 2013). Secondly, the decision-making process is a group decision in which the consensus alternative is attained through compromise and does not always comply with the views of all the policy-makers involved (Iverosn, 2012).

3. CASE-STUDY CONTEXT

Madrid is the third largest metropolitan area in the European Union with a population of 6.5 million in 8,030 km². The Madrid region consists of three concentric rings with Madrid as its core, the surrounding metropolitan area, and the outer regional ring. The average population density is 5,390 inhabitants/km^2 with the highest densities in the core. Due to the current sprawling trends of population and employment, a considerable growth is observed in the proportion of suburban trips versus radial trips, which increases car attractiveness. Indeed, the motorization rate is the highest in Spain with 529 per 1,000 inhabitants, with a 7% yearly growth rate. Among the 14.5 million daily trips, 45% are made by car and 40% by transit, while work trips are respectively at 35% and 32%.

In this study, we propose car restriction measures (i.e., cordon toll, parking fees) and transit promotion (i.e., bus frequency increase) as TDM measures in the Madrid region. The measures are implemented during the morning peak-hour in Madrid because of the high congestion level. Both the cordon toll and the parking fees aim to regulate the car travel demand to the metropolitan core, while the improved bus service frequency aims at providing an attractive alternative to radial car travel. In terms of policy research questions, this study focuses on the long-term implementation of the proposed measures in terms of timeframe, geographic scope, and implementation intensity. The considered alternatives are implementation starting in the short-term (starting-year in 5 years), medium-term (starting-year in 10-15 years), and long-term (starting-year in 20-25 years). The duration is from the implementation starting-year until the end of the planning horizon, for example 2017-2034 for starting the implementation in the short-term. The considered geographic scopes are the Madrid metropolitan core, the area inside the M-30 highway, and the area inside the M-40 highway.

4. METHODOLOGY

Figure 1 presents the proposed innovative integrated framework for TDM scenario design and assessment. The framework integrates the scenario building and policy evaluation by MCA on the basis of the Madrid LUTI model. With the optimization and evaluation of the TDM scenarios via the LUTI model, the proposed combined utility-regret approach based on the MCA was used to decide the 'best TDM scenario' towards the objectives. The following sections detail each element.

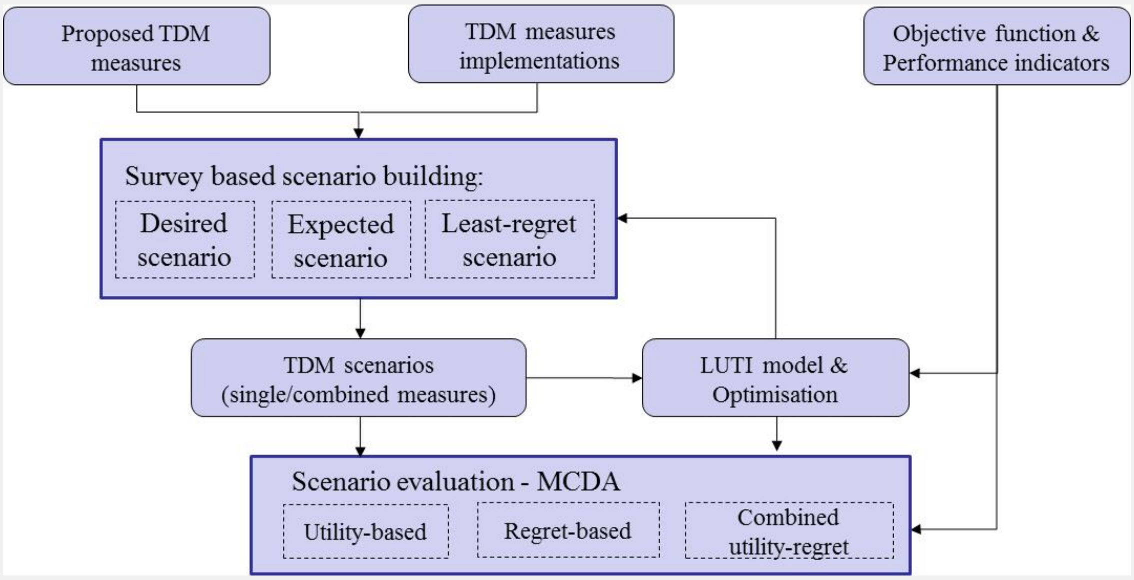

Fig. 1 - Integrated framework for TDM measures design and assessment.

4.1 Scenario Building

This part aims to present the details of the development of the two-round survey, including the procedure, the assessment criteria, the targets of each round of the survey, survey participant selection and survey pattern, etc.

Figure 2 shows the two-round survey procedure that used in this work. The survey methodology was modified to accommodate the integrated assessing approach via an interactive process involving expert decision-makers, selected transport model and participatory MCA evaluation. The survey was conducted on a web-based platform enabling to use skip-logic and feed-forward tools.

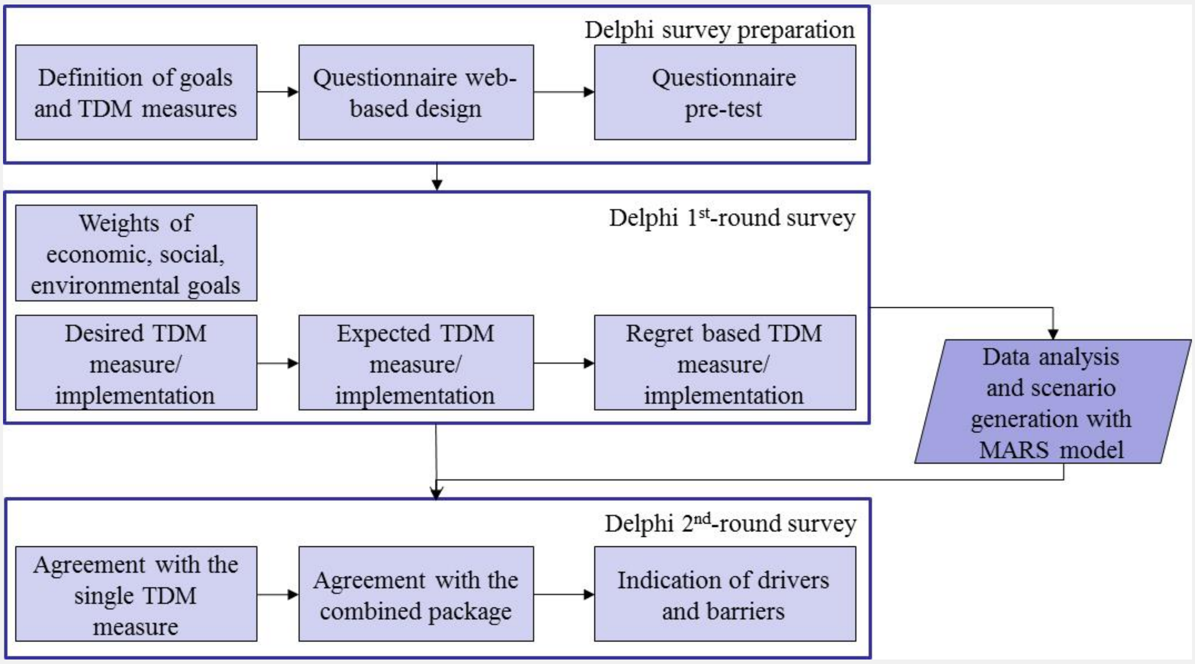

Fig. 1 -Flow chart of the scenario building process

During the survey development process, the selection of the experts was an important factor in the Delphi method and that can influence the results (Preble, 1984; Taylor and Judd, 1989). The two-round survey is designed to be sent only to the transport professionals and the number of participants varies in order to reduce respondent burden associated with multiple survey rounds.

Regarding to the survey pattern, for many reasons like time consuming and budget, this work did not allow for bringing a group of experts together for a day to achieve a final consensus on the TDM scenario building. Apart from that, a smaller workshop group, drawn mostly from nearby universities and government organizations, would have been inadequate. For example, it might not have reflected the interests of distant transport experts. Hence, a group process that could be conducted by a website is the logical choice (Sackman, 1974). Thus, this work employed a website-based set of questionnaires to conduct the survey. The survey was programmed and published through the public online survey service *Surveymonkey*®. Using website-based questionnaires could fulfil the same target of achieving the consensus on TDM measure implementation of many experts who are interested in sustainable development, but with low costs.

- **1st – round survey**

In the 1st-round of the survey, respondents were asked to rate on a 10-point Likert scale the importance level of the three objectives (are also MCA criteria), i.e., transport system efficiency, environmental protection, and social equity, and their level of anticipated-regret in the case these objectives would not be attained. In addition, the ability of the TDM measures to attain the objectives was elicited using a scale from -10 to 10, thus allowing negative, neutral and positive effects. For each TDM measure, the respondents were requested to state their opinion about the desired and the expected time-frame and geographic scope for implementation. Besides the predefined options, the respondents were provided with a ‘no implementation’ option. Then, the data about their desired time-frame and geographic scope was fed forward and the respondents were requested to specify their level of regret if a non-desired time-frame and geographic scope were implemented.

The 1st-round survey contained 43 questions, with skip-logic option upon selecting a ‘no implementation’ option. The desired alternative was associated with zero level of anticipated-regret, and the level of anticipated-regret was measured on a 0-10 scale, where 10 was the highest level. The respondents were explicitly asked about their level of regret due to two reasons. Firstly, the feeling of regret is associated with engaging in contra-factual ‘what if…’ questions. Unless explicitly requested, the spontaneous engagement in contra-factual thinking is largely dependent on the choice situation, the decision-makers´ intra-personal factors, and the assumed responsibility for the choice. Secondly, ranking alternatives with respect to the desirability or anticipated-regret largely differ, because the level of anticipated-regret not only depends on the desirability of the alternative, but also on the alternative satisfying the decision-maker’s criteria thresholds.

With the incorporation of the regret theory in the scenario building, it enables the decision maker to address the least regret TDM measures and its implementation result of the opinion of survey participants. Besides that, to incorporate the regret theory with the traditional scenario building process could help build TDM scenarios based on the desirability of the decision maker, but above all else, to avoid losing the potential best scenario.

In order to compare the contribution of each TDM measure by expert opinion and by the LUTI model, the first-round survey also requested participants to give a score to state their opinion on the contribution to the most desirable, the most expected and the least regret choice regarding the three defined criteria (i.e. economic efficiency, social equity and environment). These results could help policy designers to understand the discrepancies of public opinions and model outputs during strategic plan development.

The 1st-round was analysed with the aim of (i) evaluating the relative weights of the economic, environmental, and social objectives, (ii) evaluating the potential of the TDM measures towards achieving the specified objectives, and (iii) generating the desired, expected and least-regret implementation for each TDM measure. The relative importance weights and the anticipated-regret weights of the objectives were calculated to serve as input to the MCA objective function. The utility-based weights were calculated on the basis of both the multi-attribute utility (MAU) theory. The regret-based weights describe the importance of each criterion from a regret-based perspective. In order to assess the ability of the TDM measures to achieve the objectives, the mean value and the standard deviation of the scores were calculated, with lower standard deviations indicating possible consensus. The scenarios were generated by calculating the proportion of respondents choosing the desired and the expected implementation option for each TDM measure in terms of time-frame and geographic scope. The average level of anticipated-regret associated with each alternative was calculated across the respondents. These outputs resulted in the desired, expected and least-regret implementation option for each TDM measure.

Via the survey pre-test executed by five experts, the 1st -round survey took an average 15 minutes to be completed. According to the feedbacks in the pre-test, the questionnaire has been modified aiming to clarify several questions. However, in order to prevent the complicated questions and assure the survey length, the first survey did not contain the implementation of a combined package of TDM measures.

The 1st-round survey was administered via E-email in December 2012 to a large pool of 220 transport professionals in Spain. The professionals included decision-makers, transport operators and academic researchers in the transportation field in Spain. This round asked the participants to choose four proposed TDM measures (i.e., cordon toll, parking charge increase, bus frequency increase and bus fare decrease) and their specific implementations for the case of Madrid based on their desirability, expectation and personal attitude of regret. Finally, 116 of them entered the survey webpage, and **99** of them finished all the questions (45.0% response rate).

- **2nd – round survey**

In the 2nd-round of the survey, respondents were asked to state their degree of agreement with the 1st -round results (**survey results**) as well as with the model outcomes on implementation intensity (**model outputs**). The generated scenarios included the implementation of all the policy measures implemented simultaneously as a policy-package, accounting for complementary and substitution effects. The respondents were asked regarding their level of agreement with the desired, expected and least-regret implementation. The respondent level of agreement was elicited using a 4-point Likert scale ranging from highly disagrees to highly agree. Besides that, the 2nd-round was also asked respondents to describe the key considerations that drove their choices.

The 2nd-round was analysed with the aim of (i) confirming the validity of the scenarios by considering the respondents' agreement with the 1st-round survey results, and (ii) identifying potential drivers and barriers for the scenario implementation from the respondents' comments on this issue.

The 2nd-round survey was sent in March 2013 only to the experts who requested feedback, in order to reduce respondent burden associated with multiple survey rounds. This round was derived from the modified Delphi method, in which the experts would have been asked to verify their answers in the light of the earlier choices. Through the pre-test for the second round, it took an average 8 minutes to finish in total **9 questions**. There were eight questions to justify the agreement levels on the survey results and model outputs, both for the single measure and the combined package, and one additional open question to collect participants´ opinions and considerations.

As mentioned in the survey development, the second-round questionnaires were only presented to the participants who were willing to receive the results of the first survey. So there were in total **81** participants received the second-round questionnaires, and 41 respondents entered the survey webpage, **32** of them completely finished the questionnaire. The response rate was **39.5%** that was a bit lower than the rate of the 1st -round (39.5% compared to 45.0%).

4.2 MARS model

The framework for the MARS model and MCA-based optimization is provided in figure 1. The MARS model is a dynamic LUTI model for strategic planning, which combines forecasting, optimization and assessment (Pfaffenbichler, 2008; 2011) and was calibrated for Madrid (Guzman, et al., 2012). The land-use model consists of interrelated of sub-models of workplace, residential and housing development. The transport sub-model includes time-of-day and modal split, while demographic trends and motorization rates are forecasted as background scenarios. The system accounts for interactions between transport and land-use that are modelled by using time-lagged feedback loops between the transport and land-use sub-models until the planning horizon of 2034 in one-year intervals.

The MARS model includes a feedback loop between a simulation model and an MCA assessment that enables to optimize the implementation values (i.e., toll and parking price, bus frequency) of TDM scenarios and assess their derived effects on transport and land-use in the desired, expected and least-regret TDM scenarios. The optimization aims at obtaining the best implementation values by maximizing the value of the linear additive MCA objective function. While the MARS model can incorporate both cost-benefit analysis and MCA, as the two most prominent appraisal methods (Pfaffenbichler, 2008), the MCA was preferred in this study because of its clear advantages in the transport sustainability context (e.g., Turcksin et al., 2011; Macharis et al., 2012): (i) the possibility to represent a holistic view incorporating multiple-criteria that are difficult to monetize; (ii) the possibility to involve stakeholders and account for their priorities in the decision-making process.

The MARS model was adapted for the needs of this study by: (i) tailoring the performance indicators to include economic, environmental and social performance indicators; (ii) providing the utility-based and regret-based weights for the MCA objective function and assessment on the basis on the survey; (iii) updating the background scenarios according to recent statistical data; (iv) incorporating the regret theory and the combined utility-regret theorem as elements in the MCA method for scenario assessment.

4.3 TDM Scenario Evaluation

A combined utility and regret-based MCA approach was applied to assess the impacts of each TDM scenario (see figure 1). This approach was made from a finite set of alternatives (i.e., TDM scenarios) that were characterized by deterministic attributes, which were economic efficiency, environmental protection and social equity. An aggregate utility value of each alternative was obtained from the objective function of utility-based MCA that was embedded in the transport and land use interaction model-MARS. And a regret value was computed from a developed regret model (i.e., reference-dependent regret model, RDRM) that was conducted outside of the MARS model (Kujawski, 2005).

The MCA comprises an objective function of performance indicators weighted by their perceived importance. The weights were the utility-based and regret-based importance weights obtained from the 1st-round of the survey. The performance indicator values were obtained from the model results for the technically-optimal solution for each implementation scheme.The regert-based approach treats the emotion of regret as an additional dimension of decision making and incorporates it as an element within an extension of MCDA, in order to avoid high levels of regret (Loomes and Sugden, 1982; Kujaswski, 2005). The detailed introduction of the utility and regret-based TDM sceanrio evaluation can be found in Wang et al., (2014).

5. RESULTS

5.1 1st-round Survey Analysis

The first survey round was analyzed with the aims of evaluating the relative weights of the economic, environmental, and social objectives, evaluating the potential of the TDM measures towards achieving the specified objectives, and generating the desired, expected and least-regret scenarios.

The average utility-based importance scores were 0.353 (SD = 1.29) for transport efficiency, 0.334 (SD = 1.43) for social equity, and 0.314 (SD = 1.85) for environmental conservation. The average regret-based importance scores were 0.351 (SD = 2.44) for transport efficiency, 0.337 (SD = 2.39) for social equity, and 0.312 (SD = 2.63) for environmental conservation. The results of the utility-based and regret-based importance scores were similar in their average values, but the regret-based scores showed higher variance.

Table 1 shows the proportion of experts who perceived each implementation scheme as desired or expected, and the level of regret associated with each scheme. The results show a wide agreement across respondents with respect to the desired and expected implementation schemes for each TDM measure, albeit the proportion of respondents who agreed with the desired implementation is much higher than the proportion of respondents who agreed with the expected scenario. The majority of the respondents thought that the cordon toll should be implemented in the short-term and in a relatively large area inside the M-30. The respondents expected a later and smaller scale implementation of the cordon toll in 5-10 years in the Madrid city center. Regarding parking fees, the majority of the respondents thought that the desired implementation is in the next five years and in the area inside the M-30 ring. The respondents thought that the desired implementation is also the expected one, although they were more in consensus about the expected scheme than the desired scheme. The vast majority of the respondents thought that the bus service frequency should increase in the next five years in the area within the M-40 ring. They expected however to be implemented only in 10-15 years and in the smaller area within the M-30 ring.

While the desired implementation option was in most cases associated with the least-regret, the regret scores were similar for the majority opinion and the dominant minority opinion, and both were lower than the anticipated-regret associated with the option preferred by the small minority opinion. Notably, the anticipated-regret expressed in the 1st-round only served for generating a least-regret scenario, and not for the evaluation of the desired or expected scenarios.

Cordon toll				
Starting-year	**In 5 years**	**In 10-15 years**	**In 20-25 years**	**No implementation**
Desired	**60.0%**	17.4%	2.6%	20.0%
Expected	27.0%	**45.2%**	10.4%	17.4%
Level of regret*	**5.52**	5.87	6.03	
Geographical scope	**City Center**	**Inside the M-30**	**Inside the M-40**	
Desired	31.5%	**56.5%**	12.0%	
Expected	**63.0%**	30.4%	6.5%	
Level of regret*	5.72	**5.66**	6.31	
Parking fees				
Starting-year	**In 5 years**	**In 10-15 years**	**In 20-25 years**	**No implementation**
Desired	**63.0%**	14.8%	2.8%	19.4%
Expected	**75.0%**	16.7%	0.9%	7.4%
Level of regret*	4.27	4.24	5.71	
Geographical scope	**City Center**	**Inside the M-30**	**Inside the M-40**	
Desired	31.4%	**54.7%**	14.0%	
Expected	32.2%	**64.4%**	3.4%	
Level of regret*	**5.45**	5.50	6.84	
Bus frequency increase				
Starting-year	**In 5 years**	**In 10-15 years**	**In 20-25 years**	**No implementation**
Desired	**71.4%**	15.2%	0%	13.7%
Expected	19.0%	**40.0%**	7.6%	33.3%
Level of regret*	**1.6**	3.3	6.4	
Geographical scope	**City Center**	**Inside the M-30**	**Inside the M-40**	
Desired	2.2%	29.7%	**68.1%**	
Expected	22.2%	**43.3%**	34.4%	
Level of regret*	6.4	**4.2**	5.2	

*Note: * average regret score on a 10-point Likert scale.*

Table 1 - 1st-Round Survey Results: Timeframe and Geographic Scope of TDM Measures Implementation

5.2 Optimization Results

The optimization process via the MARS model generated the optimal starting-year and end-year values for the implementation intensity of the desired, expected and least-regret combinations of cordon toll, parking charges and bus frequency increase. The three measures were considered simultaneously as a TDM policy-package in the model runs. The optimal implementation values are presented in table 2.

In the expected and the desired TDM policy-package scenarios, the model results show a substitution effect between the cordon toll and the parking fees, and a complementary effect between the cordon toll and the bus frequency increase. The parking fees were much lower than the cordon toll and approached zero in the least-regret scenario. The results are reasonable when considering a substitution effect between the two measures because both impose a fee on car travelers to the city center, and both can be designed to affect local and non-local residents to a different extent. Likely, the model did not differentiate between the two measures. The complementary effect between the cordon toll and bus frequency increase is evident from the results because the higher the optimal cordon toll, the higher was the optimal bus frequency. Notably, the cordon toll and parking fee values in the desired and expected scenario derived from the tradeoff between transport efficiency and social equity in the MCA objective function.

Comparing the desired and the expected scenarios, in the former travelers will enjoy lower cordon toll costs and higher bus frequency, in both the medium-term and the long-term. This means that the experts' desired scenario is also superior from the perspective of the single traveler, and thus may be associated with higher political acceptability.

Comparing the least-regret scenario and both the desired and expected scenarios, the user in the least-regret scenario will enjoy lower cordon toll fees and higher bus frequency in the short-term, and will suffer higher cordon toll fees and lower bus service frequency in the long-term.

Base year 2012	**Policy package**	**Survey results**		**Model output**	
		Implementation		Optimal starting-year value	Optimal end-year value
		Geographical scope	Timeframe		
Desired TDM policy scenario	Cordon toll	Inside the M-30	2017-2034	4.0 €/vehicle*	2.9 €/vehicle
	Parking fee	Inside the M-30	2017-2034	2.5 €/hour	0 €/hour
	Bus frequency	Inside the M-40	2017-2034	52%	34%
Expected TDM policy scenario	Cordon toll	City center	2022-2034	5.2 €/vehicle	3.7 €/vehicle
	Parking fee	Inside the M-30	2017-2034	2.5 €/hour	0 €/hour
	Bus	Inside the M-30	2022-2034	36%	27%

	frequency				
Least-regret TDM policy scenario	Cordon toll	Inside the M-30	2017-2034	1.1 €/vehicle	6.0 €/vehicle
	Parking fee	City center	2022-2034	0 €/hour	0 €/hour
	Bus frequency	Inside the M-30	2017-2034	50%	22%

*Note: *Single entry to the cordon area during peak-hour*

Table 2 - MARS Model Results for the Desired, Expected and Least-Regret TDM Policy-Packages

5.3 2nd-round Survey Results

Table 3 shows the respondents' level of agreement with the survey results and the model output, showing higher agreement with the desired scenario compared to the expected and least-regret scenarios. The results agree with the first survey round, in which high proportion agreed on the compared to the expected TDM implementation scheme.

Agreement with the survey results				
	Highly agree	**Partially agree**	**Partially disagree**	**Highly disagree**
Desired	37%	37%	23%	3%
Expected	12%	44%	38%	6%
Least-regret	9%	50%	32%	9%
Agreement with the model optimization output				
	Highly agree	**Partially agree**	**Partially disagree**	**Highly disagree**
Desired	26%	37%	29%	9%
Expected	6%	33%	48%	12%
Least-regret	9%	35%	41%	15%

Table 3 - Respondent's Agreement with the Survey Results and Model Output

Respondents were invited to provide their comments regarding the main drivers and barriers for implementation of the TDM measures. Environmental concern was mentioned as a driver for policy implementation, while imposing higher transport fees in times of financial austerity were mentioned as policy implementation barriers. The respondents were unsure about the reduction of parking fees and cordon toll in the long run, possibly because it is difficult for human decision-makers to fully consider the tradeoffs in the MCA objective function. These results indicate the need for the complementary use of expert judgment and transport models, and the need for a transparent modelling and evaluation process.

6. CONCLUSIONS

This study proposes an innovative regret-based approach for building and evaluating TDM scenarios, which combines the modified Delphi method on the basis of a generalized utility approach combining simultaneously utility and regret. The new approach, combining expert-opinion and transport modelling on the basis of the combined utility-regret MCA offers a robust and transparent decision-making process.

The proposed methodological advances were demonstrated in the design and assessment of TDM measures in Madrid.

The results demonstrate the practical importance of considering regret-based approach in the scenario building framework. In the scenario construction stage, the regret-based importance scores are similar in their average values to the utility-based scores, but show higher variance, indicating that utility-based and regret-based importance trigger a different type of thinking. The difference is possibly due to the need for justifiability that is associated with regret-minimization (Zeelenberg & Pieters, 2007). In addition, the experts associated a high level of regret to their non-chosen alternatives, which indicates that expert decision-makers have strong opinions both in the majority and minority expert groups. Thus, the least-regret scenario is important as a compromise solution between the majority and the minority opinions in agreement with Iverson (2012). In the scenario evaluation stage, the desired-scenario performs better in terms of transport efficiency and environment, while the expected-scenario is preferred from the social-equity perspective and the least-regret scenario is a clear compromise in terms of the performance indicator scores. Moreover, the least-regret as a compromise solution is associated with higher user benefits in the short-term and lower user benefits in the long-term, likely leading to the higher political acceptability of this scenario in the short-term. Thus, considering regret in the evaluation process could be informative to decision-makers by considering the impact of different MCA models under uncertainty (Kujawski, 2005). Consequently, the proposed assessment of policy-packages are more robust and transparent compared to the existing approaches solely based on utility-maximization.

The new approach of scenario building involving regret theory shows that (i) an interactive process with a feedback loop between expert judgement and transport modelling is useful, (ii) regret-based ranking has similar mean but larger variance than utility-based ranking, (iii) the least-regret scenario forms a compromise between the desired and the expected scenarios.

The proposed approach is practice-ready. Expert-based scenario building, LUTI models, and MCA are well-established tools for transport planning (e.g., Shiftan et al., 2003; Hickman et al., 2012). The MARS model is applied to 14 cities across continents (Pfaffenbichler, 2011). The Delphi is a quick and cost-effective method to gather expert-based information for long-range planning (e.g., Shiftan et al., 2003; Powell, 2003). Similar to Shiftan et al. (2003), this study reveals a high response rate to the questionnaire, reasonable and diverse answers, convergence of the results of the two rounds, and modest costs due to the web-based application that allowed the participants to complete the survey at the location and time of their convenience without requiring transportation or accommodation costs required in focus group techniques. Complementary use of expert judgment and computerized models could be beneficial in terms of the acceptability of policy scenarios because of the active participation of experts in the process. The approach can be extended to public-participation in scenario building, in order to increase the public acceptability of future transport policies.

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