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Estimation of Time Loss and Costs of Traffic Congestion: The Contingent Valuation Method

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***Abstract*—**The reduction of road congestion which is inherent to the use of vehicles is an obvious priority to public authority. Therefore, assessing the willingness to pay of an individual in order to save trip-time is akin to estimating the change in price which was the result of setting up a new transport policy to increase the networks fluidity and improving the level of social welfare. This study holds an innovative perspective. In fact, it initiates an economic calculation that has the objective of giving an estimation of the monetized time value during the trips made in Sfax.

This research is founded on a double-objective approach. The aim of this study is to i) give an estimation of the monetized value of time; an hour dedicated to trips, ii) determine whether or not the consumer considers the environmental variables to be significant, iii) analyze the impact of applying a public management of the congestion via imposing taxation of city tolls on urban dwellers.

This article is built upon a rich field survey led in the city of Sfax. With the use of the contingent valuation method, we analyze the "declared time preferences" of 450 drivers during rush hours. Based on the fond consideration of attributed bias of the applied method, we bring to light the delicacy of this approach with regards to the revelation mode and the interrogative techniques by following the NOAA panel recommendations bearing the exception of the valorization point and other similar studies about the estimation of transportation externality.

***Keywords*—**Willingness to pay, value of time, contingent valuation, time value, city toll, transport.

I. Introduction

TIME is our essential non-renewable resource. The value of travel duration is critical in evaluating the benefits of investing in transportation infrastructure and rule-making initiatives. Delay Reduction for passengers is a major aim of investments, along with rules to enhance safety that sometimes includes provisions which could slow the transit. Assessing the economic value of our free time may have major impacts on how we organize economic decisions; prioritize investments and also solving the problem of lack of data on the quality of trips in Sfax. The most practical way to explain the methodology is to apply it on a hypothetical case, through a stated preference survey [1]. Today, most economists believe that economic value is subjective and it depends on individual preferences. We have been witnessing these last few years an intensive development in the methods of upgrading the environmental assess, not only on a theoretical level but also on an empirical one. The motion of preparing and carrying out the surveys of contingent evaluation are on the rise. Most of the prominent economists are drawn to the theory behind it, which itself justifies the relevance of resorting to hypothetical methods. Taking into consideration the particularities of these assets and of the data resulted from these surveys, a number of econometric estimation methods have emerged. Nowadays they are deemed to be an autonomous body of the pre-established econometric theory. The main aim of this study is primarily to provide an estimation of the time allocated for city trips, and secondly to determine the variable that are closely linked to the drivers' willingness to pay. This study relies on previous analyses on the environmental resources which were based on the econometric theory. It is also based on contemporary methodological developments of not only conception techniques, but also the survey treatment.

The mobility in downtown Sfax is the pillar of our empirical study. We selected this city for its importance as an economic, industrial and commercial hub. Also because this city is reaching a saturation point in road transport and reaching a hazardous level of air pollution.

The purpose of this paper is to review time value through the technical investigation, to declare a "WTP" equivalent to an hour a day wasted in traffic. We also want to determine whether a public policy of road pricing depending on of the use of cars, can be an effective way to enhance the time allocated to transport and thereby encouraging the concerned authorities to develop an approach to fight congestion.

A. Economic Value of Time

The term environment is often used to indicate the set of natural resources likely to interact between the living organisms and the human beings. The environment can be considered as a public wealth or common good, which makes its consumption by definition non-rivalrous, i.e. Anyone's use of this good does not reduce the quantity available to other agents. It is non-excludable, i.e. it is impossible to prevent anyone from consuming (e.g. roads), and it is available more-or-less worldwide. The total economic value is a theoretical concept that allows us to define the value of a good or a service [10]. On the one hand, it is composed of the use value, which is easily detected since it is directly linked to both the direct use of that good and the non-use value. Which itself gathers two main elements that share the common feature of the direct non-use of that good. From these two types of value, we derive the option value [4] which is equivalent to an individual's Willingness to Pay (WTP) in order to preserve a good for a potential future use.

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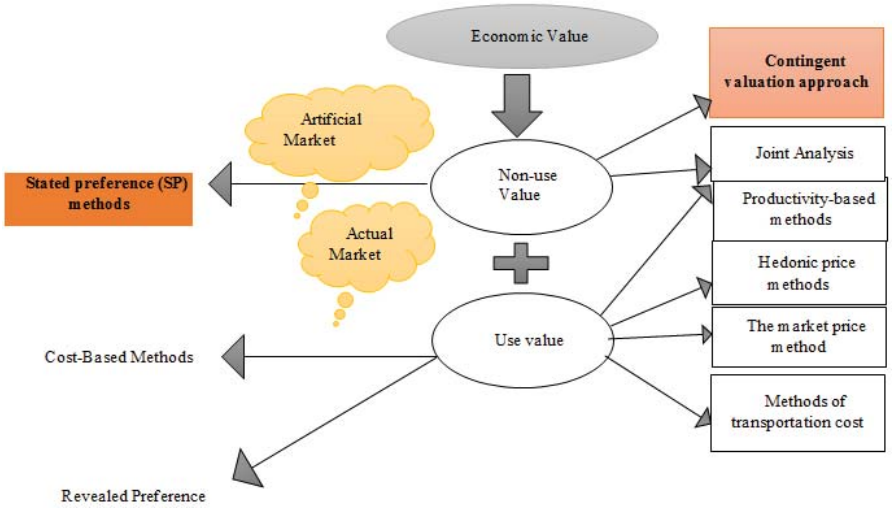

Fig. 1 Monetary Methods

II. Contingent Valuation Method

The contingent valuation method (CVM) is a stated preference approach to the measurement of the value of changes in the allocation of non-market environmental and natural resources [8]. The CVM has clear advantages when compared to revealed preference methods, in which actual behavior is used to develop value estimation. Stated preference methods are most useful when an ex-ante policy analysis considers proposals that are beyond the range of historical experience.

The CVM [13] can be used to estimate non-use values (i.e. passive use values) and willingness-to-pay under uncertainty, in advance. However, some issues may emerge since the approaches to economic value are subject to selection-bias, whereby the answers given can be insensitive to the congestion being hypothetically provided. The risk of embedding can be reduced by carefully designing questionnaires, to avoid poorly defined scenarios and imprecise definitions of the proposed policy change. The determination of WTP by means of Stated Preferences (SP) data has traditionally been associated with the CVM [3]. The CVM consists in asking people how much they are willing to pay in monetary cost for a social benefit; analogously, the Willingness-to-Accept (WTA), as shifts in compensation for an environmental damage, can be calculated. Traditionally, WTP to save travel time (in the classic transport microeconomic literature normally referred to as the subjective value of time) has been estimated by using mode choice models, by considering travel time and cost attributes in the utility function of the modal alternatives. Travel time can be expressed in terms of total transit time, or by considering separately some parts of the total duration; like in-vehicle time, waiting time, access/egress time, parking time, and so on [9]. Travel cost represents the monetary cost linked to the transport mode. According to this approach, a useful way to calculate the value of time is to find the marginal rate of substitution (i.e. the trade-off) between perceived travel times and costs at constant utility. For the linear parameters specific to the utility function, the value of time corresponds to the ratio between the estimated parameters of time and cost attributes [5].

The first inquiry was about the time wasted by drivers to pass through downtown every day. An evaluation of the impact of a pricing policy with the aim of reducing congestion was carried out.

III. Methodology

Inspired by the standard practice of contingent valuation methods, our utmost objective consists in evaluating the "Willingness to Pay to save time" which was conveyed through an open question that introduced the drivers with hypothetical situations which are time-saving but are more chargeable. Following the path of [7], [2], [12], the open-disclosure mechanism is the simplest method but the least used because it will possibly generate a sizable non-response rate. One of the advantages of direct questioning is the consideration of potential, strategic and psychological bias [11] that will help us reduce refusals to answer.

We shall start by portraying the reasons behind choosing Sfax as the target of this study, and then we will move to the presentation of the survey. The evaluation and analysis of the results will be presented in Section IV.

A. Perimeter of Study

The radial roads system and the weak orbital connections between satellites reinforce the feature of centrality and the dependency of the peripheries to the city center. As a result, the use of a private car becomes a necessity. Furthermore, the low multi-polar model reduces profitability of public transportation due to crossings of green areas and urban valleys.

Resorting to private cars certainly generated an intense traffic congestion, which is displayed through the multiple disturbances in public transportation caused by consistent

insufficiency in the city of Sfax. According to the data issued by the PDTR, almost 70% of the trips have home-work motifs and that 60% of the trips are done using a private car in 2009. This massive reliance on the car could be conveyed through the average number of kilometers covered by Tunisians (22 000 Km) in contrast to French drivers who drive an average of 14000Km/year according to an ANME study. The vehicle fleet has doubled between 1988 and 2009 reaching a number of 1.3 million vehicles that is 120 vehicles per 1000 habitants in 2009 compared to 30 vehicles per 1000 habitants in 1988.

From an environmental perspective, the use of private cars in Sfax is growing, which makes the repercussions in terms of energy consumption, pollution, congestion and safety notable with the limited role of public transportation.

In 2012, accidents rate reached a number of 9351 which significantly topped the average number in Europe and it should be mentioned that the motorization rate is four times less than in Tunisia. These accidents are major with one death/accident and 1.2 injured/accident. The size of the entire population death rate in 2012 is 140 Deaths/million habitants; a number that is 50% higher than the average. This explains that the congestion phenomenon impairs not only the life quality of drivers, but also their vital safety.

Facing such a quality of traffic, policy makers have two alternatives; whether to build infrastructures in order to compensate for the increase in demand and the use of vehicles, or direct the drivers' choice towards other alternatives (public transportation, pedestrianisation).

In order to be able to choose between the two alternatives, it is essential to conduct a benefit-cost analysis. This latter requires giving an estimation of time in the first place. However, since the good under evaluation is a non-market good, it is important that we resort to the contingency valuation method; this method is based on the creation of an artificial market. It was adopted and applied according to the states' rules on sampling by considering a sample of 450 households which represents a total 3000 drivers from a basic population of 400000 habitants. Knowing that we ask only those who pass through the city center. This further reduces the total number of motorists.

B.Sample of the Study

We have led a survey during the first three months of the year 2015. The main focus of the contingency valuation's survey is to manage to evaluate the number of allotted hours for the daily trips, and to determine the defining significant variables of the drivers' willingness to pay. The city of Sfax was selected for several reasons that we have clarified in the previous sub-section. This survey was conducted using face-to-face interviews to obtain more credible results, since they are more reliable than the other means (phone, regular and electronic post). Tables I-III provide complementary details about our sample. Table I displays the frequencies of passing through downtown and the rate of the wasted time during day-to-day trips. We pointed out also the distribution of the sample's households according to their monthly income range. We came to the conclusion that there is a direct correlation between the average income of a household and their average ability to pay (ATP)

TABLE I
SAMPLE CHARACTERISTICS

Variable	range	average
Age	18-30	28%
	31-49	52%
	50-70	18%
	>70	2%
Gender	woman	47%
	man	53%
Income standard*[1]	<500	8%
	500-900	34%
	900-1100	26%
	1100-1300	24%
	>1300	9%
profession	manager	25%
	Intellectual-liberal	33%
	Employee-worker	32%
	No fixed income unemployed	4%
Frequency of passages through down-town	➢3	50%
	➢4	8%
	➢1	14%
	➢2	28%

C.Description the Survey Instrument

We emphasize the fact that we adopted the criteria located in Table I in the design and implementation of the survey: Build the sample investigated on the basis of the most rigorous statistical methods, so that it could be truly representative of the concerned population. Proceeding to a pre-test to make sure that the questionnaire is understandable. If the questioned individual answered, for example, that he has no opinion on the valuation of the property, it is essential that the questionnaire must be improved (lack of clarity of the question, lack of interest…etc.).

The purpose of the pre-test stage is to eliminate the answers directly related to poor design of the questionnaire.

The problematic economic valuation must be clearly described and explained in advance to the questioned sample. And most importantly, the valuation questions set to explain the WTP should allow the elimination of any extreme unrealistic answer. Indeed, the questionnaire should allow the questioned individual to justify his choice of the CAP.

The duration of the investigation, which was 3 months, has been well chosen to achieve homogeneity and consistency of the responses. The interview is divided into three sections: in the first, we provide the pieces of information about the socioeconomic characteristics of the respondents (gender, age, income and frequency about using car). In the second section we analyze travel habits in the city center, however the last section of the interview includes an experiment Stated Preferences (SP) in which the motorists made a choice about a hypothetical scenario (charge toll) to define their willingness to pay to reduce congestion.

The set of constructed variables of the questionnaire are as follows:

- Environment: the air quality in the city of Sfax (ENVT= 1 if yes and 0 otherwise)

[1] A minimum income standard for the Tunisian is 340Dinars/160euro. The average salary is in the region of 360 euro per month.

- Town-access: (1 if yes and 0 otherwise)
- Tax: 1 if yes and 0 otherwise)
- Congestion: 1 if yes and 0 otherwise)
- Travel time: Time commuting through the city center
- Distance: the distance between home and destination
- Income: 5 income classes
- Cost: 1 if yes and 0 otherwise)
- Age: age of the motorist questioned
- Gender: 1 if a female
- Profession: 5 classes

IV. Experimental Results

Out of the 450 drivers of our core sample, 22 households have given zero answers that can be considered true zeros. The answers of actually zero could be explained by the fact that these households feel they already pay a high amount and are therefore unable to participate in such a project, given their low incomes. But other responses were nil protest answers; the authors estimate that the preservation is not necessary. Our aim now is twofold:

- Determine the explanatory variables on the willingness of the users to pay.
- Estimate the value of travel time.

To achieve these goals, we use the data of the contingent valuation survey that we have presented, and we will rely on econometric estimation methods that we deem most appropriate.

A. Econometric Estimation by the Direct Method

The open question allows us to estimate a linear regression model where the dependent variable is the willingness of the interviewed individuals to pay and the dependent variables are their incomes and socio-economic characteristic.

The indisputable advantages of linear regression and especially its log linear version are numerous:

- It determines the average WTP.
- It solves the problem of hypothetical bias.
- Note that the use of the log-linear model, which takes explicitly account for Mills ratio [15]

If the number of zero responses is high (including the answers which are treated as null responses) the estimation of the contingent valuation model and therefore of average WTP requires a specific econometric treatment: Indeed, the use of the Tobit model turn out to be the most appropriate to estimate the average WTP.

The homoscedasticity hypothesis, which states that all observations have a common variance, is not at all plausible in a sample of households in instant cup.

We presume that there is no multi-co linearity, so the independence between all independent variables is to be verified. Solving these two problems is absolutely necessary; that is why we must resort to multi-collinearity tests and homoscedasticity:

- Regarding the first problem by applying the rule Klein, we found that all the coefficients of any explanatory variable regressions on all the other are well below the coefficient of the starting regression. These results allow us to accept the hypothesis of absence multi-collinearity.
- By opposition, the use of the type of tests Breuch-Pagan, Harvey and White, has allowed us to detect the existence of homoscedasticity.

The correction of selection bias introduced by non-responses is eliminated through Tobit model, that all null responses and non-responses were now considered equivalent to consent to pay zero. Moreover, protest answers which were excluded from the data when estimating by log linear, are included in the estimate of Tobit [14].

TABLE II
The Estimation Results of the Open Method

Independent variables	MCO Model	Tobit Model
Gender	0.002 (3.18)	0.347 (-0.94)
age	0.441 (-0.77)	0.173 (-1.37)
profession	0.031 (2.16)	0.005 (2.85)
income	0.000 (5.16)	0.000 (4.46)
Town-access	0.044 (2.02)	0.057 (1.91)
Environmental	0.083 (-1.74)	0.572 (-0.57)
tollgate		0.371 (-0.89)
_cons	0.31 (0.754)	0.893 (0.13)
Log verisimilitude		-1553.5297
R2	0.13	0.019

(Coefficients in parentheses are the Student t)

We estimate willingness to pay models for one variable (congestion). We use all exogenous variables as instrumental variables to estimate the WTP, which is conceived to depend on the age, income, profession, environmental quality, and socioeconomic variables. We choose these demographic variables as the identifying variables because they are strongly related to perceived quality. The willingness to pay equation is designed to depend on the income, profession, congestion-related variables, and acknowledgement of the congestion toll's benefits.

B.The Value Time Declared

The individuals' willingness to pay (with a WTP>0) is transcribed in the Table III. It corresponds, following self-reflective questions, to a WTP of 6.7 TND.

A difference between the two genders stands out whereby, Female subjects have an average WTP of 5.3 TND compared with 8.1 for male subjects. In terms of age structure, subjects in their 70s seem to be less susceptible to the issue of congestion, which was manifest in a WTP of 0.6 TND. Unlike the 50 to 70 age-group, whom answers seem to qualify them as "generous" with a WTP of 8.4 TND compared with a WTP of 6.1 TND for the 31 to 49 age-group and a WTP of 5.6 TND for the 18 to 30 age-group.

TABLE III
DECLARED WTP VALUE (IN TUNISIAN DINARS)

	Man	Woman	Age 18 30	Age 31-49	Age 50-70	Age > 70	Managers, Intellectuals, Liberal Professions	Employees	Jobless
WTP	8,1	5,3	5,6	6,1	8,4	0,65	6	7,2	2

For what concerns the professional and social classes, logically speaking the professional classes (managers, intellectual professions, and employees) would reveal a WTP superior to the other social classes whose WTPs are around 7 TND. Overall, it seems that the inactivity of individuals (jobless or retired subjects) doesn't affect the WTP (around 2 TND). What is striking though is the fact that the employees as a social class discloses the highest WTP and seem to bring together the group of people most eager to gaining time. It is logical because employees cannot adjust their work schedule and they are penalized for every delay. The damage can even go to them losing their bonuses in case of frequent lagging. Thus, their willingness to improve the traffic conditions, especially during peak hours.

The WTPs mentioned earlier take into account only the individuals disclosing a WTP>0 which corresponds to the highest estimation (ceiling value) of what subjects can pay.

Like [6], we can carry out a second estimation by integrating the WTP=0, which would be established as a conservative approach to the average amount revealed by subjects (minimum value). This floor value of WTP would be of an estimated 6.1 TND per a family. It should be also noted that 10 drivers over the 450 subjects qualify the value of wasted time during transportation to an amount of 50 TND. After removing this overly estimated suggestion, the revised amount of WTP would be of 5.4 TND.

V. CONCLUSION

The main purpose of this research is to provide a tool for calculating consumers' Value of time, with the objective of reducing traffic congestion. The Value of time in terms of congestion attributes represents a quantitative measure of the monetary cost that the user would pay to improve some qualitative aspects; such as saving time and reducing air pollution. These values are generally neglected because of the difficulty of their evaluation and quantification in monetary terms. WTP values may be used for calculating the project revenues in transport service investments. Overcoming traffic congestion is a long-term process, which requires a supportive policy framework. The process also requires institutional development components, which must be in place and functioning before projects are launched. The study concludes that it is extremely difficult to fix traffic issues solely with pricing policy, and that similar project should also address public transport policy in order to enhance traffic conditions.

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