Approach to Design Behavioural Models for Traffic Network Users

Choice of transport mode

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Abstract: Our research work concerns the development of a multimodal urban traffic simulator designed to be a tool of decision-making aid similar to a game wherein the user-player can test different scenarios by immersion in a 3D virtual city. Our approach is based on the activity-based model and the multi-agent technology. The implemented result is a hybrid simulator connecting numerical simulation and behavioural aspects coming from real data. This paper is focused on two points: firstly, we introduce how a final user (the traffic regulator) instantiates and assembles components so as to model a city and its urban traffic network; secondly, we present the use of Dempster-Shafer theory in the context of discrete choice modelling. Our approach manipulates input variables in order to test realistic representations of behaviours of agent categories in a decision-making process. The traffic modelling is based on a questionnaire elaborated from standard arrays of Taguchi. The significant variables and interactions are determined with the analysis of variance which suggests a reduced model describing the behaviour of a particular social category. The belief theory is used to take into account the doubt of some respondents as well as for the preferences redistribution if the number of alternatives changes. The effects of external traffic conditions are also quantified to choose a 'robust' alternative and to use the agents' memory.

1. INTRODUCTION

The search for realistic representations of behaviour in travel demand modelling is explained by the need to assess impacts of strategies of transportation planners and engineers. Over the past few years, simulation

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has assumed a predominant role within the framework of an activity-based approach because of its flexibility, its realism and strong behavioural foundations. But it is well-known that, in order to capture intelligence of human groups, it is necessary to have interactions between mental simulations and real world. In this context of travellers' behaviour study, researchers use many approaches where individual or traveller groups are the main unit. One good method to achieve this goal is the use of multi-agent simulation; there are few operational tools, e.g. ALBATROSS (Arentze, Hofman, et al. 2000), TRANSIMS (Raney and Nagel, 2004) and FAMOS (Pendyala, Kitamura, et al., 2005). The chain of activities included in a diary is the result of an individual decision process and in some cases it integrates a negotiation step with a partner. Discrete choice utility-maximizing models often used do not always succeed in reflecting true behavioural mechanisms underlying travel decisions (Pozsgay and Bhat, 2001). The second approach emphasizes the need for rule-based computational process models. Some of these models use a set of decision trees. Recent works show that Bayesian networks are particularly valuable to capture the multidimensional nature of complex decisions (Verhoeven, Arentze, et al. 2005).

This paper is structured as follows. Firstly, an overview of particularities of our multimodal urban traffic simulator is given as well as the multi-agent architecture and the principle of our adaptive ground model in order to be able to build a three-Dimensional city. Secondly we propose an approach for decision-making process linking the belief theory and particular questionnaire for testing quantitative or qualitative input variables; our approach is shown in the case of behaviours of driver agents choosing a transport mode. The last section presents the interest of our approach to design scenarios used by our simulator for various categories of people who may change preferences according to different external conditions.

2. PARTICULARITIES OF OUR SIMULATOR

Somebody in charge of traffic regulation must use our simulator for two purposes: as a simulation decision aid-making tool or as an electronic game. For that, he must have the possibility to manipulate a great number of input variables (socio-demographic, economic, urban, transport…) in order to test scenarios in the short or long term.

We want to give a spatial representation which reflects the real environment of the user. The basic idea is to consider that an urban traffic network can be modelled using square blocks. Each block having predefined properties, infrastructure, and functioning rules represents a part of the studied system. The user can instantiate and assemble components in order to model a city and its urban traffic network, see *Figure 1*.

For a realistic representation of the travel demand, the basic idea is to develop a framework to test easily many input variables effects as well as to predict the behaviour of travellers for a given scenario. For that, a great number of categories of traveller agents must be defined in order to propose a 'mean' behaviour based on a similar perception of effects of variable changes. The classification is based on socio-demographic characteristics as age, gender, employment status, presence of a physical handicap.

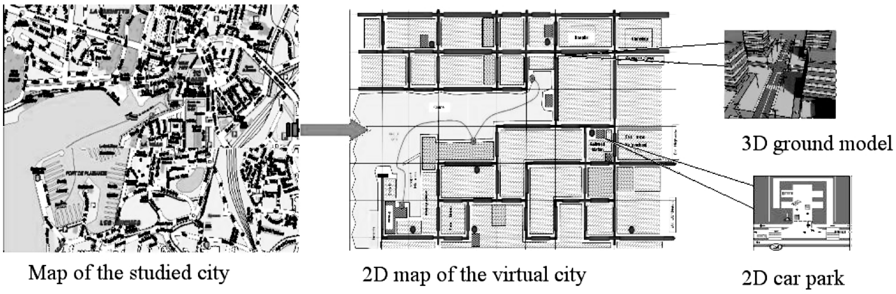

Figure 1. Global view of spatial representation of a city.

Another aspect is that behaviour models must be able to illustrate the evolution of agent preferences or of transportation system characteristics. In the short time, the memory effect of agents must be taken into account (e.g. the predicted result for the trip duration was modified by external traffic conditions). In the long term, new alternatives must be tested for a realistic representation of the decision-making process; that means the classification of choices per agent must be done by taking into account effects of a new alternative independently of the others.

2.1 Simulator Architecture

We provide a framework to build easily the model of a system existing or future (Augeraud, Boussier, et al. 2005). This framework is depicted in *Figure 2*. The multi-agent system (MAS) is divided in three subsystems. The first one concerns the urban traffic simulation. Agents participate to the activity of the city (vehicles, bicycles, pedestrians…). The second one concerns information system service behaviours. In this part, agents model employees and computing system of the information system itself. Actions of agents belonging to this subsystem are the result of interactions between agents of the simulation of the Urban Traffic System. These interactions may generate new vehicles, new pedestrians… into the system. The third one is dedicated to decision aid making objective of our tool. The system produces a synthesis of the whole analysis taking into account the statistics wanted by the user and by collecting simulation data from the other subsystems.

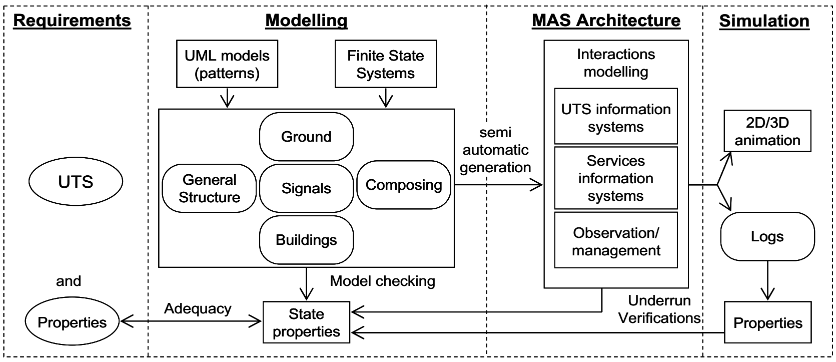

Figure 2. Our proposal for a framework.

Global behaviour of the system would emerge from the interactions between all various agents. Because behaviours of agents are formally expressed using finite states machines, structure properties and some functional properties may be verified by using model-checking techniques. UML and Coloured Petri Net formalisms are used to represent states and interrelations between agents.

2.2 Design of the Adaptive Ground Model

The used structure is based on graphs using a top-down approach and an analysis of the domain. We use a particular type of nodes called connection node to connect blocks. When blocks are assembled, connection nodes disappear because they represent nothing for the urban traffic network. This scheme is applied to nodes of all networks without type differentiation (pedestrian, vehicle…). Blocks are built to be linked in a seamless way.

Figure 3-a shows that graphs are placed on a square area. Graphs are built by taking into account the infrastructure and the various entities.

There are two types of areas: the area which can be used by agents, and the area only displaying scenery. So cars and pedestrians can only move on their dedicated network of the system. A space is reserved for buildings. They are placed to model real social or economical attractive locations in the city. The associated 3D model is presented in *Figure 3-b*.

In our tool, we can change the buildings and we can decide if a node is usable or not.

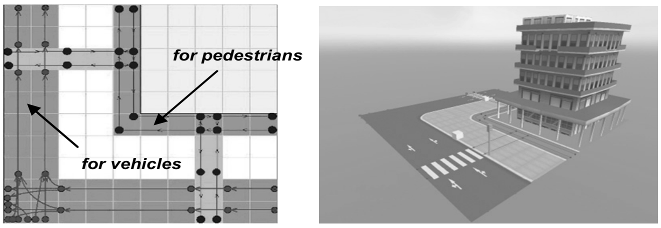

Figure 3. a) A part of the cross graph model. b) Three-Dimensional representation.

Figure 4 shows the model of common crossing which is composed of four blocks. We can see the corresponding 3D representation.

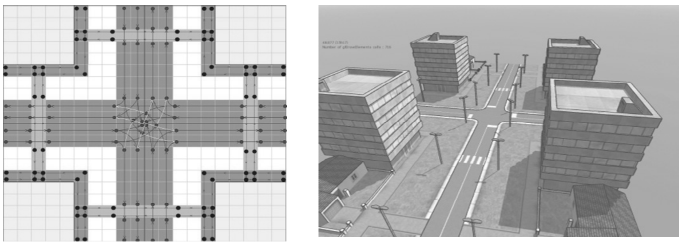

Figure 4. The cross graph model and the 3D representation.

This realism is exploited in the short run within the framework of a video game and will lead to the development of a decision-making tool aid out of urban matter. We are designing a technique of optimization allowing the breaking up of the graphic elements into many independent sub elements. With this opening, we will be able to set up a system of procedural construction of the buildings, to adapt precisely their forms and their functions to space available (Parish and Müller, 2001). With current techniques, it is not possible to describe easily buildings on great surfaces. We will base our works on techniques of image processing to define one description language of such buildings. From the viewpoint of buildings and infrastructures, one key point is the estimation of their cost and their environmental impact on urban traffic.

The design of a system includes the following ordered steps:

- Assembling two blocks, by means of the graphical editor, creates a new bigger block. At the same time an abstract view of the system is built by means of pedestrian and vehicle networks; the result is a directed graph. A data structure is bounded to each vertex. It carries all the information required by a vehicle about its environment.
- The signs and vertical signals, such as traffic light or road panels are edited. The graphical editor produces 3D graphical representation from templates and also produces information for the MAS. This

information is twofold. First it consists in an abstract representation of the roadmap. And it consists for each agent in all data needed by MAS and also by the behaviour editor.

- Scenery elements can be placed on dedicated areas on each block. Such elements can be bank, theatre, hospital, town hall, and supermarket… As the centroïds are defined in the 4-stage model, social attractiveness and economic attractiveness can be given to those elements.
- The MAS is designed and, in input, uses data provided during the second step. Then, agents can be set either as common agents or as agents' generators. They can be dragged and dropped on the previously edited ground.

3. BEHAVIOURAL MODEL

The advantage of the agent-based approach is that, at least in principle, the behaviour of each individual entity can be represented in a realistic way. Nevertheless, there are limits to this performance: the knowledge about human behaviour must be performed and the necessary input data available.

3.1 Approach to Design the Behavioural Model

There are several problems to solve: how to introduce a great set of input variables without decreasing simulator performances? How to quantify the effect of qualitative variables? For a studied city, how to take into account the effects of its particularities on the perception of some variables (accessibility, congestion …)? Interesting works (Bos, van der Heijden, et al. 2005) also added qualitative variables to describe some aspects of the travel demand. There are based on results of specific questionnaire using orthogonal tables (Louviere, 1987) which generally give interesting results for the classification of main variables in a decision making process. However, how to take into account uncertain responses given by some respondents? What are agent behaviours in a dynamic framework: travel conditions change, an alternative (choice) appears or disappears? How is the memory effect used?

By coupling two methods, we answer to the above questions. Taguchi's method (called Design Of Experiments) (Taguchi, 1987) is typically used in the optimization of industrial process for understanding the relationship between process parameters and the desired performance characteristic. Dempster-Shafer theory (called Belief theory) (Shafer, 1976) provides an approach efficient to take into account doubt or ignorance during a decision-making process.

The reliability of this approach is based on the possibility offered to regulator to define finely social categories of citizens. Because of their homogeneity, we consider that a 'mean' behaviour can be modelled for all decision-making process. The study is done for one particular category (male, about 22 years old, students without physical handicap). The approach is illustrated for analysis of transport mode choice (on foot, bicycle, car and bus).

Many models of transport mode choice have been developed in which the mode choice is typically conceptualized as a function of characteristics of alternative travel modes and a set of individual and household characteristics; see (Hess, Polak, et al., 2005) for a good overview. Recently, techniques of Artificial Intelligence were also used for the decision making process: see (Postorino and Versaci, 2002) about Fuzzy Logic and (Verhoeven, Arentze, et al., 2005) about Bayesian Decision Networks.

In our approach, the Taguchi's method and the Belief theory are conjointly used like *Figure 5* shows it:

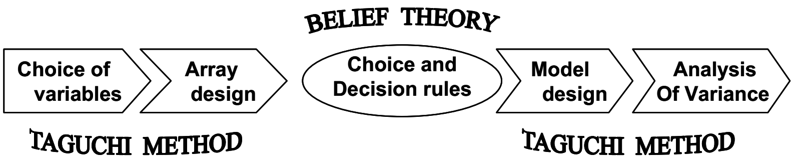

Figure 5. Steps of the decision-making process with the methods.

3.1.1 Choice of Variables

'*Input variables*' are independent parameters under study which can be controlled. The '*level*' of input variable refers to the number of values (states) of the variable to be analysed. The paper aim being the description of our methodology and not the proposal of a model for modal choice, we did not focus our reflection about selection of input variables (5 variables with 2 levels). The characteristic 'quality' to be optimized is the output or the '*response*' variable to be observed. After preliminary tests, we concluded a set with more than 6 linguistic variables is laborious to be manipulated by the respondents of the questionnaire. Input variables, corresponding levels, responses and corresponding evaluations are presented in *Figure 6*.

Input variables	level 1	level 2
Weather	favourable	not favourable
Risk of incidents	low	great
Distance	short	high
Conditions to travel	with parcel	without parcel
Timing	to be in hurry	not to be in …

possible Responses

Linguistic evaluation	Crisp value
very rarely	1
sometimes	2
frequently	3
very frequently	4

Figure 6. Input variables and responses.

3.1.2 Design of Questionnaire

The Taguchi's method uses fractional factorial designs which are a subset of full factorial designs (using fewer runs, generally lower than 20). The selected array is the $L_8(2)^7$ array (matrix). Varying several design variables simultaneously may have interactive effects on the studied response; when the effect of one variable depends on the level of another one, an interaction exists. The linear graph is used to affect columns (see *Figure 7*). For example, the input variable A is put in the first column; the third column can be used for the parameter C or for the interaction between A and B.

	Input variables and Interactions						
Test	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

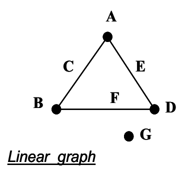

Figure 7. $L_8(2)^7$ array and one of its linear graph for affectation of columns.

Figure 8 presents two scenarios and its responses corresponding to two alternatives for transport mode (bicycle and car). For this example, only 5 columns (A, B, C, D, G) are affected to input variables; the two other columns can be used to compute (see the linear graph) the effects of two interactions: 'Weather'- 'Conditions to travel' (column E) and 'Conditions to travel'- 'Risk of incidents' (column F). People must give a response for each transport mode (linguistic evaluation) and for all scenarios.

For a dynamic analysis (number of choices which changes), deliberately no classification of transport modes is required to respondents for a given scenario. We proposed only 4 responses for each mode. Somebody can give the same evaluation for different modes. For our analysis 1,472 responses were treated.

	Input variables					Answer of a respondent	
Scenario	**Weather** (A)	**Risk of incidents** (B)	**Distance** (C)	**Conditions to travel** (D)	**Timing** (G)	**Bicycle =V**	**Car =C**
1	favourable	low	near	with parcel	to be in hurry	sometimes	sometimes
:	….	….	….	….	….	….	….
6	not favourable	low	far	without parcel	to be in hurry	very rarely	frequently
:	….	….	….	….	….	….	….

Figure 8. Input variables and responses for two alternatives (bicycle and car).

3.1.3 Classification of Given Answers about Choices

All scenarios are concerned by a non-negligible percentage of doubt or ignorance. The classification is done with the Dempster-Shafer theory.

Let us take $\Theta = \{ H_1, H_2, H_3, H_4 \}$ to be the set of hypothesis which make up the frame of discernment with H_i potential alternatives.

In our case, the frame of discernment is: $\Theta = \{\text{on foot, bicycle, bus, car}\}$.

The assigned probability $m_\Theta(A)$ measures the belief exactly assigned to A and represents how strongly the evidence supports A. A basic probability assignment is a function which is called a mass function and satisfies:

$$2^\Theta = \{\Phi, H_1, \ldots H_1 \cup H_2, \ldots \Theta\};\ m_\Theta : 2^\Theta \to [0,1];\ m_\Theta(\Phi) = 0;\ \sum_{A \subseteq \Theta} m_\Theta(A) = 1$$

where 2^Θ is the power set of Θ; Φ is the null set; A is any subset of Θ, $m_\Theta(\Theta)$ is the degree of ignorance.

For each respondent and for each scenario, the normality assumption can be recovered by dividing each mass by a normalisation coefficient. For a respondent who answered ‘frequently for on foot’, ‘sometimes for bicycle’, ‘very rarely for bus’ and ‘frequently for car’, the belief masses would be:

m(on foot, car) = 0.66 ;   m(bus) = 0.11 ;   m(bicycle) = 0.22.

The discounting operation consists in taking into account the reliability of source (respondent) R_j (α^{R_j}); the discounted belief function is:

$$\forall A \neq \Theta,\ m_\Theta^{R_j\,\alpha}(A) = \alpha^{R_j} \cdot m_\Theta^{R_j}(A)\ ; \quad m_\Theta^{R_j\,\alpha}(\Theta) = \left(1 - \alpha^{R_j}\right) + \alpha^{R_j} \cdot m_\Theta^{R_j}(\Theta)$$

For us, all beliefs are reduced by the factor α computed with a linear function: if the same evaluation is given for the 4 alternatives, α=0.25; for 3 alternatives, α=0.5; for 2 alternatives, α=0.75 and α=1 when no redundancy.

After the successive application of the orthogonal addition (Janez, 1996), a single belief function is obtained for all focal elements and subsets of the discernment framework.

After that, for each scenario, the mass of the subsets which are not singletons is redistributed by the pignistic transformation

$$\forall\, H_i \in \Theta\,,\quad P_\Theta\left(H_i\right) = \sum_{\substack{A \in 2^\Theta \\ H_i \subset A}} \frac{1}{|A|}\, m_\Theta(A) \tag{1}$$

where $P_\Theta(H_i)$ is pignistic probability for H_i; $|A|$ is the cardinality of A.

Figure 9 presents an example for a scenario and the results after pignistic transformation. In order to give a global evaluation for each scenario j and each mode k, a score is defined according to *Equation 2*:

$$S_j^k = \lambda \cdot P_\Theta{}^j\left(H_k\right) \tag{2}$$

where λ is an arbitrary crisp value and $P_\Theta^j(H_k)$ is the pignistic probability of k mode belonging to the scenario j.

	singleton hypothesis				sub-set coupling hypothesis										ignorance
	P	**V**	**B**	**C**	**P☎V**	**P☎B**	**P☎C**	**V☎B**	**V☎C**	**B☎C**	**P☎V☎B**	**P☎V☎C**	**P☎B☎C**	**V☎B☎C**	**P☎V☎B☎C**
survey results	17	11.1	12.4	3.9	14.8	7.5	0	14.8	0	0	14.8	0	0	0	3.7
pignistic transform	33	34.3	28.4	4.8											

Figure 9. Mass distribution and pignistic probabilities for transport alternatives (in percentages).

For the studied scenarios it is possible to give a classification of transport modes. But the scores are only computed for 8 configurations corresponding to the $L_8(2)^7$ array. From here, we are going to see the how to assign the scores to the 24 other scenarios.

3.1.4 Model Design

One of our hypothesis being the homogeneity of a category, we search a 'mean' behaviour which is representative for the studied category. The basic idea is the superposition principle; we adopted an additive model based on Analysis of Means (ANOM) proposed by Vigier (Vigier, 1988).

$$S = S_{mean} + (a_1 \quad a_2)A + (b_1 \quad b_2)B + ... + \begin{pmatrix} a_1b_1 & a_1b_2 \\ a_2b_1 & a_2b_2 \end{pmatrix} AB + ... + \varepsilon \tag{3}$$

where S_{mean} is the mean value of all responses; a_i are matrix elements representing the mean effect of variable *A* at level *i* and a_ib_j are matrix elements for the mean effect of the interaction *AB* when *A* is at level *i* and *B* at level *j*:

$$a_i = S_{mean}(A_i) - S_{mean} \; ; \quad a_ib_j = S_{mean}(A_i, B_j) - S_{mean} - a_i - b_j \tag{4}$$

with $S_{mean}(A_i)$ is the mean value of responses of the scenarios where *A* is at level *i*; $S_{mean}\,(A_i, B_i)$ is the mean value of responses when *A* is at level *i* and *B* at level *j*.

For example, the variable *A* is at level *1*, the variable *B* is at level *2* and …, then the score S is computed as follows:

$$S = S_{mean} + a_1 + b_2 + a_1b_2 + ...$$

A numerical application is applied from *Equation 3* to produce the determining part of the model giving the score associated to the bicycle use:

$$S_b = 2.3 + (0.081 - 0.081)A + (0.022 - 0.022)B + (0.345 - 0.345)C + (-0.085 \;\; 0.085)D + (0.059 - 0.059)G + \begin{pmatrix} -0.02 & 0.02 \\ 0.02 & -0.02 \end{pmatrix} AD + \begin{pmatrix} 0.04 & -0.04 \\ -0.04 & 0.04 \end{pmatrix} BD$$

3.1.5 ANalysis Of VAriance (ANOVA)

Significant variables and interactions are classified by comparing the variance of the mean effects of input variables V_A and interactions V_{AB} with the residual variance V_r.

for an input variable: $$V_A = \frac{m}{n_A(n_A - 1)} \sum_i a_i^2 \tag{5}$$

for an interaction: $$V_{AB} = \frac{m}{n_A\, n_B\, (n_A - 1)(n_B - 1)} \sum_i \sum_j (a_i\, b_j)^2 \tag{6}$$

for the residual: $$V_r = \frac{1}{\gamma_r} \sum_i \sum_j \left(S_{ij_{resp}} - S_{ij_{th}}\right)^2 \tag{7}$$

with *m*: number of tests; n_A, n_B: number of levels for the variables; a_i^2, $(a_ib_j)^2$: mean effects of variables and interactions; γ_r: residual degree of liberty; S_{ijresp}, S_{ijth} : the measured and theoretical value of the response.

The Fischer-Snedecor test allows to obtain a reduced model and to assess the score. In the case of bicycle use, the significant input variables are the distance, the travel conditions and the weather:

$$S_b = 2.3 + (0.081 \quad -0.081)A + (0.345 \quad -0.345)C + (-0.085 \quad 0.085)D$$

Because of the homogeneity of the category hypothesis, we claim that the same model can be used to estimated 2^5 scenarios. Similar reduced models are obtained for the three other alternatives (bus, car, on foot). E.g. for the car, the significant input variables are: distance, risk of incidents, weather.

4. INTEREST OF OUR APPROACH TO DESIGN SCENARIOS FOR THE SIMULATOR

The same approach can be used for the choice of the destination or the car park. According to the perception that a category of users has for the traffic characteristics of their city, it is possible to obtain different behavioural models for different cities. For the same city, different categories can have a different behaviour. See our work about car park choice done by two individual categories (Boussier, Estraillier, et al., 2005).

4.1 Behavioural model per defined categories

The regulator defines only characteristics of agent categories (age, gender, employment status, presence of a physical handicap) and the input variables to be tested for a step of traffic module (car park choice, destination or mode choice). The Taguchi's tables and their corresponding linear graphs are stored in a library; an orthogonal array is suggested according to the number of variables to be studied. Interactions are also suggested to refine the model. After the collection of questionnaire results, the regulator distributes the answers according to each category.

Scores are computed and the number of information is reduced with the analysis of variance for each category. That means that even if initially the number of input variables was great, the simulator performance will not be affected by the data number needed by agents for the decision-making processes. If an agent must do a choice between transport modes, it is possible to compute scores and to classify alternatives according to the highest score among all scenarios. Initially, agents of the same category have the same behavioural model used to define their behaviour for all scenarios; the differences between agents' behaviours result from individual diaries and constraints (married or not, departure time, traffic conditions, and memory effect).

4.2 Redistribution of Preferences

The inconvenient of classical models is the difficulty to reclassify alternatives in a dynamic context. In our approach, the classification takes into account added or eliminated alternatives.

If one of alternatives is not possible (e.g. the student has not a private car), we can use the conditioning law of Dempster which consists in no taking into account the mass of the focal elements (singletons) which become impossible. The mass is transferred on the hypothesis which could be truths (Janez, 1996). After renormalisation, another mass distribution and a new set of pignistic probabilities can be computed. For example, let us consider in *Figure 9* the case where the bus is an impossible alternative. The redistribution of 'preferences' is given in *Table 1* after the conditioning.

Table 1. New mass distribution using conditioning law of Dempster and new pignistic probability without the 'bus' alternative.

	F	V	C	F∪V	F∪C	V∪C	F∪V∪C
Initial survey results	28.0	29.6	4.4	33.8	0.0	0.0	4.2
New pignistic transform	46.3	47.9	5.8	-	-	-	-

We have also tested the possibility offered to a regulator to redistribute preferences using the conditioning law of resemblances. In our example, one chosen criterion could be the pollutant mode (car, bus) or not (on foot, bicycle). In the absence of the 'bus' alternative, all preferences (singletons and subsets including bus) are distributed on the 'car' alternative.

It is also possible to add a new alternative (e.g. tramway); the respondents complete the questionnaire concerning this new hypothesis. The new discernment framework is: $\Theta' = \{on\ foot, bicycle, bus, car, tramway\}$. A new mass distribution with corresponding scores is established for each scenario and each mode after the pignistic transformation.

4.3 Effects of External Conditions

It is accepted that the result of choice previously done can be affected by 'parasites' or external conditions as accessibility, safety, traffic information which are independent of input variables. A jointly study of the effects of input variables and external conditions must be done. For that, we used a combination between two tables; see the example in *Figure 10*. In this table, the score 1 corresponds to all scenarios evaluated for a good accessibility, a good safety during the travel and with real time information. The scores are assessed as previously shown (mass distribution, pignistic transformation, model elaboration steps).

For a bicycle, a coupled model symbolically can be presented as follows:

$$S_b = S_{bmean} + \underbrace{A + B + C + D + G + AD + BD}_{array\ L_8} + \underbrace{H + I + J}_{array\ L_4}$$

where S_{bmean} is the general average of all 32 responses. The matrix elements of input variables and interactions are computed with *Equation 3* and *Equation 4* where the mean value of a score for a scenario is the average between the scores (computed on lines). For the elements of *H, I, J*, the average value is computed in columns.

$L_8(2)^7$ — *Input variables* — $L_4(2)^3$ — *Extend conditions*

						Information (J)	yes	no	no	yes
						Road safety (I)	good	bad	good	bad
						Accessibility (H)	good	good	bad	bad
Scenario	Weather (A)	Risk of incidents (B)	Distance (C)	Conditions to travel (D)	Timing (G)	Score	1	2	3	4
1	favourable	low	short	with parcel	in hurry		2.8	2.1	2.2	1.9
:	....	....	....	....	....		....	....	....	....
6	not favourable	low	great	without parcel	in hurry		1.6	1.4	1.2	1.3
:	....	....	....	....	....		....	....	....	....

Figure 10. Double arrays for the bicycle evaluation.

Then, for a homogeneous category of agents it is possible to compute a score for the 256 (=32*8) scenarios for each transport mode. For greater configurations, questionnaires would be laborious.

There are two interesting uses for this coupling.

Firstly, let us suppose that an agent wants to perform a scenario where the mean score associated to the bicycle is nearly the same as for the car (a limit value may be established by the regulator). We claim that the agent will choose the most robust (cautious) solution, i.e. the transport mode for which the travel is not strongly affected by external conditions. The most robust solution is obtained by computing the ratio signal/noise (*S/N)* for the *j* scenario and the *k* mode (Taguchi, 1987).

$$\left(\frac{S}{N}\right)_j^k = 20log\left(\frac{S_{mean\,j}^{\ k}}{\sigma_j^k}\right) \tag{8}$$

where $S_{meanj}^{\ k}$: average of scores for scenario *j* and for the mode k_j; σ^k: square of variance of the scores attributed for the scenario *j* and the mode *k*.

The chosen mode for the scenario *j* corresponds to the maximum of *S/N.* Of course, only the part of the model corresponding to L_8 array is taken into account. If the scenario is not included in the array $L_8(2)^7$, it is possible to design models of *S/N* for each transport mode (*Equation 3* and *Equation 4*).

Secondly, let us imagine that, for a scenario with input variables defined beforehand, the choice of transport mode is done. The travel duration is computed for the scenario corresponding to the best external conditions in order to minimize the trip duration. This case is the first vertical column of the L_4 array, i.e. a good accessibility, a good safety during the travel and a system giving information. While the agent travels, traffic conditions change (e.g. congestion, real time information …); so, the consequence is the increase of trip duration. An agent will use this knowledge as follows. The next time for this scenario, the taken score will be that of the configuration of external conditions corresponding to the last trip of this scenario. Another classification of modes could be suggested.

5. CONCLUSIONS AND PERSPECTIVES

The conceptual framework underlying a forthcoming multimodal simulator based on multi-agent technology has just been presented. Our aim is to provide a framework in which people in charge of traffic regulation will only have to manipulate existing network components in order to model their system. To help decision maker to build his system, graphical interfaces are offered in our framework to design a block and to assemble blocks together. The realistic representation of travellers' behaviour is modelled using results from questionnaires made with the Taguchi's method. An example illustrates the choice of transport means done by students, where effects of quantitative and qualitative variables are tested. The belief theory is used for a preliminary distribution of preferences for transport modes; the answers of all respondents are taken into account even if there is doubt or ignorance in their decision process. Using the Analysis of Variance, significant variables are defined and, in hypothesis of a homogenous category, a reduced model illustrating a 'mean' behaviour is designed for all scenarios. We showed how the belief theory is conjointly used to redistribute preferences if the number of alternatives changes. The effect of external variables as the 'accessibility', 'safety', 'real-time information' is also discussed during the Taguchi's approach use. So, we proposed a way to use the memory effect for an agent in order to modify its initial choice.

A future work will be to replace the crisp values, used for the score computation, by fuzzy variables in order to better quantify the uncertain character of some answers to the questionnaire. The choice of path will be differently solved because the number of alternatives is too great. Our approach becomes relatively 'greedy' in computing times. For that, we will use a classification technique based on combined supervised learning for system diagnosis using Dempster-Shafer theory.

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