Optimization of Choice Modelling in Complex Urban Contexts

Applications in planning for sustainable development

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Abstract: This paper focuses on the capabilities of choice models in assisting planners in the development of transport policies and interventions for strategic transport planning for urban systems. Models are looked at as part of a decision support system for the development of transport measures for sustainable mobility. The use of participation is looked at as a tool for the understanding of the real needs in terms of mobility in the complex contemporary society and for the construction of the future transport scenarios and transport alternatives.

1. INTRODUCTION

1.1 Decision processes in transport planning

This paper faces the possible enhancement of the available tools for planners for the definition of transport solutions in modern urban areas. In particular, the focus is stressed on the optimisation of the instruments that can support the decision processes for transport planning, which are specifically designed for complex modern urban areas.

Contemporary urban areas are day-by-day becoming more complex; in such areas, new activities are being established and are replacing traditional ones. Innovative ways for the work organisation are dramatically changing the internal organisation of good production, as well as timetables and the geographical distribution of workers. In these phenomena, the role played by technological solutions is predominant. Information and Communication

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Technologies are quickly changing the organisation of many economic activities; they are stressing the flexibility of the economic systems, proposing new forms of business organisation. Due to this trend, in the most developed countries (and more recently in developing countries, too), we are witnessing the replacement of many physical transport flows with communication flows, as well as the generation of new flows, not always easy to estimate.

In such urban contexts, the role of planners is becoming comparably more complex. In spite of the availability of more powerful tools, associated to the implementation and widespread of technological devices with increased computational capabilities, urban and regional areas often show planning problems and conflicts, of difficult resolution. Public authorities have to face this improved economic organisation, capturing the needs arising from the society and supporting the economic growth of the area; at the same time they must succeed in providing acceptable solutions to support the economic development, not exceeding the financial restrictions for public interventions, and facing the environmental concerns that every intervention on the territory involves.

1.2 Towards the adoption of optimal choices in planning

What is an *optimal choice*? It is not easy to define if an optimal choice in a process of planning can be found. Planning processes usually imply the analysis of many possible intervention on the territorial system. This is carried out on the basis of many attributes and elements which are selected as relevant in the process of evaluation of the alternatives.

Several methods were developed for the evaluation of the possible actions to undertake. Evaluation methods can be useful in the selection of a the actions and policies to pursue. Several evaluation methods are nowadays available; they can be divided into several main groups, depending on the number of alternatives they can take into consideration and the criteria they use in the valuation of the alternatives (Korhonen *et al.*, 1993). Some of these approaches admit the use of fuzzy measures for the evaluation of the alternatives and some other do not do it (Munda, 1995). Such methods cannot define the *optimum* for a specific problem of planning; but they are useful in generating an order of preferences between the available alternatives, with the related argumentation to support it, for the selection of the actions, policies and interventions to adopt.

Moreover, the selection between different alternatives in planning can be carried out with the use of Mathematical programming models, too. This kind of models, such as Multi-Attitude Decision Making, Multi-Attribute Utility theory, etc., can be usefully applied in decision making for the

evaluation of different projects, considering multiple objectives. The main limitation to the use of such methods is given by the difficulty in defining crisp input data to obtain meaningful results. For the reason, such approaches are not very often used in the selection for interventions in transport fields, in which usually a high level of uncertainty is associated to the available alternatives.

In transport sectors, compensatory models have been applied for the selection of policies and projects, with the aim of evaluating the compensatory effects of the projects in satisfying the different objectives and allowing tradeoffs between the different objective values. Also for these methods, some approaches based on the use of fuzzy set theory have been proposed (Avineri *et al*., 2000).

1.3 Objectives for sustainability in strategic planning

Planning for sustainable development is one of the main goal to be assessed in the definition of the interventions to be carried out in complex urban contexts. To pursue the objective of a sustainable development, a great importance is attributed to the definition and widespread of the best practices to all sectors of the public interventions, from the selection of the projects and the construction of new infrastructures to the adoption of new laws and regulations for economic activities to be set up.

In this field, the definition of correct measures to address the development of the transport systems is extremely important. Contemporary society shows great flexibility and high capabilities to evolve its characteristics, involving a relevant amount of consequences on people quality of life. Transport considerations play a relevant role in designing the shape and the organisation of cities and regions; anyway, current trends in transport look like not sustainable in long terms (Button and Nijkamp, 1997).

In this framework, planners are called to implement methodologies for strategic planning, in order to design the fundamental interventions for the future development of regions and cities, with the perspective of a more sustainable development of urban activities, in terms of natural resources and energy consumption, land use, wilderness area reduction, air and water pollution. With this aim, the objective of the strategic planning is focused on the definition of the best interventions to promote forms of sustainable mobility, in relation to the local characteristics of the territorial systems.

In this work, the methodologies for the definition of the possible alternatives for sustainable mobility are discussed, with reference to the construction of future scenarios for transport systems in urban areas. The research focuses on the development of policies for sustainable transport planning, which correspond to people mobility needs, as they arises from

participatory processes, in order to get the best response to the interventions planned. To do this, a possible approach is proposed: alternatives are designed in strictly relation to the proper needs arising from the population, as well as their impacts among the population are evaluated through the application of the tools of choice modelling.

2. CHOICE MODELS FOR TRANSPORT SYSTEMS

2.1 The estimation of travellers' response to transport alternatives

Strategic planning for sustainable mobility in urban areas requires planners to investigate the best alternatives among all the available for the implementation of transport measures, policies and solutions to enhance the objectives of sustainability of transport in urban areas. Anyway, in the definition of the transport policies and measures to adopt, it is highly important to evaluate the response these transport solutions will obtain among transport system users and the local population of the area involved in the planning processes. This part of the planning process requires great attention and, indeed, several methodologies have been developed in order to better describe the choice behaviour of travellers when choosing the alternative for performing travel activities. The optimisation of such methodologies represents an important topic for research activities in transport fields; this is in part due to the need for better methodologies for the understanding of choice behaviour and decision processes of travellers: in fact, many times it is possible to find a considerable gap between the observed choice behaviour and the assumption which guide transport policies, e.g. for the mitigation of congestion in urban areas. And this can often lead to the failure of such transport policies, which are not able to satisfy the objectives for which it was designed (Salomon and Mokhtarian, 1997).

2.2 Behavioural models in literature

Most part of behavioural approaches to predict human choices derives from econometric studies. They were at first developed in order to predict choice behaviour in all contexts in which the alternatives are proposed to decision-makers in terms of monetary outcomes.

In such approaches, some basic assumptions are introduced to describe human behaviour. First of all, in many choice processes, the total number of feasible alternatives (universal set) is quite high. Realistically, the decision-

maker can consider only a limited number (choice set) of these, also owing to the time and cost involved in seeking information about all alternatives. In the evaluation of the alternatives that belong to the choice set, the decision-maker is assumed to show a rational behaviour: he/she tries to maximise his/her personal utility (as a *homo oeconomicus*) choosing the option that gives him/her the greatest benefits with minimal costs.

The best-known behavioural theories are based on this hypothesis, such as the Expected Utility Theory (Von Neumann and Morgenstern, 1944). According to this theory, choices are based on an Expected Utility value that is associated to each choice option. The Expected Utility is simply defined in a probabilistic way:

$$EU = \Sigma_i p_i u(x_i).$$

The EU is a function of the utilities $u(x_i)$ associated to the possible outcomes x_i of the option and of the probabilities p_i associated to those outcomes; decision-makers are assumed to select the alternative with the maximum EU value. Due to the simplicity of this probabilistic approach, Expected Utility Theory is world-wide widespread as an easy way to predict choice behaviour with a quite good degree of approximation.

2.2.1 Random Utility Models and travellers' behaviour

Choice predictions given by the Random Utility Theory (Ben Akiva and Lerman, 1985), commonly used in transportation planning, are based on the hypothesis of rational behaviour, too. This theory asserts that the utility U_j^i associated by the user i to the option j is a random variable, given by the sum of a systematic utility V_j^i, which is a linear function of the attribute values, and of a random error term ε_j^i :

$$U_j^i = V_j^i + \varepsilon_j .$$

Several sources of randomness of utility lead to the introduction of the random residual ε_j^i such as (Cascetta, 2001): measurement errors in evaluating the attributes involved in systematic utility, unobserved attributes difficult to evaluate, taste variation among different users or errors in the evaluation of the attributes by the decision-maker.

The probability distribution associated to the random term of utility defines the different behavioural models belonging to the group of the Random Utility Models. For these models, the probability of choosing an option j is equal to the probability that the perceived utility of the option j is higher than those of all the other options belonging to the choice set.

2.3 The implementation of behavioural models

Choice models based on the RUT have been commonly used in transport planning to predict travellers' behaviour. However, the rising complexity of transportation systems and the need of well argued predictions of travellers' choices in complex contexts have pursued towards the implementation of more complex choice models. Many experimental results have highlighted how several emotional or perceptual aspects play a relevant role in choices, not respecting rational rules (Allais, 1953).

The implementation of choice models represents nowadays an important topic in research, in relation both to a more realistic estimation of human behaviour and to a more complex definition of choice conditions (choice options, bounded rationality of decision-makers, limitations in the availability of the options). A shift in choice modelling is claimed by many authors, with the aim of creating more powerful tools for the estimation of human choice processes, based on more psychological assumption of human behaviour (Kahneman and Tversky, 1979). Also fuzzy theory (Zimmermann, 1996) has been applied in order to better describe the vagueness of human behaviour under condition of uncertainty (Teodorovic, 1999). In this field, fuzzy inference shows interesting properties in describing the attributes involved in transportation choice context. In many travel choice contexts, in fact, the travel alternative attributes are not easy to be defined in a *crisp* way. The implementation of fuzzy models for predicting travel choice gave interesting results when applied to the prediction of choices in several travel choice contexts: the use of the possibility theory in the comparison of the utilities of the alternatives gave the basis to implement fuzzy choice models. In this models choice predictions are defined by the use of possibility and necessity measures (Dell'Orco and Kikuchi, 2004).

A more psychological perception of choice behaviour has led to the application of Prospect Theory (Tversky and Kahneman, 1992) for the estimation of travel demand in transportation contexts (Avineri, 2003; Binetti *et al.*, 2005). In such models, more complex utility functions were proposed in order to explicitly capture the effects of uncertainty when predicting travellers' choice.

3. PARTICIPATED MODELLING FOR TRANSPORT PLANNING

3.1 The objectives of the study

This paper faces the concerns related to the definition and modelling of transport interventions and policies in urban areas, in order to enhance the sustainability of transport solutions. The research moves from the consideration that many failures of transport planning processes, which get results below expectations, are due to an incorrect estimation of the effects of the planned solutions in terms of people behaviour. In other terms, such processes are not able to define the interventions that can be perceived by users as the best suited for their mobility needs. With this aim, we discuss the effects of the use of choice modelling to predict people reactions to the adoption of new transport solutions. At the same time we wonder about the capabilities of participatory approaches in implementing modelling techniques. The use of participation (both from 'experts' and from the users) is seen as a tool to reveal the correct perception of the alternative attributes among the decision-makers. It gives contributions to define measures and interventions for the construction of future sustainable scenarios for transport systems, which are expected to be the best suited on the real needs of the population.

3.2 Transport Systems in Modern Society

All over the world, urban systems are day-by-day growing in their size and complexity. At the same time we are witnessing the growth of complex nets of cities, which involve new material and nonmaterial transport flows. Assessing the rules of such growth, defining acceptable measures for the evolution of these complex systems, is universally understood as a very high-responsibility challenge (Monzon *et al.*, 2005). It must be efficient in proving consistent decisions for the future form and organisation of these urban and regional structures, at the same time facing environmental concerns on the impacts of such measures. Strategic policies represent the guidelines for the future structure of the city, whose consequences as long term actions have a crucial impact on such complex systems. They influence the future development of major infrastructures and the consequent organisation assumed by the urban system, according to the visions of the future that inspire these strategic measures.

Being the matter extremely complex and wide (if we think to all the fields of actions which are involved), the objectives of sustainable development can be summarised as to achieve:

- Social justice;
- Sustainable economies;
- Environmental sustainability.

All the three issues are equally important; in the implementation of our methodology, we focus on the development of transport solutions and interventions in urban areas that are able to meet the mobility needs of resident population as a way to meet the objective of environmental sustainability of transport systems. They are intended to minimise the impact of transport activities on the environment, ensuring the best running of the economic activities of the city and supporting an equilibrated development of the city structure. There is no doubt, indeed, that the three previously stated issues are strongly interrelated, and that the same measures that are defined with the perspective of environmental sustainability produce effects (positive or negative, depending on the case) referring to the remaining two objectives; for sure, such other effects should be considered when defining the measures and policies for strategic planning of regions and urban areas.

Transport activities are responsible of several relevant effects on the environment: in particular, they imply the consumption of non-renewable resources (as for fuel consumption), and/or the consumption of renewable resources at an excessive rate. Besides, as a consequence of the increased demand for transport and infrastructures, transport solutions are responsible of the arising of further matters, related to the further urbanization of land and the increase of the number of vehicles circulating (Greene and Wegener, 1997).

3.3 An integrated approach to transport planning

The level of sustainability of transport activities depends on several elements which are related to urban and regional systems and their transportation sub-systems: first of all, it is strictly interrelated with the structure and the organization of the territorial system, as well as it is related to the endemic characteristics of the local transport systems, and to people habits and mobility behaviour.

However, there is, to date, little evidence concerning what constitutes the "ideal" settlement structure from the point of view of sustainable transportation (Greene and Wegener, 1997). From a similar point of view, it is almost impossible to define what an optimal (or "ideal") choice is, in terms of sustainability, in the selection of the transport solutions. Anyway, in transport planning processes, it is possible to define a set of possible measures, which arise from a selection of the available options. In such decision processes, it is important, in order to define consistent measures and interventions that enhance the sustainability and environmental quality of the

system, to check the response such measures get among local people and travellers.

From these considerations, a planning approach is hereafter presented, for originating future scenarios of transport systems, which are defined to be suited on people needs towards mobility. To do this, a participatory integrated approach is defined. It implies the use of participation for a dual goal: on one hand, it aims to investigate the real perception of the characteristics of the system, in order to plan interventions for the enhancement of the information and knowledge travellers have of the transport system (soft interventions). On the other hand, the use of participatory techniques is seen as a fundamental part of the process of definition of transport alternatives and solutions, in the framework of the creation of scenarios for sustainable future transport in urban areas, which are suited on the real needs of the local population and that are able to meet the environmental concerns towards transport activities (hard interventions).

3.3.1 The role of participation in transport planning

The participated methodology that is here proposed, as summarized in *Figure n*. 1, aims at increasing the level of knowledge in planning processes about the information and confidence people have with transport system, as well as in the construction of sustainable future scenarios and alternative solutions for transport planning in urban areas.

As previously stated, choice processes look like very complex phenomena to be modelled in all research fields. Every choice is the result of a complicated knowledge-based decision process not easy to be described. Human beings make their decisions taking into account many different attributes. Some of them are quite easy to be defined and estimated, while others seem to be really obscure and cannot be easily identified or expressed in a deterministic way.

To improve the reliability of transport forecasting and the efficiency of planning processes, in recent years the use of choice modelling in transport planning has been increasingly assisted also by the use of participatory processes. Such processes have been used to directly enroll groups of stakeholders into decision processes for the definition of the priorities in transport planning, for the selection of the possible transport solutions, and for the definition of the characteristics of such solutions, as number and locations of stops, frequencies and timetables (Schiefelbusch, 2005); as well as they have been applied in order to facilitate the finding and the identification of not previously foreseen specific needs arising from the local system and from the population. Being such processes useful in the enhancement of decision-making outcomes, the internalization of a number

of additional actors and stakeholders into planning processes make decision processes in transport more complex and time consuming (Stough and Rietveld, 1997).

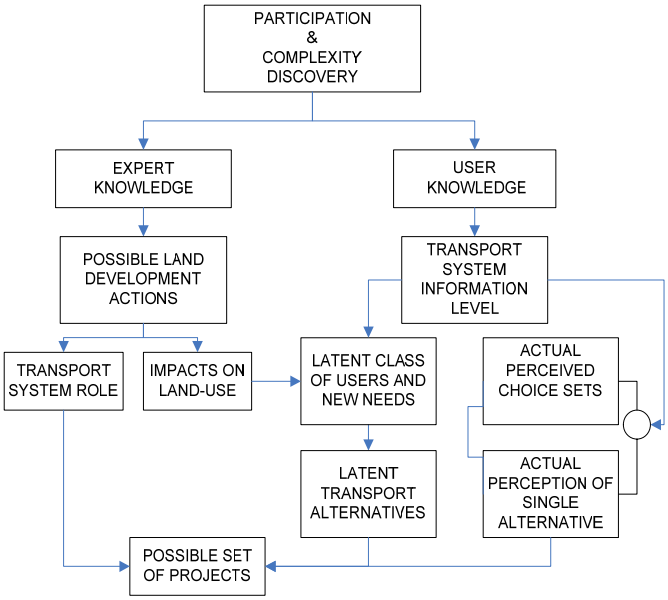

Figure 1. Participatory scheme for transport planning processes.

The proposed methodology implies the enrolment of groups of stakeholders in the whole process of planning. Diffused knowledge about the system, provided both by transport system users and local population and by groups of relevant "expert" stakeholders, aids planners in detecting weaknesses and lack of efficiency in the actual transport system, as well as it is directly involved by planners in the process of scenario building for sustainable future transport.

The first step of the process consists of the definition of the groups of stakeholders to be enrolled in the participatory process. As shown in *Figure n.1*, both experts' and users' knowledge is looked for in the process. "Experts" are represented by the categories that hold a specialized knowledge about the local territorial system: they do not include only transport "specialists" (professionals and researchers). Relevant further groups of experts are formed by planners, local economists, entrepreneurs and contractors, public officials and executives. They hold a deep knowledge of the local territorial system, as well as they are aware of the local needs, and are key actors in representing and assuming decisions of great impacts on their home institutions. Expert groups are involved in focused group

meetings, where their knowledge helps planners to identify the current conditions of the system, including its weaknesses (blind spots), and to define possible actions and interventions to improve the efficiency and the environmental sustainability of the system.

Users' knowledge is required in the process as well as experts' knowledge. Local people and transport system users contribute to the development of the planning process in both phases, as they are involved in verifying the perception of the characteristics of the system (leading to the definition of *soft interventions* on the system), and they directly play a role in the decision making process, as hereafter explained (planning of *hard interventions* on the system).

3.3.2 Participatory processes for enhancing the efficiency of the systems

The first aim in using participatory techniques in the proposed approach is to verify the level of information travellers have of the real transport system, in order to test and, if necessary, define the necessary interventions for the enhancement of travellers' information. In fact, most part of the approaches for choice modelling is based on the assumption of rational behaviour of the decision-makers. This implies the hypothesis that transport system users always choose the travel option that maximise their personal utility. To do this, travellers are assumed to know all the available alternatives belonging to the *choice set*, being well informed about the attributes and characteristics of all alternatives. Anyway, as observed in many transport systems, these basic assumptions on travellers' information and behaviour are not always completely satisfied. Such a consideration greatly affects the consistency of choice modelling outcomes in several choice contexts. The differences between the real perception of the available alternatives and of their attributes and the basic assumptions of choice models can be jugded as responsible of the failure of several transport policies, which do not meet the defined goals (Salomon and Mokhtarian, 1997).

In this approach, the use of participation is seen as a useful tool to investigate the level of knowledge travellers have of the local transport system. Referring to *Figure n.2*, transport systems' users are involved in a participatory process with the aim of verifying and improving the capacity of the actual transport system. To do this, the system description and modelling is carried out with the contribution of local groups of experts.

Through the use of specialised forums or surveys, representative groups of the local population are called to show their attitude towards the available travel options, as they are known in the real local contexts. Further information about travel options is provided in steps (as well as in different

way to different groups of travellers), verifying which differences, if any, arise between choice behaviour in the "everyday" local context and choice preferences expressed after the provision of relevant information about the system.

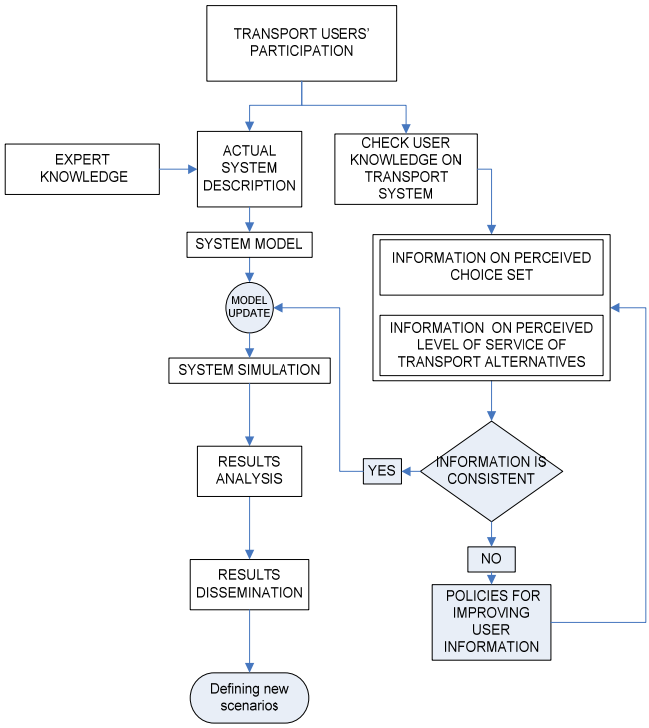

Figure 2. Experts' and users' participation to enhance information and knowledge of the transport system (soft interventions).

Throughout the process it is possible to verify the level of knowledge travellers have of the transport system; if highlighted by the process, the need for interventions to enhance the information provided to travellers can lead to the implementation of specific solutions.

Such solutions can be directed into two basic directions:

1. To improve information and knowledge on the choice set, in order to pursue the information about those travel alternatives which are not well known among users.
2. To enhance the information about the alternative attributes, with the aim of correcting the wrong perception (or *lack of knowledge*) of the alternative attributes.

The use of dedicated information systems can be introduced to enhance the level of information for travellers, following the outcomes of the process.

Such interventions can gradually lead to a partial re-equilibrium of the use of the transport systems. Besides, the use of ITS solutions to implement information systems is able to increase the capacity of the transport system (Stough and Rietveld, 1997), as well as it can contribute to increase the use of those travel alternatives that show better properties with reference to sustainability and environmental matters, but that are often underestimated by the users and consequently often underused.

3.3.3 Participatory processes for the definition of scenarios for future transport

The definition of the necessary interventions in order to improve transport solutions for a sustainable equilibrium in urban areas requires a more complex approach. It involves considerations on the current growth trends in the urban system and on the main objectives to pursue in the implementation of transport solutions and policies. In this approach, the technique of scenario building, a way to assess planning for improving transport planning processes (Shiftan *et al.*, 2003), is used in strong relation with the application of transport modelling and simulation. Experts' and users' knowledge is involved in the process for the definition of the possible scenarios for future transport solutions.

Representative groups of 'expert' people, which include, as previously noted, groups of actors with specialised knowledge of the context, are involved in the definition of the possible projects and interventions. The interactions between these actors and a wider group of stakeholders, through synchronous and asynchronous processes, lead to the definition of the possible projects to be modelled, as shown in *Figure n.3*. The participatory process allows investigating the real needs in terms of mobility of the local population. This implies an improvement of the quality of the solutions provided, which are supposed to be better suited for the specific needs arising in the local context.

Moreover, the participatory approach allows investigating the arising of new forms of unexpected mobility needs, which are not easy to be predicted in traditional modelling. In most developed countries, new forms of work organization, as the e-commerce and the telecommuting, lead the evolution of communication systems and generate relevant flows of data. The evolution of contemporary society is deeply influenced by the widespread of such technological innovations. As evident, the effects of the widespread of ICT are able to modify people mobility needs and choice behaviour (Choo *et al.*, 2005).

After the application of the modelling and simulation phase, the outcomes are checked with reference to the objectives of efficiency and

environmental sustainability, which lead the planning process. The consistency of the outcomes with the objectives is presented in an iterative way to the actors involved in the process (*Figure n.3)* in order to implement the quality of the solutions provided.

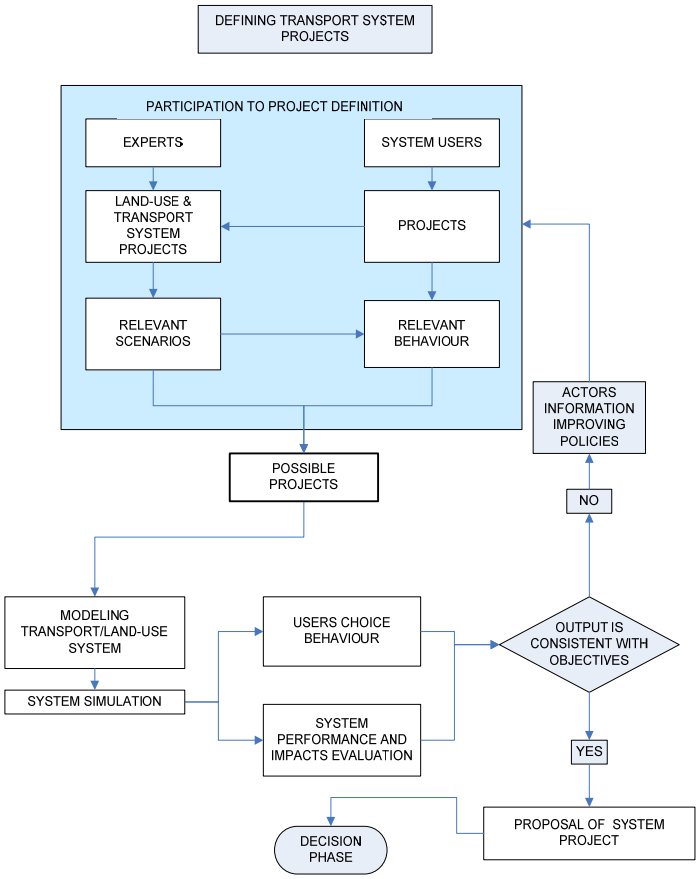

Figure 3. Scenario building for future transport solutions through participation and modelling (hard interventions).

The awareness of the results of such future scenarios leads to an implementation of the planned transport solutions. Further applications of the iterative process are expected to improve the quality of the planning process, leading to the definition of acceptable measures and solutions to be realised.

3.4 Integrated planning for complex contexts

The proposed methodology is intended to be applied to the definition of future scenarios of sustainable transportation, in the development of the strategic plan for the city of Bari, Italy. The need for a shift in travellers' behaviour, towards the adoption of more sustainable transport solutions, represents an extremely relevant goal for the development of planning processes and policies in southern Italy, where the general inadequacy of the public transport and the widespread of private transport are not able to support the development of economic activities in a perspective of sustainability, with the current settings.

Thus, the use of public participation is seen to provide an important aid for the definition of those solutions that better combine the requirements of environmental sustainability with the definition of solutions which are best suited on the real needs of the local population. In this way, applying such an approach, it is foreseen the chance to define a procedure for the definition of future transport solutions, and for the simulation, at the same time, of their impacts and of the response they get among users.

4. CONCLUSIONS

The definition of sustainable transport solutions in complex urban contexts requires, as a basic assumption for such measures to be efficient, a positive response among users to the interventions that are introduced, in terms of people travel behaviour. The proposed methodology has been developed with the aim of improving the consistency of transport solutions, defining interventions that more successfully correspond to people mobility needs, as they arises from participatory processes. Two basic objectives are faced in the methodology: on one hand, the use of participation in transport planning processes is seen as an important tool to verify the information about the transport system among the users, and to evaluate the needs of specific interventions to improve it.

On the other hand, the participatory process is seen as a tool for making new conceptions of the transport system emerge, contributing to the construction of future scenarios for transport planning. Such a process is seen to be able to detect and formalise advanced needs existent in the territory, and to contribute to the definition of the complex framework which is gradually emerging and which will increasingly have effects on the economies and on the mobility of the future society.

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