A problem-oriented categorisation of FTA-methods for transport planning

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Abstract

Purpose – *As in other socio-technical fields, future-oriented technology analysis (FTA) methods are used in transport planning to provide knowledge for decision-making. Potential effects of policy interventions should be assessed; risk and uncertainties should be reduced; unintended effects should be avoided. A variety of tools and methods of rather different character are applied, none of these methods are able to systematically reproduce a complete system; they all have their specific limits. It is not always clear, however, which method could be used for which purpose. In this paper, a transparent and problem-oriented categorisation of FTA-methods is suggested. It aims at supporting an appropriate usage of FTA-methods in planning processes.*

Design/methodology/approach – *A literature review carried out in context of the EU funded transport project OPTIC (see www.optic.toi.no) reveals that differentiating between different types of uncertainty is possible. This sets the basis for the problem-oriented categorisation of FTA methods. Key criteria for the categorisation of methods are their abilities in dealing with different types of missing knowledge.*

Findings – *Two categories are introduced which are called ''structurally open methods'' and ''structurally closed methods''. It is shown that the openness-closedness dichotomy is highly important for the type of unintended effects that can be detected with a method.*

Originality/value – *The paper has a novel approach for structuring FTA techniques that goes beyond the traditional quantitative/qualitative approach. It juxtaposes a problem typology and a typology of methods*

Keywords *FTA methods, Transport planning, Risks, Uncertainties, Unintended effects, Uncertainty management, Strategic planning*

Paper type *Conceptual paper*

1. Introduction

Transport is highly crucial to economic wealth and quality of life. At the same time, the transport system is confronted with many challenges that reduce economic vitality and quality of life, such as climate change, the emission of pollutants and noises, accidents, congestion; or of the consumption of non-renewable resources (like oil). Decisions therefore need to be taken. In general, these can be based on information gathered by using a broad range of advanced tools and methods that can be allocated to the field of Future-oriented Technology Analysis (FTA, see Scapolo and Porter (2008) for an overview). In Cagnin and Keenan (2008, p. 4) it is emphasised that FTA is based on principles such as future orientation, evidence, multiplicity of perspectives, multidisciplinary coordination but also on a strong action orientation by supporting actors in actively shaping the future.

Even if FTA-methods are applied, it can be observed, however, that in many cases transport policy and its projected outcomes are considered highly controversial. Critical attitudes towards the projected outcomes of planning processes are surely fed by experiences with previous transportation projects, which led to unintended effects that had been ''proven'' in *ex post* analyses (see TSU Oxford *et al.* 2010). For example, it is stated by Flyvbjerg *et al.*

(2003) that in most Megaprojects costs are underestimated, revenues are overestimated and the environmental effects are undervalued.

In part, at least, these unintended effects and theses controversies are rooted in the complex nature of the transport system. Transport is strongly based on a modern technology-infrastructure combination. This ''hardware'' co-evolved with what we can observe today as modern travel patterns. But it is well known that transport is a derived demand. In general, the decision to undertake a trip is motivated by very different factors drawn from all fields relevant in daily life, such as going to work, shopping, visiting family and friends etc. Also, the technology-infrastructure systems are dependent on, and enabled by, technological developments in different areas; the most important of which might be the energy sector and the development of information and communication technologies. So, transport is a socio-technical system that is influenced by, and interwoven with, many factors inside and beyond its boundaries. Political interventions into this field have many effects within the system, but also various impacts outside the transportation sector. Not least because of this complexity, the effects of policy interventions in the transport sector are not entirely predictable, notwithstanding that political rhetoric tends to feed the impression that risk and uncertainties can be excluded or a least controlled.

In view of the high degree of complexity and uncertainty, it is not astounding that a huge variety of tools and methods for the anticipation of unintended effects of transport policies are applied to give guidance and orientation for planning processes. The rapid progress in information and communication technologies enabled the application of sophisticated transport models. Cost-benefit analyses based on advanced modelling are standard procedures in many planning processes. In the meantime, it can be observed that more qualitative and discursive methods are stipulated by actors in the process or proposed by the project leaders. There is a discussion about the potentials of discursive tools in the literature related to participative Technology Assessment (pTA; see for example Klüver *et al.* 2000, Renn *et al.* 1995). Whereas the intention of quantifications using numerical models or cost-benefit analyses are often quite clear to decision-makers, it seems that is not always understood in which way discursive methods can contribute to the improvement of planning processes.

So, a broad range of rather different FTA-methods is used in transport planning to improve the quality, robustness and legitimacy of decisions. The results of a planning process are shaped by the specific combination of the different approaches. The huge variety in tools and methods, however, makes it difficult to understand where exactly their potentials and limits are. As a key thesis of this paper, it is assumed that a pragmatically usable and easily communicable categorisation of methods is able to support both a more appropriate usage of methods in planning and decision-making processes, as well as a more appropriate interpretation of the results of assessment tools. In doing so, there is a need to look at risks and uncertainties that could lead to unintended effects.

2. The problem: risks and uncertainties

Uncertainty and risk are only in very rare cases a consideration in transportation planning and transportation policy decision making. On the contrary, typical, widely used transportation planning tools more often than not provide the impression that the consequences of policy interventions like new infrastructure projects, pricing measures or technology incentives on travel behaviour are predictable to a very high degree. For the outside observer, this might be surprising for at least two reasons:

1. Practical experience contradicts these validity claims since many policy interventions (and the actors responsible for them) are regularly confronted with unforeseen adverse – some authors even call them perverse – effects.
2. The issue of uncertainties and risks in decision making is the object of academic study and scientific debate (see for example Renn 2008) for a long time.

Risk, uncertainties and unintended effects are obviously a problem for transport planning. Generally speaking, the scholarly literature shows consistently that all decision making takes place under conditions of uncertainty and that certainty in decision making is only an idealized limiting case. However, for this paper we basically want to link theory to practical application. Therefore, a problem-oriented approach is required. Problems linked to missing or incomplete knowledge in transport panning need to be addressed. Although, from a theoretical perspective, it makes sense to state that any intervention may have catastrophic unforeseen consequences, such a position would not be very helpful to a real life decision maker. One might even argue that, in a dynamic and complex world, a *laissez faire* policy (''do nothing'') might as well lead to the same type of consequences. The question then is how to provide policy making with the best available knowledge about the impacts of interventions (that achieve the intended goals and have limited side effects) without forgetting that the reliability of these information is limited, varying and depending on the nature of these information themselves. Or, to put it paradoxically, how to reduce the level of uncertainty while at the same time acknowledging that uncertainty is limitless.

A literature review carried out in context of the EU funded transport project OPTIC (see DLR and KIT, 2010) reveals, that differentiating between different levels of uncertainty appears to be a promising approach. Positions differ on such typologies of uncertainties and the relationship between knowledge types and uncertainty. An overview of the historical development of the latter is given in van Asselt and Rotmans (2002).

Knight, in his widely acknowledged conceptualisation of risks, distinguished between ''risk'', which involved effects for which knowledge and parameters are available to assess the likelihood of an outcome, and ''uncertainty'', referring to a more genuine lack of systematic understanding of causal relations (Knight 1921, see also Runde 1998). For example, noise effects on human productivity may partially be predicted and a risk assessment can be made; while noise effects on human creativity may be impossible to parameterise or even conceive (see TSU Oxford *et al.* 2010). In a similar way and by referring to von Schomberg (2005), Armin Grunwald (2007, p. 246) argues:

> While risk is a quantifiable parameter where there is both significant scientific knowledge about the probabilities of the occurrence of certain effects and reliable knowledge about the nature and extent of possible harm, uncertainty is characterised by a limited quantifiability, a lack in knowledge, epistemic uncertainty/or unresolved scientific controversies.

Additional refinements were proposed by other authors. Kleindorfer (2008, p. 7) distinguishes between ''epistemic risks'', which arise from a lack of knowledge about the appropriate model or theory that might be relevant for a particular phenomenon, and ''aleatory risks'', that arise from randomness inherent in the phenomena (though this randomness itself can be defined or qualified by the underlying epistemic assumptions). van Asselt and Rotmans (2002) provide a categorisation of the sources of uncertainty, whereas a general differentiation is made between uncertainty due to variability and uncertainty due to limited knowledge of the system. In a similar way, Walker *et al.* (2010) argue that, in order to manage uncertainty, one must be aware that different levels of knowledge exist. The authors differentiate between four levels; two of them are subcategories of so-called ''deep uncertainties.'' The latter ones are similar to the third category that Sven Ove Hansson (1996) has added to the discussion of uncertainty. ''Great uncertainties'', as he calls them, are situations in which a decision maker lacks most of the information about his options and of the values of the different outcomes.

Against this background, we propose to differentiate between three levels of knowledge (as also presented in Table I):

1. *Knowns*. A category that is, in principle, related to what is called risk in the Knightian sense. Solid knowledge is already available. The relationship between cause and effect and the contributing factors are well known and understood. Uncertainties may exist with respect to the actual quantifications but these may be reduced with increasing empirical research that improves the error margins.

Table I Knowns and unknowns in decision-making

Category	*Unknown unknowns*	*Known unknowns*	*Knowns*
Description	Most features of the situation neither known nor well-defined (options, their possible consequences, reliability of information, value of different outcomes)	No sufficient basis for assigning a precise and accurate likelihood to a particular outcome, most other features of the situation well-defined and known	Both the likelihood of a particular outcome, and the nature of its impact, are well understood
Related concept	Great uncertainty	Uncertainty	Risk[a]
Strategies	Build awareness about reasons for fundamental limits to knowledge Attempt to anticipate, identify and reduce the impact of ''surprises''	Build awareness for limits to identify causal relationships Reduce the role of a potentially hazardous development or agent	Improve knowledge about causal relationships and their quantification Reduce exposure to the hazardous agent
Strategy type	Precaution	Precautionary prevention	Prevention
Examples	Car friendly urban policy in the 1960's leading to congestion several years later. Car friendly urban policy in the 1960's leading to urban sprawl. From a 1970's perspective: heavy growth rates in freight transport in the EU on roads from and to eastern European countries	Effect of a bypass road on kilometres driven in an area (additional traffic might be attracted). Segregation effects (new road) on biodiversity. Effects of market penetration of electric vehicles on travel patterns (e.g. on modal split). Consequences of global warming on economic growth	Effects of speed limits on emissions and number of accidents Health problems caused by noise or pollutants Effects of fuel prices on person kilometres driven in a region Correlation between the development of GDP and growth rates in freight transport

Note: [a]The reader should note that risk has various meanings, depending on the scientific discipline within which it is used. Building on the work of the German Risk Commission (Risk Commission 2003), in the context of this paper risk is understood, in its economic/toxicological/engineering sciences definition, as a quantitative characterization of adverse effects in terms of the probability of its occurrence and the level of its impacts

2. *Known unknowns*. These are the uncertainties in the Knightian sense or as described by Grunwald in the quote above. There are some indications that a certain cause may lead to certain effects. Some anecdotic evidence, maybe some basic knowledge or some evidence about the effects of certain interventions is available, but this is more like a ''black box''; the actual cause-effect relations are neither very well understood nor can they be quantified.
3. *Unknown unknowns*. There is no knowledge about potential effects or cause-effect relations. It is the sheer complexity of the system that might lead to the *ex ante* assumption that something unintended could happen. There might also be some weak signals or experiences with somewhat comparable situations pointing at the potential unintended effects. In general, however, the unintended effects emanating from this category are surprises or ''wild cards''. Once they are identified and thus known, unknown unknowns are turned into known unknowns.

It should be highlighted that there are not distinct borders between these categories. But this typology is assumed to be helpful for a categorisation of FTA-methods. We argue that it is crucial to understand to what extent the different FTA-tools and methods are able to address these types of knowledge. In the following chapter a categorisation is introduced that helps to better understand the limits and potentials of tools and methods for addressing knowns, known unknowns and unknown unknowns. It is labelled problem-oriented, since it aims at tackling the problem of unintended effects of policy interventions, which is often rooted in the knowledge-base of decision making[1].

3. The methods: ''structurally open'' versus ''structurally closed''

The transport system is embedded in the broader social, economic and environmental systems. From a policy analysis perspective, the transport system, with its components and their interrelations, could be understood as an abstract conceptual model and as a web of nodes that are interlinked. This web-model of the transport system illustrates well that, when tackling one of the nodes, this is not an isolated phenomenon but other nodes are affected as well, via the linkages between these nodes. At the more or less blurred borderlines, other systems (energy system, land-use patterns and economic system) are attached and interact. Planners and researchers know some of these nodes, some nodes are anticipated but not exactly known, and other nodes are completely unknown. Remaining with this ''web of nodes''-model, a policy intervention in the transport sector directly affects at least one, maybe several of these nodes. At the same time, a number of other nodes can be affected indirectly, via the linkages. The directly and indirectly affected ones start swinging and influencing each other, potentially generating rebound effects. The model illustrates that a policy intervention can lead to widely ranging effects, and some of them may only become visible after the measure was implemented. Many of these nodes and linkages are known and well described. Others are known to exist but not sufficiently conceptualised, and a third group of nodes and linkages are completely unknown. This widely corresponds with the categories, ''unknown unknowns'', ''known unknowns'' and ''knowns'' illustrated above.

Looking at the web of nodes it becomes obvious that prospective tools and methods will never be able to systematically reproduce the full web, neither in scope nor in depth. There are epistemic limitations to obtaining the complete picture. All FTA-methods focus on – different – aspects of the web of nodes. They either systematically cut out a certain area of the web which largely can be described by quantitative relations (transport models) or, at the other extreme, provide more punctual knowledge from rather different areas and are mostly built on experience, anecdotical evidence and tacit knowledge (for example brainstorming or open space).

Transport models show a certain slice or cut-out of the web, with some selected nodes and the linkages between them. On the one hand, working with such a cut-out enables the detailed study of a certain area of the web; of certain cause-effect relations. It should be noted that the original epistemic function of a model is to reduce complexity in order to get a better understanding of selected factors and linkages between these factors. But there needs to be a clear understanding of the relevant parameters and of the causal relationships between theses parameters. In relation to the typology of levels of knowledge described in chapter 2 it can be concluded that models are mainly focussed on improving knowledge in the field of knowns. But wide parts of the ''real world'' cannot be included in modelling approaches; it is not possible to detect any effects in excluded areas. So, models are hardly able to deal with known unknowns or unknown unknowns. Other tools with a different and/or broader focus are needed.

Based on this reflection, we make a general distinction between two groups of tools along the following criteria: does the structure of the method allow for a high degree in openness concerning the inclusion of parameters and linkages between parameters, or is the method rather characterised by a pre-defined set of nodes and linkages between these nodes? Accordingly, we introduce one category that is called ''structurally open methods'' and one category called ''structurally closed methods''. In ''reality'', there is rather a continuum than a clear borderline between these two categories. Notwithstanding these reservations, Table II illustrates that it is possible to define clear characteristics for both of them (see DLR and KIT, 2010; Justen *et al.*, 2010).

This categorisation has considerable overlaps with the distinction between qualitative and quantitative approaches. One of the main criterions to distinguish between tools and methods is whether they use and/or produce qualitative or quantitative data. We prefer to use ''structurally closed'' and ''structurally open'' as main categories, since this openness or closeness, which is determined by the underlying structure, is highly important for the type of unintended effects that can be anticipated.

3.1 Structurally open methods

This category comprises tools and methods that are providing a rather open structure. In general, these are dominated by qualitative information. Quantitative data might well play a role, but the main characteristics of these approaches is the way in which they seek to

Table II Categorisation of FTA-methods

Structurally open methods	*Structurally closed methods*
No fixed setting Mainly explorative Never purely quantitative, strongly shaped by qualitative elements Integrate knowledge of experts, stakeholders or lay people Help to structure arguments and to separate facts from norms Help getting a rough understanding on effects Open in principle to detect effects beyond system boundaries > focus on unknowns (uncertainties)	Pre-defined setting More or less clear understanding of relevant parameters and causal relationships between parameters Mainly quantitative Focus on effects inside the pre-defined system Effects outside the system cannot be detected Specifications and quantification of knowns rather than for the detection of unknowns > main focus on knowns (risks)
Examples: Brainstorming Open space Expert workshops Focus groups pTA methods Explorative (qualitative) scenarios	*Examples*: Quantitative models Cost-benefit analysis Multi-criteria analysis

integrate knowledge of experts, stakeholders and also of laypeople in the process of policy making. The basic principle of integrating information is the formulation of arguments, perspectives and judgements. This can be done in form of one-way communication as it is usually practiced in expert hearings or in the public consultations that are conducted by the European Commission to get reactions on strategic documents. Approaches for two-way communications are based on the exchange of arguments in a predefined situation. Again, these approaches can be widely unstructured or more strongly formalised. Examples include round tables, future workshops, planning workshops with citizens, focus group exercises etc. These methods in general have a structure, but are quite flexible in integrating new arguments and views. Extremely open methods are open space activities or a brainstorming. Typically, they are used to screen the possible options and/or effects in a broader context. More structured approaches could be workshops, where a pre-defined set of key questions is used to guide the discussion.

The openness or closeness is determined by the degree of pre-structure in the design of such methods. The less the issue is pre-structured, the more open is the method and the less effects are excluded from the beginning. A wide range of unintended effects might come to the fore. The information might not be detailed enough to get new insights into the probabilities for the occurrence of any known effects. But these methods aim at improving the epistemic basis of decision making by focussing mainly on the categories of known unknown and unknown unknowns (see Figure 1).

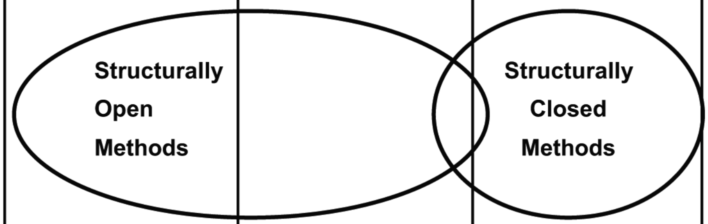
3.2 Structurally closed methods

Structurally closed methods are characterised by highly formalised and pre-structured approaches. They are designed by including and excluding factors and relationships between factors, or by defining certain factors as being constant and other as being variable. Therefore, they build up systems with clear and sharp borderlines. In general, they allow for the further specification of knowns rather than for the detection of any unknowns (see Figure 1). Typical examples are transport models. They basically allow for a quantification of effects, whose basic structures are actually known by the experts. There might be surprises regarding the magnitude of an anticipated effect. In the case of complex models in particular, there might also be surprises regarding the character of the effects; previously unknown effects might become visible, but only for factors that are already considered in the model.

Another example for structurally closed methods are cost benefit analyses (CBA), which is a widely used and, in many transport projects, mandatory step (see for example Mishan and Quah 2007). CBA is about comparing the gains and losses of undertaking a new project or a policy. All gains and losses thought to be relevant are measured in the same units to enable

Figure 1 Appropriate FTA-methods for addressing different types of knowledge

Category	Unknown unknowns	Known unknowns	Knowns
Description	Most features of the situation neither known nor well-defined (options, their possible consequences, reliability of information, value of different outcomes)	No sufficient basis for assigning a precise and accurate likelihood to a particular outcome, most other features of the situation well-defined and known	Both the likelihood of a particular outcome, and the nature of its impact, are well understood
Appropriate FTA-methods			



their aggregation. The typical unit of measurement is money (Hanley and Barbier, 2009). The overall intention of CBA is the assessment of projects, planning or programmes. There is a need to understand relevant causal relations to apply the method properly. So, in general, the method helps to specify or quantify knowns.

A third example for this field is multi-criteria analysis (MCA), also termed multi-criteria decision analysis (MCDA) or multi-objective decision-making. MCA is a structured decision-making tool developed and used in complex and conflicting situations where multiple criteria are involved (Mendoza *et al.*, 1999). It is often considered as an alternative or an extension to pure CBA in cases where important effects cannot be monetised MCA allows decision makers to include a full range of social, environmental, technical, economic, and financial criteria. Similar to CBA, a rough understanding of the causal relation relevant for a policy intervention is needed to apply MCA. Therefore, the evaluation of knowns surely can be considered as being the main purpose of MCA or MCDA; it helps to clarify which known effects are less and which are more relevant. As for the other tools described in this chapter, the process of reflection and systematisation might also improve the knowledge of known unknowns. However, these are rather side effects that do not emanate from the main purpose of the methodology. Therefore MCDA or MCA can be assigned to the category of structurally closed methods.

3.3 Combinations of methods

It was highlighted above that there is no sharp borderline between the structurally open and structurally closed categories *per se*. But it seems to be possible to allocate tools and methods to either of the two categories. In practice, however, they are often applied in combinations. Quite often several methods are packed together under the umbrella of more integrative approaches. These tools are used to integrate data of different character and sources. There are a huge variety of possible combinations in this field, which is briefly illustrated here with the help of two methodological examples: scenario building and strategic environmental assessment.

The term ''scenario'' subsumes a broad range of tools and methodological approaches. In general, several tools are combined in a scenario process (workshops, CBA, trend analyses, models, Delphi, roadmaps and others). Scenarios are defined by many authors as a coherent illustration of possible future situations together with pathways that might lead to these situations (Kosow and Gaßner 2008). Scenarios help to reflect on the consequences of decision-making. They can serve as arenas, where certain policy interventions are ''tested'' to get a better understanding of the related causal relations and of the anticipated effects. They help to systemise and deepen knowledge in a certain field. They help identifying uncertainties, blind spots, contradictions or dilemmas. So, they allow the identifications of unknowns and help to turn such unknowns into knowns. However, the ability to detect specific unintended effects depends on the scenario methodology applied and, thus, has to be discussed in relation to the different variations of the methodology. For example, explorative scenarios are usually designed in a rather open way and should be able to explore unknowns.

The other examples are environmental impact assessment (EIA) and strategic environmental assessment (SEA). Both instruments are related to the assessment of the environmental consequences of an activity. SEA and EIA use combinations of different tools rather than only one tool. Scenario processes and modelling approaches quite often play an important role. In particular for SEA, participatory or consultative methods are also frequently used (see Rauschmayer and Risse, 2005). EIA is narrower in its focus and stronger in specifying or quantifying effects from the category knowns. SEA clearly is of explorative character, it offers a broader focus. It is more strongly linked to structurally open methods and, thus, is able to deal with unknowns (see Therivel 2004).

4. Illustrative exemplification of the approach

The main intention of the differentiation between structurally open and structurally closed methods is to support an appropriate usage of the FTA tools in transport planning. In this chapter some real life examples are given to illustrate briefly the potential of the approach. The focus is put on the combination of structurally open and structurally closed methods since in transport planning generally more than one method is applied.

A typical issue, which goes through the history of transport planning, is the case that quantitative modelling is used but leads to either controversial results or - from an *ex post* analysis perspective – was proven to regularly provide obviously wrong results. The latter case was somewhat characteristic for the 1950 and 60'ties. In this period, a highly optimistic view on the predictability of developments in the transport sector was dominating. The ''predict and provide'' approach was the established planning paradigm. For example Banister (2002, 31; based on Evans and Mackinder, 1980) illustrates that many of these forecasts turned out to be wrong in the UK. Obviously, there was a too optimistic view on the potentials of these methods and not enough reflection on its limits. These limitations often related to the fact that it is not acknowledged enough that crucial assumptions, which are creating the basis for transport planning models (TPMs), might be subject to a high degree in uncertainty. This relates also to external factors which might take an influence on developments in the transport sector, in particular in transport demand. Banister (2002, p. 134) stipulates:

> Two crucial issues in all TPMs have been the assumption of stability in model coefficients over time and the assumption that variables excluded from the model will not be instrumental in modifying travel behaviour over time.

According to the approach introduced in this paper, it would have been subject of open methods to clarify these assumptions. This could have been a structured workshop with experts and/or stakeholders. Even if in the meantime this highly optimistic view towards the ''predict and provide'' paradigm has somewhat been corrected (at least rhetorically) and, on the other hand, quantitative tools such as models have become much more sophisticated, there are still many examples that uncertainty in relation to such assumptions is not sufficiently acknowledged.

This can be illustrated by a recent example for which the question of clarifying the assumptions of modelling still is a crucial issue: the planning of an underground railway station for the City of Stuttgart, abbreviated as S21 (Stuttgart 21), which caused large protest activities in the area of Stuttgart and even beyond (see S21, 2010). It is not possible to illustrate the long and complex discussion process which accompanied the planning. But we will focus here on some examples related to the methods used and the levels in uncertainties in the process. Among others, one central element of the conflict about S21 was the discussion about the capacity of the new station. The capacity was calculated with the help of a transport model (simulation). According to proponents of the planning the results proved that the station would have sufficient capacities. In contrast, the opponents of the planning considered the results as invalid, since the modelling had been based on assumptions which they considered as being wrong. For example, they criticised that the assumed time for boarding and de-boarding will not be sufficient during rush periods. With the help of structurally open methods, more clarity could have been achieved on this point in advance; remaining disagreements could have been identified. It could have been discussed to what extent there is a lack in knowledge which needs further elaborating before a simulation (a structurally closed method) can lead to results accepted by both parties.

Another issue in the context of the S21 planning is a good example for a known unknown. According to the original planning, more than 50 kilometres of tunnel need to be built. It was known that the complex geological structure might well lead to ''surprises'', in form of difficult geological structures which might make the planning more expensive. An effect would be that the cost-benefit ratio, a crucial basis for the political decision to realise the project, would have been worsened significantly. A structurally closed method alone, here the CBA, is not able to cope with such a known unknown. It needs to be accompanied by an open approach, which allows for discussing the potential consequences with experts and decision makers.

Another example is the phenomenon of so-called ''induced traffic'': It is often discussed – and empirically proven – that new road capacities, for example a bypass circumventing a city centre, frequently attract additional traffic. That effect usually was not visible before the infrastructure was built simply because it was not shown in the results of *ex ante* modelling approaches. Again, this means that the cause-effects relations between infrastructure supply and traffic demand were obviously not fully understood, important effects were not reproduced by the modelling. Also in this case, more open methods would have been needed to raise awareness for the uncertainties in the planning. Such a method could have been interviews with experts or stakeholders from different fields, not only form the transport sector.

In a study on inaccuracies in travel forecasts in the USA, Parthasarati and Levinson (2010) conducted interviews with experts. The inability of the models to understand and predict fundamental societal changes was the most often stated reason for the inaccuracies. ''The change in the labor force due to increased participation of women was one of the commonly quoted examples of the model's inability to properly account for travel behaviour''. Such factors can be considered as known unknowns: it is known that transport is derived demand and is highly dependent on developments in society but it is difficult to assess which development will take place and to what extent they will actually take influence on transport demand. Rather open, interdisciplinary assessments are needed to cope better with these uncertainties and to provide for a better basis for the quantification of potential effects.

A positive example for a careful application and integration of results of different FTA-methods is the development of the European Commissions (Commission of the European Communities, 2008) ''Action Plan for the deployment of Intelligent Transport Systems'' (ITS). It includes six priority areas for action which are connected with specific target dates, ranging from 2009 to 2014. Although this timeframe constitutes a short to medium time perspective, the action plans aims at building a long-term vision, defining the role ITS will play in the future road transport system in Europe. In preparation for the action plan, an *ex ante* impact assessment was conducted to examine the options for action regarding ITS and to consider their probable effects. Notable on this assessment is its deliberate use of various FTA- methods. For example, different scenarios were developed; models were used for quantitative assessments. A wide range of stakeholders have been involved as well as, on a smaller scale, the wider public in form of an online survey. This consultation process is well documented and accessible for the public. The documentation includes ''reflexive'' elements, pointing at the potentials but also at the limits of the tools and methods used for the assessment. The impact assessment combined structurally open and structurally closed methods in a careful and transparent manner.

5. Conclusions

Policy interventions in the transport sector have to consider risks and uncertainties, which become visible in the form of unintended effects after policies have been implemented. A broad range of tools and methods exists that are used for assessing the impact of transport policy decision-making by trying to anticipate such effects. None of the tools and methods are able to ''guarantee'' that no unintended effects occur. An *ex ante* assessment of future effects is always based on assumptions and simplifications. In general, these assumptions and simplifications are based on knowledge of different type. Whereas some phenomena are well known and the underlying cause-effect relations are well understood, others are rather unknown and the cause-effect relations are only roughly described. Finally, one has to be always aware of the existence of unknown unknowns which might lead to surprises of all kinds. So, problems of missing knowledge can be clustered in these categories. This sets the basis for the problem-oriented categorisation of FTA-methods which was introduced above.

In this paper, FTA-methods were discussed in relation to the concepts ''structurally open'' and ''structurally closed''. The key argument is that closed methods are rather usable in situations where the system under consideration can reliably be described and the network of interdependences as well as the underlying cause-effect relations are known. Structurally closed tools are mainly of quantitative character, cause-effect relations can, to a large extent, be expressed in numbers and figures. In contrast, open methods are suitable to deal with situations or developments where knowledge about the system and its internal structures is rather weak. The latter is falling into the categories of known unknowns and unknown unknowns (see Figure 1). In general, structurally open methods are strongly shaped by qualitative elements; they seek for the integration of knowledge of different quality and character, for example in highly interdisciplinary contexts.

The theoretical background as well as the examples given in this paper illustrate that both types of methods are needed in planning processes. The quantification of effects always is beneficial as long as solid data on relevant factors and the relation between these factors is available. Limitations of models and other quantitative approaches have to be discussed in relation to the data that is included in the process. Grunwald (2009, p. 1129) argues in relation to quantitative tools: ''quantitative'' is often equated with ''objective''. Subjective questioning of evaluation should be ''objectivised''. This is difficult, for example, if social phenomena are analysed as, in general, only selective knowledge can be gained on social phenomena through quantification due to the fact that the models normally only consider a reduced amount of variables that describe social realities (Grunwald, 2009). Obviously, open methods are needed to better cover such social phenomena. The latter can be highly relevant in complex socio-technical fields such as the transport sector.

Such a problem-oriented categorisation of FTA-methods supports a better understanding of the potentials of different methods. The categorisation should underpin that as soon as a structurally closed method is applied, a decision was made on what to include or what to exclude. This decision is always based on an explicit or implicit prioritisation, a step that is based invariably on normative positioning, on preferences, values, norms, and their changes over the course of time. For transparent decision making procedures it is crucial to make preferences, values and normative assumptions visible as far as possible. In a similar way, Gordon *et al.* (2005, p. 1066) emphasise that, instead of forecasting methods to produce single-value deterministic images of the future, uncertainty and underlying assumptions should be made explicit. The categorisation suggested here helps to raise awareness for this step of including and excluding factors. It supports transparency and it helps to sharpen sensitivity to risk and uncertainty in planning processes. Further, the categorisation increases awareness for a more careful design and integration of structurally open methods. It helps to get a better understanding of discursive or participative approaches, on their potential role for gaining knowledge that is needed for anticipating unintended effects of policies.

The approach is not solving problems such as inaccuracy in data; it does not provide directly for new knowledge; even if applied properly, many problems will remain; the future is and will remain uncertain. However, as it was pointed out in the beginning of this paper, the approach aims at supporting a more proper handling of uncertainties by enabling a more appropriate application of FTA methods. The examples given in this paper illustrate that crucial weak points in planning processes can be revealed by using the categorisation.

Further research will be needed to elaborate on how the categorisation can be used most effectively for designing planning processes in the transport sector and beyond.

Note

1. Problem orientation is used here in a rather straightforward way: providing orientation knowledge for solving problems in the transport sector. However, a broad range of literature exists, dealing with problem-oriented transdisciplinary research (see for Hessels and van Lente, 2008 for a critical review) in greater depth. It is often linked to the concept of ''Mode 2'' knowledge production (see Gibbons *et al.*, 1994). The structurally open / structurally closed approach (see chapter 3) could be discussed within this context but further elaboration would go beyond the scope of this paper.

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