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ID 1508 | A HEURISTIC FRAMEWORK FOR EXPLORING UNCERTAINTIES IN TRANSPORT PLANNING

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1 INTRODUCTION

In recent decades, the effectiveness of positivistic approaches in transport planning has been growly contested by academics and practitioners (Innes and Booher, 2010). The idea of planning for a single model of reality is becoming obsolete when considering the fast and radical changes that society is experiencing at present and in the near future (e.g. ICT advances, environmental concerns, social inequalities, changes in mobility behaviour, etc.) (Batty et al., 2012; Lyons and Davidson, 2016; Marsden et al., 2014). The

discussed crisis of the rational-planning model has generated a great deal of interest in those rationalities pursuing “alternative realities” of planning, rooted in critical realism, constructivism and pragmatism (Khisty and Arslan, 2005). However, practitioners and policy-makers are still comfortable with the idea of planning as “enlightening the future”, also reinforced by traditional planning cultures, legal frameworks, and political institutions (Lyons and Davidson, 2016). Placed in a crossroad of approaches, motivations and perspectives, the issue of unveiling uncertainty has been gaining relevance among transport-planning researchers (Martens and van Weelden, 2014).

Attempts at understanding uncertainty have mostly been made from a decision-making perspective, especially from the transport-modelling field (van der Pas et al., 2010; Walker et al., 2003). However, those approaches face what is known as the "uncertainty paradox": the recognition of higher levels of uncertainty goes hand in hand with the expectations of positivistic science and knowledge to tackle them (van Asselt and Vos, 2006). Moreover, despite multiple dimensions of uncertainty having been explored in literature (Brown, 2004), they seldom encompass the plurality of perspectives (and also languages) involved in transport planning. At this point, previous systematization and conceptualization efforts need to converge into common overarching frames, which are flexible enough to embrace this plurality of uncertainty dimensions.

Such attempts may help in improving the perception and communication of uncertainties in planning. This paper addresses the following research question: how can uncertainties faced by transport planners and policy makers be framed and compared? To explore potential answers: (i) a heuristic framework has been developed to summarize a set of existing sources and levels of uncertainty in transport planning; (ii) this heuristic framework has been used to carry out a literature review of situations of uncertainty, that is, specific perceptions and consequences of uncertainty in planning; illustrative examples of those situations were provided, with the implementation of a new public-transport infrastructure (i.e. a Light Rail Transit systems) as a background.

Section 2 outlines the research design. Section 3 shows the bases of the proposed heuristic framework to identify situations of uncertainty in transport planning. Section 4 further develops the description of the framework according to different dimensions of planning, using references from transport literature and some examples. Section 5 closes the paper with reflections and some concluding remarks.

2 RESEARCH DESIGN

The research design consisted in a literature review comprising two main phases: in the first phase, a review was conducted on academic publications under an open search basis, aimed at identifying uncertainty, complexity and risk concepts (i.e. how uncertainties are represented, located, and assessed); two perspectives were explored: i) the planners' perspective on uncertainty, involving how and where uncertainties are perceived and communicated; and ii) the policy-makers' perspective on uncertainty, involving how uncertainties are analysed, assessed and managed. In the second phase, the previous concepts were used as keywords for a systematic search of references in the Scopus database. The resulting selection of 364 references was manually refined to 44 papers according to their relevance (i.e. mostly, discarding offtopic references, insights on mathematical modelling and research on operational processes and transport engineering) and their availability in consulted sources. After a first scan of the content of the final selection of papers, a heuristic framework was proposed (Section 3) for connecting different levels of uncertainty with features and dimension of planning represented by authors (Section 4).

To facilitate the understanding of the theoretical insights during the literature review, some situations of uncertainty have been pictured with examples involving the implementation of a Light Rail Transit system (LRT) (Section 4). LRT projects have cast claims and doubts over the potentials of such systems for transforming existing urban spaces and upgrading the transport system of medium and small urban regions (Babalik-Sutcliffe, 2002; Priemus and Konings, 2001). The examples provided here are mostly inspired in the recent implementation of an LRT project in Granada (Spain), close to the authors' experience.

3 A HEURISTIC FRAMEWORK FOR UNCERTAINTY IN PLANNING

The heuristic framework was built as a thinking device for identifying different situations of uncertainty in planning. Those situations are described linking two questions: (i) where uncertainties are located (i.e. object and subject); and (ii) how important they are (i.e. their impact).

Concerning the object of uncertainties, information, knowledge and decisions have been central to their study. Uncertainty manifests when something is unknown, or cannot be known, due to certain limitations related to the very nature of knowledge (i.e. "what we know"), how it is processed (i.e. "how we know") and how knowledge is used (i.e. "what we do"). In literature, these aspects have been related to different locations or sources of uncertainty (Enserink et al., 2013; Hansson, 1996). Nonetheless, a more complete understanding of uncertainty sources in planning also requires attention to their subjects, highlighting how perceptions and actions of planners and policy-makers are inherent to their confidence, expectations and state of surprise (Hutter, 2016).

The heuristic framework conceptualises the possible sources of uncertainty in transport planning according to three overlapping layers. Uncertainties are generated as interactions or tensions between pairs of features in each layer (Figure 1):

Layer 1 or "planning reality" (context – environment): this layer corresponds to the notion of the world outside the planning process, as perceived by both planners and policy-makers. It involves the planning context, as the less or more complex "physical reality", which planners cannot directly control or influence (e.g. infrastructures, transport systems, flows, demography, economic cycles, technological changes, behaviour of travellers, etc.); and the planning environment , or the "social or organisational reality", as the network of actors which links material reality and the planning process by gathering information and practical experience and sharing information and knowledge with other actors.

Layer 2 or "planning process" (concepts – artefacts): this layer would be embedded in the transportplanners' side, regarding how disperse information and knowledge from the planning reality is actively screened, processed and interpreted by them to define and solve planning problems. Concepts stand for those planning problems and premises steering the transport-planning process to its resolution (e.g. restraining cartraffic volumes, reducing traffic emissions, promoting TOD, etc.). Artefacts are the devices or knowledgebases which help planners to describe, explain and validate concepts (e.g. judgements or argumentations, simulations, planning-support systems, decision-support systems, etc.). At the same time, the definition of concepts motivates the choice of those artefacts that can interpret them.

Layer 3 or "planning products" (outputs – outcomes): this layer would be embedded in the policymakers side, considering how planning knowledge is effectively used. Outcomes characterize the available options of the plan and their expected impacts (e.g. decisions it expects to influence, objectives to achieve, policies it delivers, alternatives it proposes, etc.). Outputs are the real planning impacts, as decisions are made according to outcomes. At the same time, outputs are used for validating and questioning planning outputs.

The implications or impacts of uncertainty are addressed in our framework through the addition of levels of uncertainty. Levels have been used in other works to measure or express the severity of uncertainty, or its consequences, within a spectrum from completely deterministic knowledge to 'total ignorance' (Bertolini, 2007; Enserink et al., 2013; Lyons and Davidson, 2016; Walker et al., 2010). Here, we also consider levels as related to the main nature of uncertainty (Enserink et al., 2013; Hansson, 1996): epistemic, originating from lack of knowledge about phenomena; ambiguity, a type of epistemic uncertainty coming from the plurality of frames under which reality is understood; and ontic, originating from the limits of cognition and representational systems. We distinguish four levels (Figure 2): Reducible uncertainty (level I): information may be eventually incomplete, but known causal relationships (deterministic knowledge) can help to retrieve the "missing parts". Shallow uncertainty (level II): knowledge is incomplete but still reliable, linked to a single frame, in a way it can effectively bridge the information gaps.

Deep uncertainty (level III): it corresponds to conditions of incomplete and unreliable knowledge, in which information gaps cannot be properly bridged, due to the existence of conflictive frames (i.e. different perceptions of the same issue).

Radical uncertainty (level IV): this level exacerbates the limits of knowledge and the lack of reliability on past experience. Therefore, information gaps cannot be even defined, as previous knowledge frames turn useless.

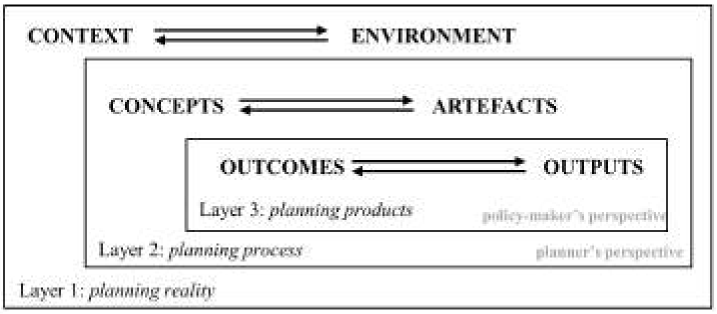

Figure 1 - Conceptualization of the three layers of the heuristic framework.

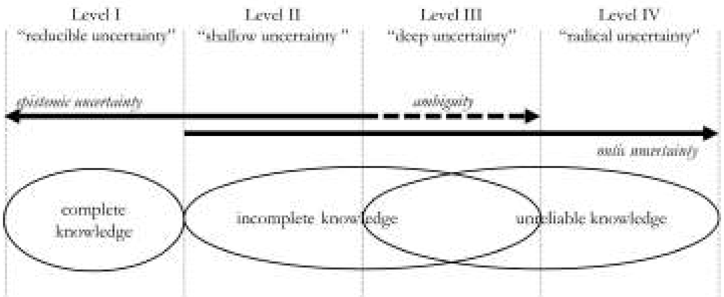

Figure 2 - Levels of uncertainty.

4 SITUATIONS OF UNCERTAINTY IN TRANSPORT PLANNING

In this section, situations of uncertainty are described according to intersections between layers and levels of the heuristic framework (in each sub-section). The features of planning at different layers (i.e. context, environment, concepts, artefacts, outcomes and outputs) are further developed in 14 dimensions, concerning different aspects relevant in transport-planning literature. Tables 1 to 6 summarize key situations of uncertainty, and offer some examples picturing the planning and implementation of an LRT system.

4.1 UNCERTAINTIES FROM THE PLANNING REALITY

The situations of uncertainty authors acknowledge within the notion of reality of planning (layer 1) are mostly associated to the planning context (physical reality) and the planning environment (social reality) (see Section 3).

Uncertainties in the context have been linked to planners and policymaker's perceptions of past change (see Table 1). Objects of change in transport planning seldom work in isolation (level I), but they involve different components and their mutual relationships, usually arranged in systems: transport systems, land-use systems, social systems, etc. Uncertainties are related with different types of complexity in systems, which range from the complexity due to increasing number of components and properties (e.g. a transport network growing in nodes and links) (levels I and II) to the complexity of dynamic systems, shifting behavior and functions (level III), or interacting with outside drivers (level IV) (Bertolini, 2007; Dimitriou et al., 2013; Koppenjan et al., 2011; Martens and van Weelden, 2014; Ramjerdi and Fearnley, 2014; Salet et al., 2013). On parallel, nature of change refers to the pace, continuity, reversibility and dynamicity observed in transformations of the context (Bertolini, 2007; Lyons and Davidson, 2016; McDowall, 2014). Accumulation of change dominates transport planning, for instance, in the inherited urban forms and infrastructures. From a level-II perspective, fixed elements, such as infrastructures, may help to retain structures and deliver stability (Gifford, 1994); nonetheless, under a level III perspective, such elements are perceived as irreversible and path-dependent (i.e. the sequence of historical events influences future possibilities) (Bertolini, 2007; Herder et al., 2011; Ramjerdi and Fearnley, 2014). Combination of reversible and irreversible elements is usually associated with transitional and discontinuous changes (levels III and IV).

Dimension of planning	*Level 1*	*Level 2*	*Level 3*	*Level 4*
Object of change (*what changes?*)	components of systems	structure of systems	regime of systems	external conditions of systems
Nature of change (*how does it change?*)	incremental	stable	transitional	discontinuous

e.g. What changes will LRT bring to Granada's context?	
Lvl. 1	Plans claim that the LRT will extend the public transport coverage (a simple physical dimension of transport systems). As a consequence of this increase in coverage, public transport demand is also expected to rise.
Lvl. 2	LRT implementation generates new components into the previous transport systems (e.g. new stations, transfer nodes, etc.); these new components and structures are also intended to "create order out of chaos", concerning the multiple transport services operating in Granada (i.e. urban and inter-urban public buses), as well as reinforcing the functionalities and complementarities of those services (e.g. the metropolitan dimension of metropolitan transport systems).
Lvl. 3	LRT will induce new mobility behaviours in public transport users. At the same time, the new travel dynamics induced by LRT will transform the corridor functionality, which will create pressures and interests in developing spaces with new roles, which, again, will generate additional travel needs and, therefore, new infrastructure demands.
Lvl. 4	LRT has been an opportunity for channelling external investments in Granada (i.e. regional and European funds), which have been dependent on the economic context over the last two decades (the property boom and the economic downturn), and external political decisions.

Table 1 - Uncertainties from layer 1: context.

Uncertainties within the planning environment are linked to barriers on knowledge exchange, regarding planning actors and their modes of interaction (see Table 2). Firstly, uncertainties perceived in planning actors, as knowledge-sharers and knowledge-holders, have been connected to their organisational structure (Boelens, 2011; Gifford, 1994; Koppenjan et al., 2011; Marsden et al., 2012). Increasing levels of uncertainty are depicted as problems of fragmentation and coordination, moving from “top-down” (i.e. vertical, centralized, organization-based, institutionalized) (level I and level II) to “bottom-up” structures (i.e. horizontal, spontaneous, agent-based, networked, actor-relational) (level III); at the level IV extreme, the strong influence of independent actors, such as coalitions, lobbies or political champions, is also acknowledged (Dimitriou et al., 2013; Salet et al., 2013). Modes of interaction involve how exchange of knowledge occurs between actors in the planning environment. Uncertainties have been related to the quality of information formats, and transparency of knowledge exchange (Boelens, 2011; Grant-Muller et al., 2001; Isaksson et al., 2009; Khan, 1989; Koppenjan et al., 2011; Marsden et al., 2012; Tapio, 1996). In theory, while lack of information on level I and II comes from the assumption that well-defined information requirements have been previously set (format, procedures, standards…), higher levels of uncertainty are generated in the overwhelming amount and diversity of information managed within collaborative environments, often full of contradictions, misinterpretations, gaps and redundancies (level III), or in the lack of transparency or traceability of knowledge, mostly produced in informal interactions between actors (level IV).

Dimension of planning	Level 1	Level 2	Level 3	Level 4
Planning actors (who interacts?)	institutions	organisations	agents (sectors)	individuals
Modes of interaction (how do actors interact?)	procedural	normative	collaborative	informal

e.g. in which arenas have been the LRT discussed?

Lvl. 1 LRT-system solutions (routes, designs, vehicles, etc.) were developed and promoted by regional government for different Andalusian cities. Communications involved specific features of the systems and in-detail issues, which should be integrated in local planning. They were implemented through formal technical documents (as part of the LRT-survey and project documents).

Lvl. 2 While local governments are expected to commit to the project previsions ("top-down" decisions), problems of coordination arise concerning land-use, other services, and infrastructures. In response, the regional government formally requested information from local departments and organizations concerning a close set of issues (e.g. about new developments, transport demand).

Lvl. 3 Local actors promoted modifications to the LRT route ("bottom-up" decisions), according to different conflicts of interest, preferences, etc. Those modifications are sustained in different types of communications, meetings, round tables, claims, etc.

Lvl. 4 The option of building the central part of the LRT route underground was finally taken as a consequence of pressure from local officials and political parties, disregarding other options recommended by local experts and supported by retailer associations and transport operators.

Table 2 - Uncertainties from layer 1: Environment.

4.2 UNCERTAINTIES IN THE PLANNING PROCESS

Uncertainties within the planning process encompass two features: concepts (planning motivations, premises, and problems) and artefacts (knowledge constructs as mechanisms validating or supporting concepts) (see Section 3).

In reference to planning concepts (see Table 3), a first dimension of interest is their value as future hypothesis. A future hypothesis may be past-dependant, relying in few variations over known trends, theories, probabilities or policy pathways (levels I and II) (e.g. the "predict-and-provide" approach); or it may divorce from past and show higher tolerance towards alternative hypothesis (level III), even raising speculations (e.g. technological "hype") (level IV) (Lyons and Davidson, 2016). A second dimension of concepts is their contextualisation, which concerns the "policy transfer" of planning solutions (Marsden et al., 2012) and their "permeability" regarding context influences (Dimitriou et al., 2013; Gifford, 1994; Marchau et al., 2010; Tapio, 1996). In this sense, uncertainties can be related to the definition of universal planning concepts (in isolation from the context) (level I); to local exogenous factors that influence the use of certain concepts (e.g. problems of applicability in concepts underlying some transport analysis) (Ma and Lo, 2015; Malone et al., 2001); or to concepts surrendering to local forces and singularities (e.g. critical components, opportunities, barriers, vulnerabilities, events, community images…) (levels III and IV). In third place, the definition of concepts may rely on accurate expressions (e.g. quantitative previsions of demand/capacity, accurate prescriptions, etc.) (level I) or accommodate the higher variability and fuzziness of natural language and statistical science (e.g. time-travel intervals, "higher/lower" accessibility, spatial arrangements, road levels of service, scores…) (Kikuchi and Pursula, 1998; Lambert et al., 2013) (level II). In addition, concepts can take the form of parameters (level I) and closed categorical properties (level II), or be based on loose structures concepts lacking a single underlying categorisation, but retaining some meaning or purpose related to the issue (levels III and IV).

Dimension of planning	Level 1	Level 2	Level 3	Level 4
Future hypothesis (how are concepts preconceived?)	as predictions	as assumptions	as possibilities	as speculations
Concept contextualisation (where do concepts come from?)	global	local-influenced	local-oriented	singular
Concept definition (how are concepts expressed?)	as parameters	as categories	as meanings	as thoughts

e.g. how is the LRT concept introduced in Andalusia and Granada transport planning?

Lvl. 1	LRT solution relies on the hypothesis of increasing travel demands, supported by forecasts in the metropolitan area of Granada. These needs are based, at the same time, on universal (i.e. formal/mathematical) definitions of service demand and capacity. Along the same line, parametric premises are proposed in the LRT project, such as reducing car travel by over 10%.
Lvl. 2	LRT is a solution for satisfying a range of projected mobility demands and preferences, associated with promoting public transport use. Concepts of capacity must be reconfigured to address more complex spatial and social factors in the context, such as car dependency and modal preferences. Categorical qualities of multi-modality (modal share) and PT competitiveness (concerning travel times, priorities, use of street section etc.) are associated with LRT.
Lvl. 3	LRT is a critical factor for future transformations towards more sustainable mobility patterns. Such transformations involve multiple local issues and options, such as reducing traffic impact in the city, encouraging city center regeneration, etc. Moreover, the model of "sustainable urban mobility" is ill-defined in plans, and there is a convergence of many conflictive meanings (local visions).
Lvl. 4	LRT is associated with the idea of a modern transport system, both as a solution to mobility demands and as a symbol of city prosperity in the future. At the same time, despite the external origin of the LRT, it has been deliberately given the nostalgic appeal of the old electric tramway system, which worked in Granada until 1975.

Table 3 - Uncertainties from layer 2: Concepts.

Concerning planning artefacts (see Table 4), their knowledge requirements are directly connected to the levels of uncertainty. Thus, artefacts operating under lower levels would require conditions close to perfect information to perform (level I), or, at least, in which information can be externally validated (by technical expertise, institutional support, etc.) (level II). On the other hand, artefacts under level III assume some degree of fundamental ignorance, caused by the impossibility of gathering sufficient evidence to support planning concepts by "natural" laws or probabilities (Kikuchi and Pursula, 1998; Kronprasert and Talvitie, 2015). Other important dimension is the artefacts structure. Structures at level I are analogical, that is, they resemble physical and economic laws (level I) (e.g. gravity models and impedances, cost-demand laws, laws of human behaviour, etc.) (Batty et al., 2012; Khan, 1989); higher uncertainties admit more flexible and diverse structures, either systematic/structurally closed (lelvel II) or holistic (level III), allowing a greater variety of qualitative techniques (e.g. stakeholder panels and workshops, narratives and intuitive scenario-planning techniques, open indicators, direct transfer of planning ideas…) (Schippl and Fleisher, 2012). Level IV artefacts, despite their lack of proper deliberative structures, can still be powerful instruments to change public opinion (Richardson, 2001). Finally, uncertainty has been connected with debates about prevalent rationalities in planning approaches and methodologies (Martens and van Weelden, 2014; Richardson, 2001; Tapio, 1996). Situations of uncertainty are inherent to the particular knowledge mechanisms or grounds which allow artefacts to validate concepts: strong cause-effect explanatory logics (level I); judgements resting on a coherent structure of thinking (e.g. experts and expert systems, etc.) (level II) (Berrittella et al., 2008; Khan, 1989; Rayner, 2004); heuristics and bias mechanisms for supporting arguments (e.g. case similarity, lessons of success and failure, common sense, rules of thumb, etc.) (level III); or even non-rational use of artefacts built in rhetoric, legitimacy, fairness, public trust or fear, etc. (level IV) (Isaksson et al., 2009; Martens and van Weelden, 2014). Higher uncertainty levels relax the conditions of expertise required (Kronprasert and Talvitie, 2015), and also lead to more sophisticated uses of artefacts (e.g. instruments for contestation, narratives, etc.).

Dimension of planning	Level 1	Level 2	Level 3	Level 4
Knowledge requirements (what do artefacts need?)	complete series of information	comprehensive information	incomplete/contested information	no information
Artefacts structure (how are artefacts built?)	analogical	systematic	systemic	unstructured
Rationalities (how are artefacts used?)	to validate cause-effect logic	to generate judgements	to support arguments	to support discourses

e.g. how has the LRT concept been supported?

Lvl. 1 LRT implementation has been supported by transport demand models, whose generations/attractors logic relies on gravity models (analogy with physical model). These transport-demand models link causal factors with the positive effects of LRT (increasing PT use, reducing traffic, etc.). They also rely on a predefined set of variables and data.

Lvl. 2 Alternative LRT routes have been compared in various project stages using MCA, concerning not only functional features (demand), but also encompassing economic, urban integration and environmental objectives. These methods admitted the use of multiple indicators, and qualitative and quantitative attributes (especially from the report on the environmental impacts of the LRT project) for assisting final decisions. In parallel, multidisciplinary technical boards were asked to draw up expert judgements on some key decisions, such as building part of the LRT route underground, considering similar criteria.

Lvl. 3 Arguments on the systemic evolution of Granada towards a metropolitan area have supported the idea of a metropolitan rail system, addressing the future growth of suburbs and the loss of population and activities in the city center. However, the strength of these assumptions (only relying on observed demographic trends) has been weakened by the prevailing importance of the city center.

Lvl. 4 The LRT solution has been justified with discourses on improving citizens' quality of life, with no information support or structured argument.

Table 4 - Uncertainties from layer 2: artefacts.

4.3 UNCERTAINTIES IN THE PLANNING PRODUCTS

Planning products ("plans", to abbreviate) (layer 3) include two planning features: outcomes (planning options) and outputs (planning effects) (see Section 3).

Uncertainties from planning outcomes are observed in the content of plans, as well as in how plans are expected to accommodate future change (adaptations) (see Table 5). Firstly, uncertainties in contents obey to how planners foreclose the list of problems and alternatives before moving to decision-making. On level I, all decision-related aspects are expected to be foreclosed, leaving policy-makers with a complete set of descriptions, statements and designs of future systems (planning as blueprints). On level II, only the list of planning problems is foreclosed, and contents consist on all-encompassing guidelines and statements still anchored in a complete end-state image of the future (i.e. statutory planning, comprehensive planning or master planning) (Bunker and Searle, 2007; Gifford, 1994; Khan, 1989). In levels III and IV, policy-makers confront ill-defined problems, either with an underlying idea or motivation toward their resolution (e.g. an urban or transport program) (level III) or without it (i.e. "wicked problems") (Dimitriou et al., 2013; Batty et al., 2012; Martens and van Weelden, 2014). Secondly, planning adaptations involve how uncertainties are handled by policy-makers through a balance of adaptability, flexibility and robustness in planned systems (Bertolini, 2007; Dimitriou et al., 2013; Ramjerdi and Fearnley, 2014; Salet et al., 2013). In the lower levels (I and II), this balance lean towards protecting outcomes from external changes (i.e. "closing systemperspective"), trading off robustness against overall flexibility. On the contrary, flexibilities are prioritized against robustness in most aspects of decision-making (e.g. systems scale, definition of components, reversibility, etc.) on the higher levels (III and IV), to mitigate their negative consequences and amplify the positive consequences (Herder et al., 2011; Van De Riet et al., 2008). Level IV would only leave room for improving resources and learning capacities of actors following their actions (e.g. "policy experiments").

Dimension of planning	Level 1	Level 2	Level 3	Level 4
Contents (what kind of options exist?)	blueprints	guidelines	programs	actions
Adaptations (how options accommodate changes?)	isolating from context	increasing robustness/resilience	increasing flexibility	increasing adaptability
e.g. which options were considered for implementing the LRT in Granada?				
Lvl. 1	Some features of line 1 of the LRT, such as itinerary and stations near city center, were fixed at great detail from the early planning phases (as evidenced in regional infrastructure plans and spatial plans). Such planning decisions were also isolated from later events (e.g. the substitution of the line 2 project with a high-capacity bus line), building trust amongst land developers, property owners, retailers, etc.			
Lvl. 2	Regional infrastructure and spatial plans created a set of guidelines for fostering the multi-modality of LRT with other transport modes in Andalusian cities. Own right-of-way systems (including LRT and tramway) were part of a strategy of protecting adaptations of future public-transport systems against traffic problems.			
Lvl. 3	Among the final LRT project definitions, a set of general measures and orientations for re-structuring traffic flows and urban-bus network was proposed. These measures took advantage of the potential flexibility of the urban bus system, operated by a city company (if compared with the rigid concessional system of metropolitan buses).			
Lvl. 4	While the LRT project has not yet produced great changes, local master and transport plans have learnt from previous actions implemented in Granada at the beginning of the 1990s, on the whole pedestrianisation projects and car-access restrictions. These individual actions have led to a complete overhaul of mobility patterns in the historic city-centre, including the reduction of car traffic and the improvement of urban bus system reliability.			

Table 5 - Uncertainties from layer 3: outcomes.

In relation to planning outputs (see Table 6), uncertainties are associated to planning expectations (success conditions) and where are they materialized (implementations). Uncertainties on implementations are intrinsic to the aspects of decision focused by plans (Koppenjan et al., 2011; Marsden et al., 2014): control over material outputs (e.g. planning of daily transport operations) (level I); directions on decisions to be made by organizations and actors (level II); indirect influence over the way actors make decisions (level III); or, in broad terms, recommendations on general issues that should be engaged (level IV). Uncertainties over success conditions of plans are linked to the nature and range of those expectations, or, in other words, how unexpected effects are managed (Schippl and Fleischer, 2012). At level I uncertainty, success conditions assume that changes observed in reality must fit all previsions of the plan as close as possible (e.g. definition of targets). At level II, success conditions are set in terms of progress and achievement towards more general planning goals; decisions are governed by preferences towards intended effects, while unintended effects are managed as risks. At level III, success conditions relate to the capacity of plans for creating agreement frameworks, in such a way that potential surprises related to policy-maker actions can be overcome (Boelens, 2011; Koppenjan et al., 2011). At level IV, the success of plans is limited to basic acknowledgement of issues, which can set the difference between being prepared or not to address the most unexpected consequences of decisions.

Dimension of planning	Level 1	Level 2	Level 3	Level 4
Success conditions (what expectations exist?)	targets	achievements	agreements	acknowledgements
Implementations (where are expectations placed?)	applications	directions	influences	discussions/ references
e.g. what transformations are plans expected to make in Granada following the LRT implementation?				
Lvl. 1	Infrastructure plans incorporate monitoring indicators related to number of public-transport stops per inhabitant; in addition, they fix quantitative targets related to LRT average frequency (8 minutes).			
Lvl. 2	Multi-modality guidelines are promoted in regional infrastructure-plans, which create a directive framework for city interventions in transport systems, such as park-and-rides, multi-modal facilities, inter-service coordination, etc.			
Lvl. 3	The LRT project is expected to influence the definition of corridors and services-sharing conditions for the next concession of metropolitan bus services. In this sense, the LRT has created a background for setting agreement between urban and metropolitan transport operators.			
Lvl. 4	Regional-infrastructure plans include broad references to a “sustainable urban mobility model”, which, without more in-detail specifications, aims to raise concern and stir up debate before future environmental challenges (e.g. peak-oil, climate change, etc.).			

Table 6 - Uncertainties from layer 3: outputs.

5 CONCLUSIONS

The recognition of uncertainties in transport planning has been traditionally used as a provisional closure for technical questions, for avoiding conflicting topics or, on the other hand, as a call for straight action (Marsden et al., 2012; Rayner, 2004; Salet et al., 2013). Conversely, this research argues that many useful interrogatives can be opened after uncertainty has been acknowledged. But, how can uncertainties faced by transport planners and policy-makers be framed and compared? To address this, a heuristic framework was developed to explore situations of uncertainty at four distinct levels (reducible, shallow, deep and radical), concerning three layers of planning: planning reality, planning process and planning products. Some concluding remarks are made:

Framing uncertainties. Compared with theoretical insights to uncertainty, both conceptual (Brown, 2004; Hansson, 1996) and mathematical (Kikuchi and Pursula, 1998; Kronprasert and Talvitie, 2015), a rather practical and intuitive approach was used. This heuristic character has been proven useful for processing and comparing references from a wide and disperse range of research fields within transport planning (i.e. decision-making, modelling, scenario planning, transport policies and governance, etc.). Furthermore, the understanding of uncertainty across methodological boundaries and planning paradigms is considered central here (Khisty and Arslan, 2005; Martens and van Weelden, 2014; Tapio, 1996). This framework offers an excellent platform for (re)formulating further research questions on how specific situations of uncertainty are perceived and handled by actors involved in transport planning.

The communicative approach. Positivistic approaches seldom explain uncertainties beyond levels I or II (reducible or shallow), ignoring the more extreme and complex situations described by transport-planning literature (i.e. “black swans”, “wicked problems”, adaptive or flexible planning approaches…) (Lyons, 2016). While the “uncertainty paradox” (see Section 1) prevents any effort from actually “knowing uncertainty”, it leaves space for creating a common language for understanding its implications in planning. This research contributes to making explicit differences between grounds and values in planning actors, and to creating flexible frameworks for communicating uncertainties within a transactional planning environment, that is, where conditions of “truth”, expertise and knowledge validity are constantly bargained (Abbott, 2005).

Lastly, this study was motivated by the challenge that emerged during the search for new scopes on scenario building in transport policy. Such insights demand new theoretical and practical foundations for understanding the role of scenario exercises in building meaningful futures (i.e. plausible, consistent, desired, challenging, etc.), while managing the uncertainty deriving from its conceptualization, expectations and use in practice. In addition, a framework for exploring uncertainties may enable new branches of research, focused on empirical and experiential exercises (in real planning conditions or controlled experiments) about how actors relate specific layers, features and dimensions of transport planning with uncertainty and how comfortable they feel under different levels of uncertainty. In this way, more suitable context-sensitive planning tools can be offered in the future.

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