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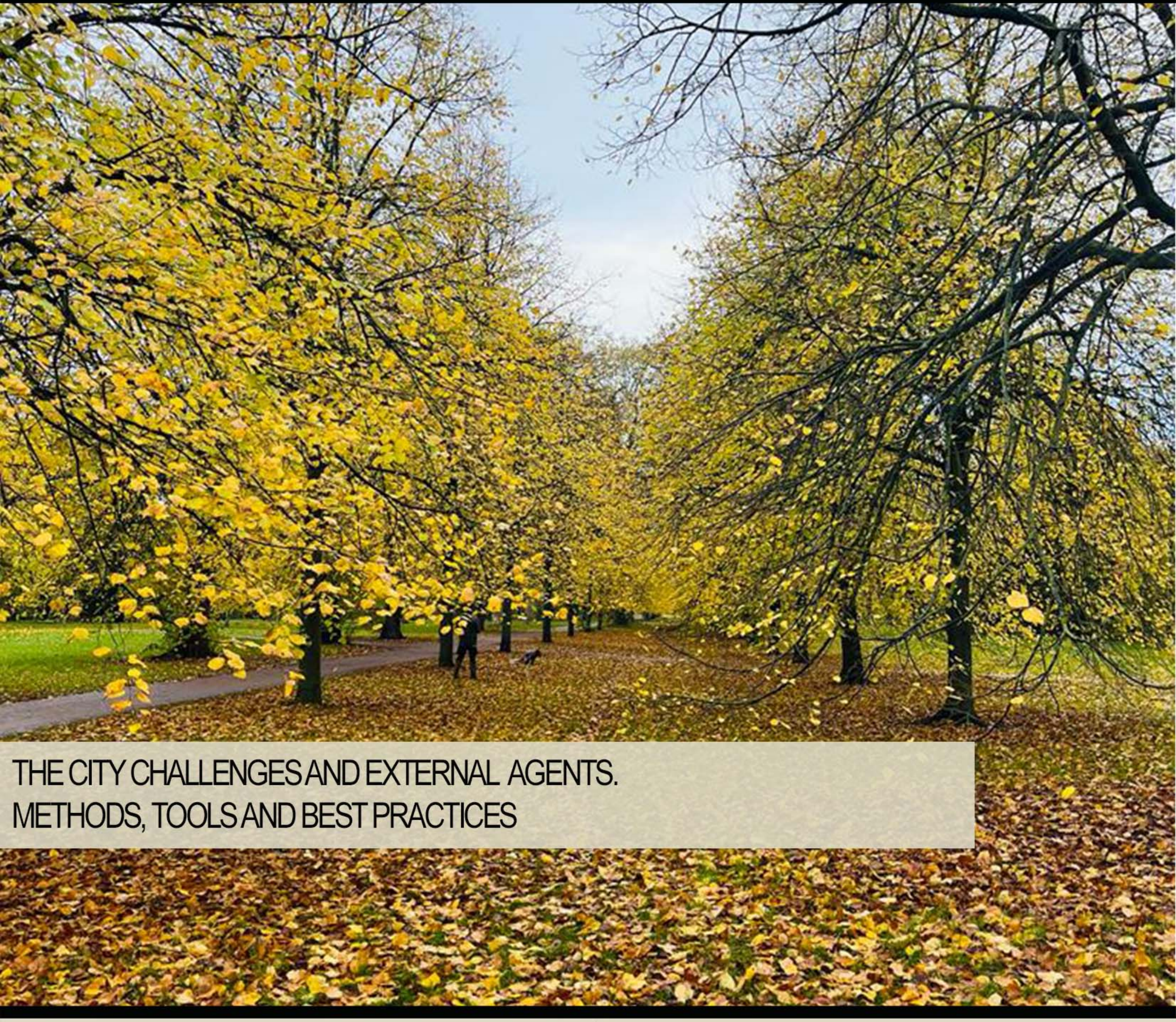

THE CITY CHALLENGES AND EXTERNAL AGENTS.
METHODS, TOOLS AND BEST PRACTICES

Vol.16 n.3 December 2023

print ISSN 1970-9889 e-ISSN 1970-9870
University of Naples Federico II

TeMA

Journal of
Land Use, Mobility and Environment

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3 (2023)

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

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Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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The cover image shows a view of Hyde Park in London (United Kingdom) during the autumn season.
The photo was taken by Enrica Papa in November 2023.

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Contents

REVIEW NOTES

TeMA

Journal of
Land Use, Mobility and Environment

TeMA 3 (2023) 479-497
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/10325
Received 12th October 2023, Accepted 17th December 2023, Available online 30th December 2023

The evolving regional transport planning: the case of Piedmont region

A tribute to the work of Sergio Cristoforo Bertuglia

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Abstract
An overview of the four Regional Transport Plans (RTPs) laid out in Piedmont since the late 1970s is presented. Three different although interwoven perspectives of analysis are proposed.
The first perspective, denoted as functional, takes into account the principal functions of transport planning and outlines their changes across the regional plans. The second, labelled as organizational, adopts a system based view of transport planning and shows how, over time, the organization of the activities has become progressively more complex. The third perspective, called knowledge based, highlights some salient features of the approaches which have been applied during the forty years of the regional planning activities. The knowledge based perspective, in particular, allows us to appreciate Sergio Cristoforo Bertuglia's contributions to the investigation of the Piedmont transport system and to the development of effective modelling tools to support policy activities.
A claim is made that these arguments are particularly relevant for the so-called reflexive dimension of transport planning which cuts across the other two main dimensions, the theoretical and procedural. Developing the reflexive dimension, in fact, is a major challenge in today planning efforts oriented at sustainability.

Keywords
Regional transport planning; Planning dimensions; Mobility changes; Land-use transport models.

How to cite item in APA format
Occelli, S. (2023). The evolving regional transport planning: the case of Piedmont region. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (3), 479-497. http://dx.doi.org/10.6092/1970-9870/10325

1. Introduction

Activities, land use and transportation are part of the human activity systems, at the different spatial scales. Dealing with their relationships over long, medium and short term periods is at the core of transportation planning. Its purpose is to design, provide and manage facilities and services for making people and goods to move in safe, fast, convenient, comfortable, economical and environment-friendly ways.

Transportation planning activities belong to a set of organizations, people, processes, and institutions that have the legitimate authority to take demands for transportation structures (e.g., roads, railways, regulations, safety programs) and translate them into specific public goods and services (Transportation Research Board, 2014). All these elements form broad socio-technical systems, whose elements do not function on their own, but are actively created and maintained by human actors, through knowledge exchanges, to close the gap between transport needs and technical performance (Withworth, 2009; Occelli, 2019). On a conceptual ground, transportation planning dwells upon three main dimensions, theoretical, procedural and reflexive. The theoretical dimension refers to the set of constructs and propositions that are established to achieve particular objectives relating to socio-economic development, the functioning and performance of the transport system (Rodrigue et al., 2006). The process dimension defines how a transportation plan is put into practice. It has three basic components (Pas, 1996), often interlinked in various ways depending on the type and level of actors' involvement: a. assessment of travel needs and goals' setting; b. formulation of planning alternatives and analysis; c. implementation of the chosen program and project management (monitoring an evaluation). The reflexive dimension cuts across the previous ones and purports to improve understanding of how planning operates (Howe & Langdon, 2002). This is an intellectual endeavor which shapes how values, actions, and outcomes are linked together in setting the conditions for the mutual development of the theoretical and process dimensions (Occelli, 2018).

Since the late 1950s, changes in the transport socio-technical system and societal determinants - such as those related to the urban socio-economic and spatial development, technological progress, and life-style - have greatly diversified transport issues thus affecting its theoretical, procedural and reflexive dimensions.

Phenomena, such as the levelling off of car travels, energy shortage, decoupling of economic growth and transportation, carbon emissions, in particular, have raised new challenges for the transport planning's theoretical dimension, while calling for a transition to more sustainable systems (Elzen et al., 2004; Guida, 2023; Mazzeo, 2013; Papa et al., 2017; Schiller et al., 2010; Pinto & Zucaro, 2012, Transportation Research Board, 2014).

Shifts in planning styles and in the procedural dimension have also taken place. For example, Innes & Booher (2003) identified four of them: the earliest one was the technical bureaucratic approach, which works best where diversity and interdependence among interests are low (technicians and bureaucracies need to respond to a single set of goals and decision maker); the political influence approach which became popular in the late seventies, is most suited to deal with diverse interests, mostly focused on achieving their own goals -; the social movement approach which appeared in eighties recognizes the importance of interdependence among a coalition of interests and individuals, but does not account for the full diversity of interests; the latest collaborative approach makes an effort to deal with both diversity and interdependences.

Awareness of transport negative externalities and uncertainty over the nature and extent of future (car) travel demand (Lyons & Davidson, 2016; Marsden & McDonald, 2019), furthermore, have made apparent the complexity of many planning situations. They are calling for an enhanced role of the reflexive dimension to strengthen the organizational capacity of the transport socio-technical system, and specifically of the agencies having institutional planning responsibilities (Cascetta et al., 2015; Landini & Occelli, 2021; Occelli, 2018).

To ground the discussion, in the following section, an overview of the 4 Regional Transport Plans (RTPs) which have been laid out in Piedmont is presented. Three different observation lens are proposed which although they have no theoretical bearing, suggest instrumental perspectives for grasping the kind of changes which took place in the region over more than fifty years. The first, denoted as functional, takes into account the principal functions of transport planning and outlines their changes across the regional plans. The second, labelled as organizational, adopts a system based view of transport planning and shows how, over time, the organization of the activities has become progressively more complex. The third perspective, called knowledge based, makes reference to the literature and highlights the salient features of the theoretical and methodological approaches which marked the development path of transport planning studies.

This perspective, particularly, helps us appreciate Prof. Bertuglia's contributions to the investigation of the Piedmont transport system and more generally, to the development of policy-oriented knowledge tools. This is presented in the third section where insights of his academic work about the land-use transport system are outlined.

Finally, in the last section a few suggestions for future research are put forward and the legacy of Prof. Bertuglia's work is emphasized.

2. Perspectives of analysis of Piedmont transport plans

Since the establishment of the Italian regional authorities in the mid-seventies four transportation plans were laid out - in Piedmont. Only two, the earliest and the most recent one were adopted and operationalised (Regione Piemonte, 1979, 1994, 2004, 2018).

The planning activity extends over nearly five decades at the turn of the II and III millennium and was affected by various epochal trends which affected the regional system in those years, e. g. the transition to a post-fordist society, the globalization of the economy, the institutional decentralization, the establishment of the EURO, the increasing pervasiveness of the digital technology. Fully assessing its long-term evolution, therefore, would require fine-tuned conceptualization and investigation efforts which go beyond the aims of this study (an exemplary case in this regard is the analysis of the changes in transport planning in California by Innes & Gruber, 2001). Here a preliminary investigation is carried out by examining the available published documents through three different but complementary perspectives of analysis each of which suggests a possible observation lens of planning activities.

The first perspective gives a general account of the regional plans. It emphasizes how the principal functions of transport planning changed over time (the functional perspective). The second (organizational perspective), adopts a system-based view of transport planning and shows how, in the study period, the organization of the activities has become progressively more complex. The third perspective, called knowledge based, highlights some distinguishing features which characterized the knowledge tools and approaches developed in the period covered by the different plans.

2.1 The functional perspective

To achieve a set of desired community goals, actors engaged in planning activities, including transport, carry out a set of functions such as needs assessment, budgeting, planning and programming, service delivery, education and outreach (Transportation Research Board, 2014). To account for the functions performed by the Piedmont transport plans, a few descriptive keys have been selected which relate to:

- plan steering activities, commonly acknowledged as process and governance, which account for plan issues, goals and types of actors involved;
- plan design and contents which primarily concern questions regarding plan overall structure, the strategy adopted to deliver transport service, the role assigned to the transport infrastructure and the reference approach chosen for implementing the plan;
- decision-making which deals with how decisions are committed to actions (programming), including assignments of the financial resources necessary to realize the designed interventions.

As a background of the context in which the regional plans were developed, a general descriptive key has been added which captures its salient institutional and societal features.

Results of the application of these descriptive keys, (see Table 1), provide a comparative reading of the main facets of the four Regional Transport Plans (RTPs), and of the changes which occurred in the transport planning functions between the late 1970s and 2010s.

A major aspect which is made apparent by these changes is that the understanding of the main issues of transport in the development path of the region has progressively extended: more specifically, over time the roles of the transportation infrastructures (and related services) have diversified and evolved from a basic growth factor to an essential multifaceted development element of the regional system. It is no coincidence that the II and III plans, got the additional label of transport and communication plan and the latest one was named regional mobility and transport plan.

Awareness of the broadened role of transport is clearly reflected in the evolving formulation of planning goals and enlargement of the group of actors participating in the planning activities.

The earliest plan (I RTP) was aimed at equipping Piedmont with adequate infrastructure, promoting a more balanced socio-economic and spatial regional development and contributing to the National Transport Plan. Two main actors, the regional/district transport officials and the (regional) experts in the field had a main responsibility in developing the plan. to were the main actors committed to develop the plan. who took part in the planning activities.

In the 1990s, the burdens of financial and institutional capacities for local authorities became more apparent and affected plan process and governance. Financial problems were given priority attention in the II RT&CP which aimed to strengthen transport infrastructures and services. Capacity obligations were more evident in the III RT&CP whose main goals were to ensure adequate standards of accessibility, effectiveness/efficiency, safety, internalizing external costs. To deal with the issues, plan's steering group was extended to include, local authorities transport providers and social actors.

The latest regional plan (IV RM&P) marks a major shift from the previous ones. It commits transport sector to the overarching goals of sustainable development.[1] This requires to move forward the plan's horizon and consequently extend the plan's duration: from approximately 10 to 30 years in order to make it possible to realize the desired transition. Stakeholders' participation is a main requirement in the IVT RM&TP, although its role in the different steps of the plan's pathway being flexible is left undefined, being limited to the consultation stage.

As for the changes in the plan's steering group two facts are worth noting.

The first is that the regional authority (the regional transport department) has a pivotal role in all plans but its centrality takes different form across plans.

- It has a main responsibility in designing plan's actions and ensuring their implementation, primarily by providing the necessary financial resources (I RTP);
- It supports negotiations among plan's actors for realizing plan's projects (II RT&CP);
- It lays out plan's guidelines and promotes coordination of local authorities' functions (III RT&CP).

[1] The notion of sustainability embraced by the plan adheres to the one stated by the European Union Council of Ministers for Transport and Telecommunications (2001), according to which a sustainable transport-socio technical system (1) allows the basic access and development needs of individuals, companies, and society to be met safely and in a manner consistent with human and ecosystem health and promotes equity within and between successive generations; (2) is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development; and (3) limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

- It sets out plan's strategic goals and coordinated committees among regional departments and within the transport department itself, to manage plan's developmental path and ensure its coherence with the broader regional development framework (IV RTP).

		1979 RTP	1997 RT&CP	2004 RT&CP	2018 RM&TP
Institutional and societal context		The region as a new institutional actor	Regional decentralisation and local development	Shared functional competences by state and regions. The impact of EURO. Progress in telecommunication networks	Sustainability, climate change and the economic crisis
Process and governance	Main issues	The role of transport infrastructure and services to contrast uneven spatial development	Ensuring the financial sustainability of transport services	A. Changing person and freight mobility; B. ITS and traffic management; C. Road maintenance and safety	A. Transport externalities; B. Spatial sprawl and environmental issues; C. Diversification of mobility demand; D. Local governance
	Planning goals	To curb polarised regional growth and support a more even spatial development	A. improve interregional connections; B. Managing mobility; C. Support transport funding	A. Increase intra-regional accessibility; B. Make mobility more efficient; C. Promote integration among transport services; D. Extend ITS applications; E. Internalize transport externalities	(8) Strategic action domains and associated targets are identified in relation to Social, Economic and Environmental Sustainability (SEES) principles
	Steering actors	Transport and Planning departments, research centres, local planning committees	Transport Department oversees negotiations and partnership among local actors	Transport Department coordinates transport functions and competences of local authorities	Political and technical committees are established to coordinate interventions at regional level. Stakeholders are involved at both regional and local levels
Plan design	How the plan is structured	By competence level (national or regional) and type of infrastructure (rail, road, airport)	By design stage: analysis, goal definition, projects, implementation	By action domains: A. Accessibility improvement; B. Mobility efficiency (e.g. road safety, PT, pollutions); C. Institutional innovation; D. Plan management (monitoring and evaluation); E. local area development	By strategic components: A. Goal related action domains; B. Regional transport sectoral plans (e.g. public transport, freights); C. Local transport and mobility plans
	Service delivery strategy	A. Integration of PT services. B. Identification of freight centres	A. Modernization of the transport network; B. Re-organization of competences and procedures	A. Application of EU ICT regulations for managing road congestion and safety. B. Road maintenance	According to tailored sub-regional SEES action domains
	Transport infrastructure	By network (problem) hierarchy: 1. the rail network as the main backbone; 2. the road network to alleviate metropolitan congestion and connect remote areas	By functional role of transport networks; 1. International and national; 2. Regional: 3. Urban	By level of network organization: A. National and international and B. Regional	By the functional hierarchy of networks: A. Main rail infrastructure; B. Regional transport corridors; C. Secondary transport lines
	Approach to implementation	An implementation pathway is defined, including administrative and technical aspects	A reference system is acknowledged: A. system values; B. Design criteria; C. Target values	Relevant information sources are envisaged: A. Regional Transport information System; B. Mobility observatory; C. Road cadastre; D. PT observatory	A set of effect and outcome indicators are defined according to the chosen action domains. They will serve for plan monitoring and assessment
Decision making	Programming	By working groups involving the relevant actors	By leveraging the set of regulations and norms	By design stage. The plan sets the stages for its implementation. A. Adoption by the regional council; B. Sectoral guidelines; C. Design of integrated land-use transport projects with local authorities; D. Definition of an evaluation strategy; E. Project implementation and procedures	By design strategy. It prompts a 30 year planning process involving public and private stakeholders. Guidelines deal with: a) a future-oriented vision centred on SEES principles; b) institutional capability and governance; c) plan performance and evaluation

Resources	Project funding is distinguished by national and regional competences. Criteria are provided to allocate financial resources to PT in local areas	Costs are estimated according to goals and financed through public-private partnerships. Budget is assigned according to institutional actor types	Financing is addressed when laying out sectoral and local plans	Funding is dealt with when implementing sectoral and local plans, by pooling available resources

Tab.1 An overview of the Piedmont Transport Plans

The second is that the actors involved in laying out the plan not only increase in number to address the different plan issues but diversify, hence increasing the risk of conflicts. The II RT&CP takes note of this and proposes a specific communication activity to inform the general public about the costs and benefits of the actions envisaged by the Plan. The issue of conflict management is not explicitly dealt with in the later plans, although III RT&CP acknowledges the need of appropriate consultation procedures to implement (integrated) projects at local level. Transport networks, Public Transport (PT) services, inter-modality are essential invariant topics in all plans. What distinguishes them across the different plans is how solutions are crafted by plans' specific "action bundles", as they result from their profile and identification approaches. In particular, two main aspects are worth noting.

The first is the attempt to treat the topics in a more comprehensive way as, over time, diversification in transport demand, and more generally, in socio-economic situations is acknowledged, locally and internationally. This is particularly evident in the treatment of transport infrastructures and networks: the I RTP distinguishes them by territorial scale and competence of the transport service providers; the II RT&CP emphasizes their different functional role and the opportunity of their integration; the III RT&CP highlights their complementarities in order to deliver better mobility services and increase road safety; the latest plan, finally, fully acknowledges the potential of digital networks to exploit these complementarities, support transport networks and deliver more sustainable services.

The second and perhaps most relevant aspect is the increasing attention to plans' outcomes, and namely to the fact that the designed action bundles should ensure adequate performance level regarding efficiency and effectiveness (as firstly introduced in the II RT&CP), safety improvements (see the III RT&CP) and reduction/mitigation of transport externalities (in particular in the IV RM&TP).

The growing attention at evaluation, in particular, may well reflect the expanding role of the planning reflexive dimension (Occelli, 2018) and its underlying features, related to values, well-being and equity. Advancements can be observed from:

- the I RTP which provided general indications to identify plan's actions (I TRP);
- to the II RT&CP which maintained that the design of projects should be based to explicitly stated values and procedural criteria;
- to the latest plan's approaches which acknowledge the need of regular monitoring activities in order to get information about plans' results, assess their impact on the regional society and environment, and update current plan's actions. In the IV RM&TP, in particular, the future-oriented perspective has a substantial relevance as sustainability principles command new ways to understand the overall plan implementation pathway. Distinguishing features in this respect are: a. the attention paid to institutional capability and governance and the focus on plan performance and evaluation.

2.2 The organizational perspective

The above discussion clearly shows that in the study period, plan issues and functions diversified and the transport planning system became more complex. To provide additional insights into the arguments, reference is made to a cybernetic inspired interpretation of system functioning, based on the notions of steering, operational and information systems discussed by Donnadieu & Karsky(2002) and Le Moigne (2006). These notions capture intrinsic abilities of systems to adapt to a changing environment. More specifically:

- the notion of steering posits the fact that systems are endowed with some mechanisms for taking decisions (setting goals), controlling and regulating their behavior in a varying environment; to do that they gather, manage and process information;
- the notion of operational system accounts for the actions systems perform to maintain and transform (reproduce) themselves;
- the information system can be viewed as an interface for coupling the steering and operational systems; by means of data, information and their interpretations it makes it possible to both derive representations of the environment and inform the actions to be carried out.

The scientists mentioned above also point out that depending on the structure of the three systems, different levels of organization can be distinguished. For example, the lowest level (e.g. the homeostasis) would correspond to a situation in which the decision process consists of negative feed-backs to attune the detected signals from the environment to certain threshold values. As the ability to filter and memorize information increases and the relationships among the steering, operational and information systems consolidate the organizational level rises. Human systems are endowed with unique reflexive properties and occupy the highest organization levels which concern auto-finalization: in fact, they can design their own transformation processes, by setting specific goals, generating the needed information, devising the actions, handling their implementation and observing their impact. By applying the above notions, the organization of the regional transport plans can be represented in the schemes of Fig. 1. As described in Table 11, two additional elements have been added concerning the principles underlying plans and the set of involved actors. Notwithstanding their sketchy descriptions, the schemes make it possible to appreciate how the organization of planning altered in the study period as system components developed and relationships became more entangled as some feed-back loops were reinforced and feed-forward loops added. They also highlight that the principles guiding plan design have been gradually refined and that their application has involved an increasingly greater number of diverse actors. To some extent, the observed changes mirror the shift in planning styles pointed out by Innes & Booher (2003).

The schemes ultimately offer a view of how the organization of the regional transport planning system may have developed over the years. To what extent this progress would have been associated with an increased planning capacity and correspondingly higher maturity levels, as argued by Transportation Research Board (2014) is an open research question.

Progress can be evaluated from a twofold position. An external one, that makes it possible to observe how organizational forms, resulting from the interlinking of system components, actors, and planning principles, would produce the desired outcomes. An internal view that, because of the potential of new information system, recognizes actors' different ways and capabilities to engage in and realize plan's interventions.

How these two positions intertwine is one major topic of enquire for the reflexive dimension of transportation planning, and its related issues of governing the transport socio-technical system (Kooiman et al., 2008; Talia, 2021). Related to this are thorny arguments about plan's assessment and performance measures. They can be interpreted in different ways (Innes & Gruber, 2001). One major view, maintains that the purpose of performance measures is about accountability of an agency to its specific mandate. A second one is that these measures are yardsticks to measure results and overall quality of service and to rate investment options. A third more extensive view, which is most prominent in the IV RM&TP, holds that planning assessment is about how a region or community is doing globally according to broad criteria of interest to people in the region. Its purpose is to help a community appraise its situation, diagnose the problem and identify what kinds of changes should be made and by whom.

The discussion of the knowledge based perspective in the following section is meant to address some of the issues: improving the learning capability of the different actors engaged in planning activities, in fact, is a challenging undertaking worth being pursued in the future.

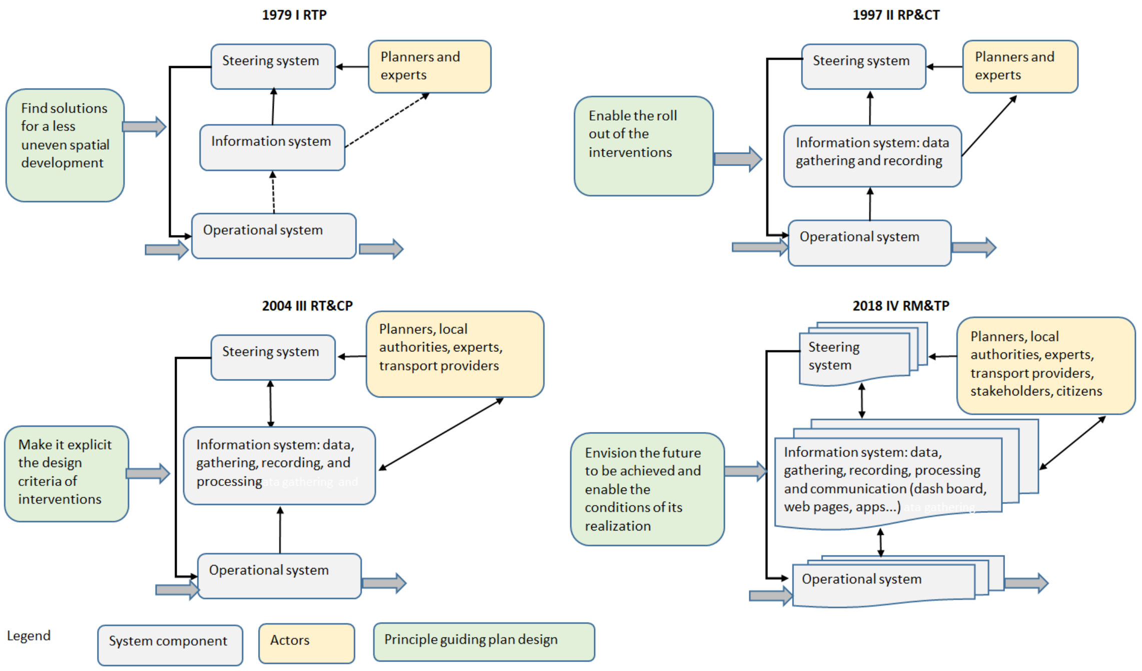

Fig.1 Progress in the organization of regional transport planning in Piedmont

2.2 The knowledge based perspective

This perspective is logically related to the "information system" component shown in Fig.1. The ultimate objective is to make available analytical tools combining theoretical approaches, methods and data to assist in the understanding of travel behavior and designing efficient infrastructure and services to meet mobility needs.

Existing documents about Piedmont transportation plans do not give clear evidence of the applied analytical tools, although a few of them were used in the preparatory studies. Only the 2018 RM&TP which has a long time horizon acknowledges the use of indicators to set plan's targets and monitor goals' achievement.

To overcome this lacking, attention is turned to the literature and an effort is made to outline the evolution of this perspective. Although sketchy, the account can provide a general reference also for the Piedmont case. Furthermore, it helps positioning some of the work of Prof. Bertuglia about the relationships between the city and the transport system (see 3).

A wide array of analytical tools is used in transportation planning which includes contributions from a range of different disciplines in the engineer and social fields. Their development occurred rather pragmatically, spurred by the need to make it available policy support tools attuned with the issues raised by societal changes (Gärling et al., 1998, Goulias Ed. 2003, Hensher & Button, 2007, Ortúzar & Willumsen, 2011; Rich, 2015). Computational requirements, as in the case of operational urban and regional models (Batty, 2008), have driven the way the tools have been constructed, and set the operational possibilities for incorporating different theoretical insights and available data.

Overall, the domain can be thought as an eco-system consisting of various types of knowledge approaches, including:

- analytical tools, e.g. travel models (Bhat & Koppelman, 2003; Goulias, 2018; Sharma et al., 2021), GIS applications (Liu et al., 2023), performance indicators (Clarke & Wilson, 1994; National Academies of

Sciences, Engineering and Medicine, 2022a), multi-criteria analysis (Macharis & Bernardini, 2015), Geographical Information Systems and participatory platforms (Giuffrida et al., 2019; Ward, 2001);

- and a set of research areas themselves exploiting and providing stimuli to the development of the analytical tools, e.g. urban spatial development (Bertuglia et al., 2003; OECD, 2018; Vitale Brovarone, 2010), behavior in space (Montello Ed., 2008), Information and Communication Technologies (Salomon & Mokhtarian, 2007; Mokhtarian & Tal, 2013), accessibility (Bellomo & Occelli, 2000; Miller, 2018a; National Academies of Sciences, Engineering and Medicine, 2022b; Papa et al., 2016), energy transition (Geels et al., 2017).

Among the travel models, the 4 Four Step Model (4SM) and the Activity Based Approach (ABA) stand out most prominently, as they represent chief conceptual references to model activity-transport relationships, at the aggregated and disaggregated level respectively: in the former individual person trips are a function of demographics and the organization of land-uses, in the latter the need to travel derives from the need to perform activities, Tab.2.

Introduced in the late 1950s during a period of rapid growth in population and economic activity, the 4SM, was developed to evaluate the impact of capital-intensive infrastructure investment projects (McNally, 2007). Over time, it has been significantly enhanced and modified but still retains the standard (four step) framework (Wilson, 1990). It posits trips as the fundamental unit of analysis. This first step, trip generation, determines the frequency of origins or destinations of trips in each zone by trip purpose, as a function of land uses and household demographics, and other socio-economic factors. In the (usual) second step, trip distribution, trip productions are distributed in proportion to the estimated attraction distribution and estimates of travel impedance (time or generalized cost) yielding trip tables of person-trip demands. The third step, mode choice, computes the proportion of trips between each origin and destination that use a particular transportation mode. Finally, the fourth step, route choice, assigns the modal trip tables to mode-specific transport networks.

The Activity Based Approach made its appearance in the 1970s motivated by new kind of travel demands associated with the fundamental changes in urban, environmental, and energy policy (Bhat and Koppelman, 2003; McNally and Rindt, 2008). It proposes a different way of thinking about transport as compared to the 4-stage model. The main idea is that people's activities are the "driver" for transport which themselves depend on norms and on the distribution of environmental resources among various land-uses and social organizations.

Features	**Four Step Model (4SM)**	**Activity Based Approach (ABA)**
Context	Post-war economic and urban growths	Urban transitions and acknowledgment of the dysfunctional impacts of congestion
Main policy questions	Expansion of transportation infrastructure and services	Management of transportation systems and services
Views of the transport demand	Travel demand is a direct function of demographics and land-use organization	The need of travel depends on the need to perform activities. These are spatially distributed and depend on the distribution of resources among organizations, land-uses, and social structures
Modelling aims	Evaluate the impact of capital-intensive infrastructure investment Trips should be forecasted in order to provide the necessary infrastructures (the who, what, where and how many trips)	Analysis of travel as daily or multi-day patterns of behaviour. Understanding activity behaviour is key to explain travel behaviour (the why of activities)
Approaches	Spatial interaction, Econometrics, Entropy maximisation, Utility maximisation	Space-time approach, RUM and discrete choice, Computational process model

Tab.2 A comparison of the Four Step Model (4SM) and the Activity Based Approach (ABA)

These activities are viewed as episodes (characterized by starting time, duration, and ending time), and they are arranged in a sequence forming a pattern of behavior that can be distinguished from others. The central focus of ABA models, then, is whether, when, and where to participate in activities and for how long. Travel is a derived demand resulting from the need for people to engage in activities outside the home. Trips are a means to reach the locations of activities; decisions related to trip scheduling, such as mode and departure time, are made to accommodate desired arrival and departure times from activity sites.

Over the last decades, activity based models have progressively expanded, to account for the heterogeneity of individuals' travel behaviours in selecting mobility alternatives, depending on the daily needs of activity participation (Axhausen & Gärling, 1992; Horni et al., 2016), individuals' characteristics, and spatial-temporal constraints at both individual and urban levels (Hagerstrand, 1970).

Existing application models have adopted two main approaches, which are sometimes combined:

- utility-based econometric models which are systems of equations that capture relationships between individual-level socio-demographics and activity-travel environment to predict probabilities of decision outcomes. Grounded in discrete choice and random utility theory, these models rely on multinomial logit and nested logit probability formulations (McFadden, 2000);
- simulation methods for representing the individual travel demand process (Horni et al., 2016). These are highly dependent on the available input data. The more precise the data, the fewer methods or algorithms are needed to synthesize parts of the demand of an individual. Compared with the former theory driven approach, these methods are more flexible and make it possible to take into account the increasing diversity of the urban lifestyle, new tendencies in mobility behavior as well as environmental impacts of land-use and transport policies at the necessary spatial resolution. The downside of these approaches, however, is their reliance on large data sets and the burden of computation. They can be distinguished in:

  a. micro-simulation methods in which each unit is represented by a record containing a unique identifier and a set of associated attributes. A set of rules (deterministic or stochastic transition probabilities) are then applied to these units leading to simulated changes in state and behavior. The result is an estimate of the outcomes of applying these rules, possibly over many time steps, including both total overall aggregate change and (importantly) the way this change is distributed in the population or location that is being modelled (Birkin, 2021);

  b. rule-based computational process models that use a set of rules (e.g., choice heuristics) in the form of condition-action (if-then) pairs to specify how a task, such as household activity-travel sequencing is carried out. Rules can be defined by experts or extracted from data (Arentze & Timmerman, 2004);

  c. Agent Based Models (ABM) in which transport entities are represented by computer objects (agents) which autonomously work within an environment in pursuit of their agenda or goals and actively interact with other objects (agents) if necessary. In addition to the conventional modelling steps - e.g. design of the model application (purpose, scale, observation windows), calibration and validation -, their implementation entails specific efforts to define agent profiles and types (in relation to their features and functionalities), and design agent behaviors and rules of interactions. A number of multi-agent based, integrated microsimulation platforms exist today that make it possible to reproduce travel decisions for different modes and timeframes and have the potential to become the standard for activity-based modelling (Huang et al., 2022; Mehdizadeh et al., 2022).

The state-of-the-art of activity-based models is fairly advanced but their use is not widespread in planning practice, mostly because of the large number of possible travel portfolio, the greedy data requirements and computational burden (Tajaddini et al., 2020). Lately, hybrid approaches are being developed which bypass the complexity of their implementation while modelling disaggregate human mobility: for example, an application has been implemented which combines a trip-based model with mobility surveys (Adenaw & Quirin,

2020) or which applies a utility-maximizing approach through an agent-based, activity-based, multimodal simulator (SimMobility) to describe daily activity schedules (Viegas et al., 2018).
Efforts have also been made to improve the connection between a disaggregate activity based approach and an integrated activity-transport system models: long-term travel choices and daily activity trips have been linked to population changes, to information about commercial and special purpose travels and to network supply models (Castiglione et al., 2015).
Both the trip-based and activity based models, logically relate to comprehensive model systems, widely known as Land-Use Transport (LUT) models. They specifically deal with the interrelations between human activities and transport (Wegener, 1995, 2004):

- land uses affect the locations of human activities (living, working, shopping, education or leisure), whose functioning in space requires spatial interactions. To overcome the distance between locations, trips are produced which require transport infrastructure and services;
- transport infrastructure and services, on their turn, create opportunities for spatial interactions (and can be measured as accessibility). They influence the location decisions of activities and which produce changes of the land use system;
- Travel behaviors and transport infrastructure, in their turn, cause negative externalities, such as traffic accidents and environmental pollutions which can impinge on land use pattern and travel decisions.

These models have a long tradition which goes back to the seminal Lowry's "Model of a Metropolis" (Lowry, 1964). Substantial progress has been made since then (Miller, 2018b), which paralleled to some extent that made in travel modelling, as a result of advances in computing technologies and disaggregate modelling methodologies.
Today evolution in LUT modelling faces both theoretical and operational challenges. Among the former, future research areas include (Acheampong & Silva, 2015): a. understanding uncertainty propagation over time and across different model frameworks; b. integrating activity-based travel demand models; c. improving the model capabilities to handle environmental and energy questions; d. developing robust methodologies for measuring accessibility to adequately evaluate the effects of land-use policies on transportation and vice versa. Among the latter, a few important operational tasks have been identified (Moeckel et al., 2018) including data storage and exchange formats, open source platforms, and model documentation and tutorials. Education and model extensibility, that is building models that are tailored to the task at hand but are flexible enough to permit new requirements, are two additional issues deserving attention. As for education, universities have the responsibility to nurture understanding of and working with integrated models; agencies have the responsibility to enable integrated model prototypes to reach a next maturity level.
Furthermore, the unprecedented changes in the transport sector triggered by new technology and services, e.g. autonomous vehicles, IoT, IA, Big Data, raise questions about the adequacy of the current modelling approaches. The arguments are not new in the literature and some of them have already called for enhanced ways to know and understand the world, based on generative epistemology and novel approaches, such as those enabled by simulation experiments (Epstein, 2006; Terna et. al., Eds., 2006; Partanen, 2022).
As for travelling, more specifically, the future generation of modelling is expected to (Miller, 2018d)[2]: a. better understand the reasons of travels. In this respect, one possible strategy suggested by Mc Fadden (2000) would be to combine psychological and consumer behavior theory through a comprehensive research effort that identified the attitudes that are most relevant to travel behavior, and devised reliable methods for scaling these attitudes and relating them; b. encourage model experimentation; c. pay more attention at an appropriately balanced aggregated-disaggregated approach in choosing the simulation approach (Miller,

[2] It is worth noting that some of the remarks about advances in theoretical knowledge and model experimentation were already present on the research agenda of planning-based models laid out in the late 1950s (Voorhrees, 1959).

2018c); d. explore the possibilities of linking existing datasets and take advantage of using high performance computing.

Eventually, these foreseen changes in the application of knowledge tools reflect some consequences of the increasing complexity in the transport planning issues and organization as made apparent by the Piedmont regional case.

3. A learning environment to nurture planning capabilities

Learning about the urban system and the ways to treat urban phenomena in order to make planning more effective have been a major undertaking in Prof. Bertuglia's work, both as a researcher above all during his earlier years at the regional Socioeconomic Research Institute of Piedmont (Ires Piemonte), and as a scholar along his longstanding academic career, from the mid-seventies of the previous century to the early twenties of this century. Arguments about the activity-transport system planning addressed in the previous section allow us to highlight some of his contributions primarily related to the ecosystem's components of the knowledge perspective mentioned in 2.3.

Fostering the use of sound planning oriented analytical tools has been a major effort since the beginning of his activity at Ires in the 1970s, when the Institute was committed to deliver preparatory studies for the Piedmont Regional Transport Plan and Turin Town Plan.

One of the these, dealt with the implementation of a 4TH model (Bertuglia et al., 1984) and the definition of transport planning guidelines through model's applications. The guidelines, pblished in 1979 with Tadei et al. (1979), and were among the first to appear in Italy.

Another challenging research effort in the 1980s was the development of a LUT model of the Turin area, as a background study for the Turin town plan (Bertuglia et al., 1980). Residential location process was at the core of the overall model, which also included population, basic and service employments, housing, land-use and transport sub-models (the latter was represented by exogenous tables of travel times). A Lowry-type causal scheme (Lowry, 1964) and a comparative static approach underpinned the model structure; entropy maximization (Wilson, 1970) and Forrester system dynamic (Forrester, 1964) approaches were used in the mathematical formulation. The impact of a few scenarios of the spatial expansion of the city were simulated along with transport measures affecting travel times (Bertuglia et al., 1986).

It is worth noting that these studies represented exemplary cases in the 80s' Italian context, where the use of quantitative methods in planning was not yet widespread.

The relationships between human activity and transport systems were once more a major theme in a few studies carried out from the middle of 1980 to the late 1990s as a part of major transport projects of the Italian Consiglio Nazionale delle Ricerche (1998). Two main lines of research stand out most prominently.

The first (carried out in PFT1) took up the challenges of providing unified field for the development of LUT models. To do this, an international group of scholars was involved to discuss the different types of approaches to LUT modelling, e.g. economic approach, operational research, spatial interaction and probabilistic approaches, and investigate the possibilities of integration (Bertuglia et al., 1987). A main claim was that this integration should be pursued through a formalizing approach and the topic was expanded in a subsequent research that specifically addressed the problems of the different speeds of changes of the LUT sub-systems. An attempt was made to advance the building of an integrated LUT model by attempting to give empirically oriented but operational approaches, such as those based on spatial interaction, with a more theoretical understanding of urban phenomena such as that provided by economic theory. A framework is suggested which articulates model components, sub-systems and possible approaches to be used for modelling the adjustments for specific component and subsystem areas (Bertuglia et al., 1990).

Consonant with the themes of the PFT2 project, the second line of research focused on the investigation of the impacts of technological innovation and, in particular of the Information and Communication Technologies on the human activity and transport system. As in the earlier works, collaborations with scholars from different disciplines and countries made it possible to probe into the several facets of the relationships between technological change, economic development and space. First, the main arguments that economic development is to a large extent a transformation process shaped by local factors and (often exogenous) technology were reviewed (Bertuglia et al., 1995). Then attention turned to the relatively less researched topic concerning the processes through which the diffusion and adoption of new technological changes occur in the context of space-time dynamics (Bertuglia et al., 1997). A latest contribution (Batten et al. Eds., 2000) suggested that the impact of technological progress on urban evolution needed to be examined in a broader perspective. In an evolving and more educated society, in fact, learning and collective knowledge exchange, through advanced infrastructure networks, are key drivers of innovation in a spatial setting.

Intertwined with the above works there were some complementary research interests some of which became prominent in subsequent years.

One of these dealt with the expanding role of analytical tools in planning practice. A comprehensive presentation in Bertuglia (1991), bestowed the author's understanding of the human activity and transport system, henceforth referred to as the urban system, and discussed the potential of using model based analytical tools in planning. The contribution paid special attention at showing how a set of indicators based on the principles of spatial interaction could be computed, building on urban model outputs (Bertuglia et al., 1994) and also used in multi-criteria analysis to assess plan alternatives (Bertuglia et al., 1992; Bertuglia et al., 1988). It was part of a major publication effort which collected essays about the overarching theme of city evolution and management prepared for the 1989 IASI-CNR continuing education course, "Techniques and models for regional programming" (Bertuglia & La Bella, 1991).

To some extent, that book set the stage for a stronger commitment to foster, primarily in Italy, a collective thinking effort at recognizing and managing the problems of today and tomorrow cities.

The challenge was taken up in a seminar, held in Perugia in 1995 with the support of PFT2, where a number of academics and practitioners from different disciplines were invited to exchange their views on the whole field of the city, its sciences and the application of the burgeoning concept of complexity. The venue gave an unprecedented opportunity, at least in the Italian context, to discuss a variety of attempts to go beyond the conventional approaches to the analysis, and the planning of the city (Bertuglia et al., 1998; Bertuglia & Vaio, a cura di, 1998; Bertuglia & Staricco, 2000).

The scientific debate about complexity and its manifold relationships with the urban system became the leitmotif of the works he carried out with Franco Vaio until his death in 2022: exploring the subjects and mathematical language of complexity (Bertuglia & Vaio, 2003); retracing the history of the various model conceptualizations (Bertuglia & Vaio, 2011); reflecting on the challenges posed by complexity to embrace a multi-disciplinary approach to tackle the countless ways cities live and transform themselves (Bertuglia & Vaio, 2019). The city life, with all its diverse and evolving manifestations, along with the strategies to move forward after the disruptions caused by the COVID-19 pandemics motivated his last call to the Italian scientific community: to share thinking for designing and managing the complex urban system (Bertuglia & Vaio, 2023).

4. Concluding remarks

The paper presented an overview of the long term evolution of regional transport planning in Piedmont. Three instrumental perspectives of analysis have been proposed, functional, organizational and knowledge based, which may inform possible observation lens. Their application made it possible to uncover a few aspects of the evolution of regional transport planning as a result of changes in the different entities of the transport system, e.g. components, actors and planning principles. The findings indicate that modifications have been substantial, and involved the theoretical, procedural and reflexive dimensions of transport planning.

The extent of transformations is especially evident in the 2018 regional plan which marks a major shift from previous planning approaches (Occelli, 2018) as it has a future-oriented vision centered on sustainability, it pays attention paid to institutional capability and governance and it focuses on plan performance and evaluation. Even more importantly it recognizes that the different entities involved (system components, actors, planning principles) have different time horizons, and that the temporal entanglement of their pathways ultimately affects plan capability to achieve its goals at the far-away 2050 horizon. Its intermediate prospects at 2030, 2040, however, may serve as reference signposts for intermediate target indicators, setting time intervals, which themselves provide observation windows of the plan accomplishments along its pathway.

Accepting the sustainability principles gives a radically new imprinting to the plan. On the one hand, it increases awareness that being embedded in the overarching sustainability-oriented culture, activities occur in complex socio-economic and environmental situations (Tabara, 2002). On the other one, it makes it apparent that planning activities have to partake the sustainability-oriented culture's own reference system which includes spatial, ethical and temporal dimensions.

Disruptions caused by the impact of the COVID-19 pandemic have not altered plan main issues, but probably raised novel thorny ones, about the overall consistency of the plan pathway (Ravagnan et al., 2022).

Bertuglia's emphasis on understanding urban systems as complex, adaptive, and evolving provides valuable arguments to address them. On a methodological ground, they highlight the relevance of inter-disciplinary approaches actors should leverage to understand situations and align efforts for moving in a desired direction. In this respect, his emphasis helps providing ground to the arguments discussed in 2.3, about the use of modeling can have an important role.

IOn a conceptual ground, Hogson's philosophical based notion of Anticipatory Present Moment (APM) (Hogson, 2013) can suggest ways to frame the problem. The core idea is that in experiencing the now, there are three determining conditions: the passing of time, the pattern of potential and the aspect of commitment and freedom to choose, which enables the creation of possibilities.[3]

The notion turns out to be specifically relevant for better articulating the internal and external view underlying the transport planning reflexive dimension (see 2.2), and making the planning activity system more capable to handle its own evolution.

As for the former, it would assist planning actors mutually appreciate the ways they experience their sense of the future mobility, the range of possibilities to get there and the best path for getting to the preferred ones (Sharpe et al., 2016).

As for the latter it would increase the awareness about the fact that plan actors and their knowledge create a same socio-technical domain in which actions and actors' behaviors also make up the domain (Kauffmann, 2009). The topic has been investigated for example by Cascetta et al. (2015) who have proposed a decision-making model for transport planning, consisting of a cognitive rational approach to organizing the decision-making process, a five-level stakeholder engagement process, and a revised role of quantitative analyses and methods.

The creation of this domain is, ultimately, the context of application of the new generation of model approaches to land use transport systems and related analytical tools (see 2.3). Knowledge based approaches are lynchpins in nurturing that context: this is one major lasting incitement of Prof. Bertuglia's legacy.

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[3] These conditions build upon Bennett's understanding of time not as a simple dimensionality but as something which "enables the whole range of human experience to be brought into a coherent system of explanation and understanding" (Bennet, 1963), It entails: a. *time* that enables humans to get sense of experiencing successive events. "The present 'exists' and the past and future do not 'exist' or at any rate do so in a different way from the present"; b. *eternity* that accounts of persistence, and the potential for a variety actualization. In all living things there is a persisting pattern that directs their development and regulates their lives. "It is impossible to make sense of this self-regulating property of life within the limitations of successive time"; c. *hyparxis* (a Greek word which has no unique interpretation) which is a manifestation of a situation that permits to pass from successive time that does not allow choice, to eternity, that makes it available a set of choices, but provides no opportunity make them. It ultimately relates to the power to connect or to disconnect potential and actual.

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Image Sources

Fig.1: Author's own source

Author's profile

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