REGION
The Journal of ERSA
Powered by WU

Volume 10, Number 3, 2023, 59–81 journal homepage: region.ersa.org
DOI: 10.18335/region.v10i3.474 ISSN: 2409-5370

Bridging the evidence gap in spatial planning: Lessons from assessing the impact of new transport infrastructure

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Received: 7 January 2023/Accepted: 9 October 2023

Abstract. The article focuses on how the use of evidence in spatial planning could bridge the gap between vision and reality through the continuous evaluation of the spatial impacts of the proposed interventions. The introduction sets the theoretical, institutional, and practical context on how evidence is used to assess these impacts in relation to both the expected outcomes and the pursued policy priorities. The research section addresses these issues based on the empirical and methodological background derived from a series of successive studies carried out between 1999 and 2014. These studies are related to the establishment and operation of the spatial impact observatory of the Egnatia motorway, a major European transport infrastructure project in northern Greece. The results section introduces a methodological approach, succinctly referred to as the IRIS model in which spatial planning is conceived as an adaptive process, and the use of evidence aims to enhance its flexibility and preparedness in dealing with the uncertainties that arise from dynamic conditions, rather than relying solely on predetermined solutions. It comprises three key components: a theoretical model that simulates the relationship between transport infrastructure and spatial development, an intermediate data model in which raw data were constructed as evidence indicators, and a combination of inductive and deductive paths in which evidence is used to assess the anticipated impact of spatial plans and to evaluate the actual spatial outcomes after their implementation. Finally, the conclusions underline the value added of the IRIS approach as a comprehensive and integrative methodology that aims to improve the efficacy of spatial planning by establishing a link between theoretical models, policy objectives, and evidence-based decision-making.

Key words: spatial planning, transport infrastructure, impact assessment, adaptive process, evidence-based planning, data-models

1 Introduction: spatial planning and the quest for evidence

The field of spatial planning has a long tradition marked by diverse approaches and significant shifts in the prevailing points of view. Despite these variations, there is a noticeable consensus that the central aim of spatial planning revolves around the establishment of sustainable human habitats. To achieve this, the development of spatial plans combines creativity and rationality, relying on evidence both as a source of inspiration and as a means of documentation. To extract this evidence, empirical data must be processed, which, in turn, requires a proper understanding of the spatial elements to be observed. This understanding helps to explain, predict, and regulate their evolving state (Davoudi 2006, Faludi, Waterhout 2006, Kaw et al. 2020, Lord, Hincks 2010). Without a fundamental theoretical foundation, it becomes challenging to decide what data are relevant to collect and how to use them effectively to address complex spatial issues that challenge the capacity of spatial planning and underscore its need for reliable evidence. This evidence serves as an indispensable input for both the initial formulation and the evaluation of the anticipated impacts of spatial plans (Intezari, Pauleen 2019, Rittel, Webber 1973). Spatial planning is a complex process that deals with dynamic parameters, value judgments, and a wide array of unpredictable factors, such as political changes, technological advances, and natural disasters. Therefore, the search for evidence becomes crucial in substantiating the scientific rationality and technical expertise of spatial plans and in justifying the scale and cost of proposed interventions. Evidence plays also a vital role in acquiring the necessary political support, social acceptance, and legitimacy for the plans (ESPON DIGIPLAN 2021, Helming et al. 2011, Msila, Setlhako 2013, Weiss 1998).

The standard scientific approach is to rely on our senses for the observation of empirical data and on our reason to derive the evidence needed to describe, explain, and possibly predict and manage the real world. In this context, there is a tendency to view data as a source of objective information waiting to be discovered and used as evidence. This optimism about the existence of truth hidden in raw data is a misleading simplification because for the data to become accessible for use it must first be collected, measured, and classified into categories, datasets, series, and indicators, and then stored in files and databases in physical and/or digital form (Elgendy, Elragal 2016, Giest 2017, Günther et al. 2017, Leonelli, Tempini 2020). None of the above steps is simple or self-evident, but instead includes choices, for example, which data should be collected, which measuring instruments are appropriate, or whether and which sampling methods should be used. Additional complications arise from the need to ensure compatibility between quantitative and qualitative aspects of the data and between similar data referring to different time periods. Choices in all these issues have critical consequences for the type and reliability of the evidence extracted from raw data, and hence on the reliability of the produced scientific knowledge.

The production of reliable scientific knowledge follows either a top-down deductive method that starts from some theoretical hypotheses using evidence to check whether they are true or false, or a bottom-up inductive method that starts from the selection and processing of data using evidence to make theoretical generalisations. Leonelli, after thoroughly examining the relationship between scientific research and data and the ability to draw evidence and formulate reliable conclusions, argues that theories should first be linked to data using 'data models' as an intermediate device representing the phenomena under consideration and only then to extract evidence compatible with theory and capable of supporting scientifically valid conclusions. In this sense, according to Leonelli, 'data models' can be placed in a representational continuum between theory and reality, with data closer to reality and 'data models' closer to theory (Leonelli 2019, 2020a,b).

Increasingly in recent years, the quest for evidence relies on the processing of big data with algorithmic methods that reinforce the inductive approach that does not need theoretical hypotheses – a situation described by some as "the end of theory" (Succi, Coveney 2019, Voghera, La Riccia 2019). This trend is aggravated by methods that allow algorithms to be transformed by themselves through machine learning processes without the intervention of human intelligence (Gandomi, Haider 2015). However, the risks posed by the algorithmic inductive findings of artificial intelligence, to the extent that they do not require external verification, may reach a point that is not accessible or understood by human intelligence. This makes it possible to produce knowledge that may seem formally correct, but without any understanding of its hidden causality and real significance (Leonelli 2020a). In addition, the selective processing of loosely defined datasets without a specific theoretical model to guide the extraction of evidence increases the likelihood of substituting valid scientific knowledge with random observations that may serve specific political or other interests. Therefore, without a sufficiently or explicitly formulated justification for sources, representativeness, and frame of reference, the structure and content of the data acquire an arbitrarily decisive role in the type of knowledge produced (Davoudi 2012, Ekbia et al. 2015, Komninos, Kakderi 2019).

Acceptance of the need to support spatial planning with evidence to meaningfully assess the impact of a spatial plan as a basic condition for its implementation also implies its comparison with the expectations and projections of the original plan. In this sense, it is important to consider conceptual and methodological aspects concerning the monitoring and assessment of the impact of specific projects and plans in relation to the objectives and priorities pursued (ESPON DIGIPLAN 2021, Helming et al. 2011, Msila, Setlhako 2013, Owens et al. 2004, Rogers 2008, Weiss 1998). The current practise of national and international organisations reflects the above needs and considerations by promoting the impact assessment of plans and major projects as a necessary step before taking final decisions (EEAC 2006, ESPON 2012). Due to more general concerns and practical difficulties, most of the above efforts narrow their scope to specific sectors. The European Commission, for example, views the impact assessment as a set of logical steps to be followed to document the feasibility of a particular project/policy. At the same time, it also considers that only the environmental impact assessment should be mandatory, although it encourages the optional impact assessment of other sectoral dimensions without proposing a comprehensive framework to integrate the findings. In response to the commitment of Gothenburg to implement a sustainable development strategy, the European Commission started in 2002 the systematic development of an impact assessment framework including the circulation of a series of guidelines with the reservation that impact assessment should remain an aid to decision-making and not become a substitute for political judgment (EC 2002, 2005, 2009).

Spatial impact assessment procedures can be made in an ex-ante perspective or in an ex-post perspective. The 'ex ante' option is crucial in supporting decision makers on a project or policy under consideration by evaluating its possible impacts. In fact, this option depends on theoretical models for projection and on the previous experience of ex post assessment of similar projects. The ex-post option is an important part of evaluating the effectiveness of a project or policy, multiplying positive and counterbalancing any negative consequences, and providing input for the ex-ante evaluation of similar projects or policies in the future. It might also be possible to include ongoing assessment of circumstantial and/or preliminary impacts of projects/policies aiming to detect possible weaknesses and propose alternative solutions during implementation. Perhaps, as has emerged in a comparative examination of the relevant methods, several of the above issues can be addressed more effectively if territorial impact integration is adopted so that all individual sectoral impacts affecting a particular territorial unit are addressed in a uniform manner, including issues of spatial governance and spatial planning (Dunlop, Radaelli 2015, ESPON 2012, Medeiros 2014, 2020).

What is certain is the need for a monitoring mechanism to collect data and extract evidence that can respond in advance to the specific characteristics of a wide range of projects and plans, the real effects of which manifest themselves only when they take a concrete form and when they have been implemented and are operating in real-world conditions. According to White (2009), the theory-based approach of impact assessment, which examines the assumptions on which the causal chain from inputs to deliverables and their results, implies that the theoretical arguments supporting an intervention must be placed in the relevant social, political, and cultural context and developed in a flexible way, ready to adapt to changing circumstances considering alternative interpretations, but also any collateral consequences. In addition, there should be methodological rigour when analysing the relevant facts and events and when examining counterfactuals using the available methodological tools. Most studies of this kind rely on quantitative 'data models' to determine whether an intervention works effectively, without always shedding light on the causes of that success. To the extent that these studies do not fulfil the promise of the theory-based approach for empirically verifiable explanations, they resort to speculation about the reasons for deviations from the theoretically expected impacts, a fact that limits their contribution to the formulation of the relevant plans and policies.

In response to the problem of how to use evidence in spatial planning the rest of the article comprises three sections.

First, the research section of the article presents the most relevant aspects of the theoretical, methodological, and empirical background of a series of four successive studies conducted over a 15-year period, from 1999 to 2014, on the conception, establishment, and operation of a spatial impact observatory of the Egnatia Motorway, a major European transport infrastructure project in northern Greece. The aim is to reconstruct the main stages of the learning process that supports the basic argumentation of the article on the role of evidence in the adaptive capacity of spatial planning. Although the presentation follows chronological order, it also has the advantage of whatever wisdom has been acquired at the end of this journey.

Second, the results section introduces an adaptive approach to spatial planning, called the IRIS approach, which emphasises the importance of evidence in formulating plans and evaluating their impact. The approach acknowledges the uncertainty and emergence of unknown situations in the future and advocates flexible spatial planning frameworks that can adapt to changing conditions. Instead of relying on preconceived one-size-fits-all solutions, the IRIS approach suggests using evidence to enhance the flexibility and readiness of spatial planning.

Finally, the conclusion highlights the critical role of evidence in spatial planning and emphasises the value added of the IRIS approach in the integration of theoretical models, data models, and policy objectives. It underlines that spatial planning is a complex process where decisions require justification based on evidence, although there is no simple answer to what kind and amount of evidence is necessary to formulate good plans. By combining deductive and inductive paths, the proposed approach facilitates the assessment of impacts and the adaptation of plans.

2 Research: the spatial impact observatory of the Egnatia Motorway

The Egnatia Motorway is a major European transport infrastructure project in northern Greece, that was among the first round of the fourteen priority projects of the Trans-European Transport Network (TEN-T), a significant European policy created with the foundation of the European Union and fixed in the Treaty of Maastricht in 1992 (Bottcher 2006). The authors coordinated a series of four successive studies conducted during a 15-year period, from 1999 to 2014, on the conception, establishment, and operation of the spatial impact observatory of the Egnatia Motorway.

The first study was a feasibility study that examined the main elements required to establish the observatory, including the European experience of spatial planning and transport observatories, the role of accessibility in location decisions, spatial impact categories and monitoring indicators (Kafkalas et al. 1999). The observatory aims, on the one hand, to assess and monitor the spatial effects of the Egnatia motorway and, on the other hand, to provide data and analyses to support spatial development and planning in affected areas.

The second study was a pilot application designed to test and elaborate the different categories of indicators, such as socioeconomic, environmental, and transport indicators (Kafkalas, Pitsiava 2001). The aim was to develop the necessary know-how and to provide a comprehensive guide and an adequate sample of the procedures and results that would form the initial core of the observatory to start its operation immediately.

The third study was the application of the system of indicators intended to provide a report of the initial or zero state of the zones of influence of the Egnatia motorway as a model for the annual reports of the observatory and more generally to develop and finalise the instructions for its normal operation (Kafkalas, Pitsiava 2004). Selected aspects of the study of the initial state are presented to demonstrate how the appropriate groups of indicators mediate between the steps of the theoretical model and the pursued policy priorities.

Finally, the fourth study was an evaluation study to assess the contribution and prospects of the spatial impact observatory after ten years of continuous operation at the time of the official completion of the construction of the Egnatia motorway (Moutsiakis et al. 2014). The objective of the evaluation was to assess the contribution of the observatory in promoting territorial cohesion and sustainable development in the wider geographical area along the motorway and to assess the prospects of its future viability.

The accumulated research experience from the above-mentioned four studies constitutes a learning process on how to use theoretical concepts to extract the kind of evidence needed to assess the impact of planned interventions. While the Egnatia Observatory example is referenced as a case study, the broader focus is on the extraction of evidence from data and its use as a knowledge base for formulating plans and evaluating their impact, rather than solely evaluating the observatory's effectiveness in collecting and explaining post-construction data.

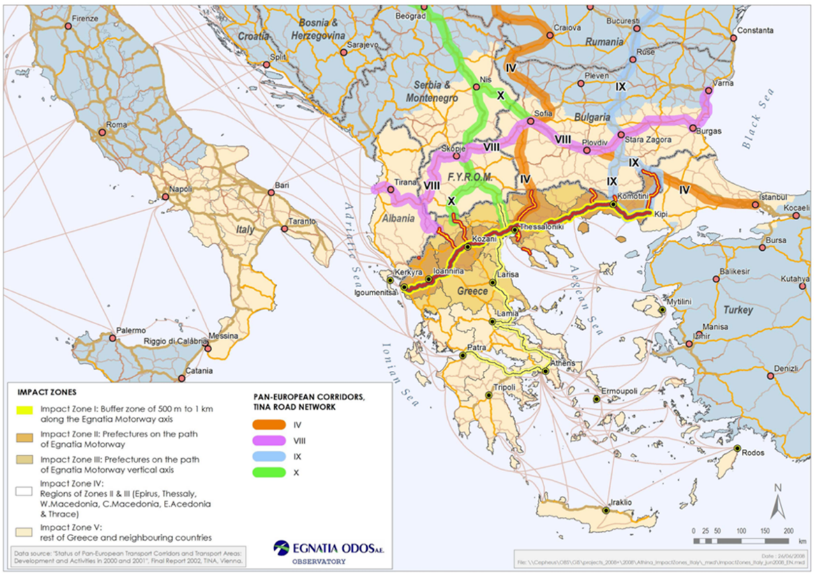
2.1 Inception: the main elements

The feasibility study was commissioned by Egnatia Odos S.A., the company responsible for the design, construction, operation, and maintenance of the entire Egnatia highway network, to examine the main elements for the establishment of a spatial impact observatory of the new transport infrastructure (Kafkalas et al. 1999). The highway is a major transport infrastructure project that crosses northern Greece with a total length of 670 km, including 40 km of 177 bridges and 50 km of 73 tunnels (Egnatia Odos S.A. 2022). The road axis, whose construction began in 1994 and was completed formally in 2014, connects the eastern border between Greece and Turkey with the port of Igoumenitsa in the west. On its route, it meets 11 important cities including Thessaloniki, the second largest city in Greece, and connects four important ports and six airports. An integral part of the project were also the vertical axes that connect the motorway with the Balkan countries and, more broadly, the system of pan-European transport corridors.

The importance of the axis and the size of the investment, which reached EUR 6 billion, underline the scale of expectations and made it necessary to promote actions complementary to its construction and operation to multiply the benefits and mitigate any negative side effects. Thus, the main objective of the observatory was the collection and processing of data with the aim of monitoring the developmental, spatial, environmental and transport impacts of the construction and operation of the axis and the provision of information and support to development planning policies and programs. It was also considered that the effective operation of the observatory would depend on the determination of the appropriate data and on the methods of their collection, measurement, and visualization.

In order to respond to the above, the feasibility study covered a wide range of issues including: (a) the European experience of spatial planning and transport observatories, (b) the current scientific debate on the role of accessibility in the choice of location of economic activities, (c) the spatial impact categories and the motorway operation system as well as the corresponding monitoring indicators with reference to European policies and guidelines, (d) the criteria for determining the geographical areas of influence of the road axis, and (e) the alternative scenarios for the organization and operation of the observatory. Of the above, the issues related to points (a) and (e) do not concern the central argumentation of the article, and thus they will not be discussed in the rest of Section 2.1, while for point (c) there will be an introductory description of the system of indicators, which will be discussed in depth in Section 2.2 presenting the pilot implementation during which the system of indicators was finalized.

The role of accessibility in shaping the patterns of uneven spatial development is reflected by the fact that in the European Union territory the differences in transport infrastructure follow, at least approximately, a similar geographical distribution to that of GDP per capita (EC 1994, Vickerman et al. 1999). Although levels of accessibility seem to be related with the location decisions of enterprises and households, this relationship is not rectilinear: different forms of accessibility affect different types of businesses in a variety of ways (McQuaid et al. 1996). The spatial behaviour of enterprises and households, in turn, has an impact on land values, natural resources, and the environment of urban areas and their rural hinterland. The most appropriate theoretical framework for the analysis of the above is the generic land-use transport interaction (LUTI) model according to which the spatial impacts of transport infrastructure consist of:



Source: http://observatory.egnatia.gr/maps/maps2008/impact_zones_2008_en.pdf
Notes: The observatory website was accessible to the public until the beginning of 2023 but is now under reconstruction as shown at the new Egnatia website https://egnatia.eu/en/homeen/. See also Fourkas, Yiannakou (2015). Furthermore, the new Egnatia website hosts a geoportal https://egnatiaodos.maps.arcgis.com/home/index.html with useful information.

Figure 1: Impact zones of the Egnatia Motorway

- The direct effects of transport, which are related with the changes in accessibility in terms of generalized transport cost, travel time, benefited population.
- The indirect socioeconomic effects which are related with the behavior of households and enterprises due to improved accessibility in terms of growth in productivity and changes in the allocation of activity and population resulting to changes in GDP, market size, population density, hierarchy at urban centers, land use patterns, etc. and
- The effects of diffusion (environmental impacts) arising from the above two types.

The theoretical and practical problems associated with the geographical range and the territorial reference base of the impact observatory of the Egnatia motorway were treated as the question of how to define its zone of influence. Due to the scale and importance of the transport axis, its influence was treated as a dynamic system of successive zones that participates in the kind, scale, and time horizon of its own impacts.

At the feasibility stage, the definition of these zones was based on two criteria linked to the key theoretical term of accessibility: (a) the spatial position of the axis, i.e., what is the geographical area that is directly or indirectly affected in terms of accessibility, and (b) its intended range of influence, i.e., what is the wider area where the optimization of accessibility is sought. Consequently, five impact zones were identified as follows: (a) zone I, the axis of the Egnatia motorway itself at a depth of 500-1,000 meters, (b) zone II, the geographical area of the prefectures through which the Egnatia motorway passes, (c) zone III, the geographical area of the prefectures through which the vertical axes pass, (d) zone IV the geographical area of the regions through which both the Egnatia motorway and its vertical axes pass, and (e) zone V, the wider area of the Greek and Balkan territory affected as a result of the changes brought about by the network of the Egnatia motorway axis and its vertical axes in the organization of the transport system as a whole (Figure 1).

Concerning the system of impact indicators, this was constructed taking into account the scientific debate on the theoretical models of land use and transport interaction, the available previous experience of transport observatories, and the relevant official guidelines of international organizations (EEA 1998, 2000, EUNET 2001, Medeiros 2014, TRIMIS 2022, Wegener, Bökemann 1998). To ensure the reliability and comparability of data, indicators had to be selected that, on the one hand, are in line with commonly accepted indicators at the national and European level and, on the other hand, adequately reflect the state of the economic, social and environmental characteristics of the areas of influence. Thus, the initial indicator system included three categories of about 50 indicators: socio-economic indicators (including spatial planning), environmental indicators, and transport function indicators.

2.2 Beginning: the pilot application

After the completion of the feasibility study, Egnatia Odos S.A. decided to proceed with the creation of the observatory of the spatial impact of the motorway. To this end, a pilot study was commissioned to complete and test the indicator system with real data (Kafkalas, Pitsiava 2001). Different indicators have different time frames and spatial impact scales. For example, indicators related to changes in land use, air pollution, and road safety are limited to the road axis and its adjacent area, while indicators related to socio-economic impacts extend to wider geographical areas. Therefore, it is important that the observatory's operation is continuous, as monitoring the effect of the motorway requires updating the data over time. In this context, 20 indicators were selected from all categories of indicators proposed by the feasibility report, and after examining several critical parameters and some alternatives, a 10 km section of the Egnatia motorway was selected as the scope of the pilot study.

In addition to calculating the 20 indicators selected for this section of the motorway, the pilot study included a detailed description of all indicators in a standard format that included all information and clarifications needed to accurately determine and calculate each indicator under real conditions. Each indicator is essentially a data model for the phenomenon to which it refers and should not be treated as a formal and self-evident process of raw data collection. In this respect, a theoretical rationale compatible with the overall approach has been formulated for each indicator and specific measurement techniques and procedures have been proposed, which may include specific theoretical models, as well as how the results should be recorded, interpreted, and presented.

Based on the results of the feasibility study and after the necessary adaptation and rationalization following the pilot application, the Egnatia Motorway Observatory monitors the indicators shown in Table 1.

Table 1: The system of the Egnatia Motorway Observatory indicators

1A. Social-Economic and & Spatial Planning Indicators
Benefited population
Market size (GDP)
Work force
Growth and prosperity level (Gross Domestic Product - GDP per head)
Unemployment rate
Accessibility of transport modes
Accessibility of industrial areas
Accessibility of sites of cultural & tourist interest
Population change
Urban population changes
Hierarchy of urban centres
Population density
Composition of production by industry sector (Gross Value Added - GVA)
Composition of employment by industry sector
Foreign trade
Urban land use changes
Industrial and commercial land use changes
Real estate changes

Table 1: The system of the Egnatia Motorway Observatory indicators (continued)

Business location
Entrepreneurship
1B. Environmental Indicators
Population exposed to traffic noise
Air pollution
Cohesion-fragmentation of settlements
Tunnel air quality
Landscape restoration
Fragmentation of natural areas
Land use changes
Proximity to protected areas
Crossings with surface waters
Water quality
1C. Transportation Indicators
Traffic volume (Annual Average Daily Traffic - AADT)
Traffic composition
Person Movements
Travel-time
Time-distance
Freight (transport of goods)
Annual Vehicle kilometres
Road safety
Level of service
Road network density
Traffic volume on National Road
Trans-border movements
Intermodal transport
Characteristics of Vehicle Movements
Passenger Journeys by alternative transport modes

Source: http://observatory.egnatia.gr/indicators_en.htm
Note: the observatory website was accessible to the public until the beginning of 2023 but is now under reconstruction as shown at the new Egnatia website (https://egnatia.eu/en/homeen/). For the initial version of the system of indicators see Fourkas (2005).

It is also worth noting here that the system of indicators developed for the first time is the basic core that can be enriched with additional complementary indicators as well as complex indicators, generated through the combination of individual indicators, depending on the phenomenon being investigated. Some examples of complex indicators are the density of road/rail network per surface and population, intermodal transport as the combination of several indicators such as the density of road/rail network, the number of terminals (railway/seaport/airports), accessible terminals and the total volume (passenger/freight) handled by terminals.

The operation of the highway is a continuous process, and the monitoring of the generated effects implies that for most indicators, the calculation procedures must be repeated to update the data according to a set time frame depending on the phenomena being studied. For example, the measurable effects of land use change can take more than three years to emerge, while the volume of travel between different cities along the axis can change at a much faster rate. In addition to differences in relation to time, the indicators differ significantly in relation to the geographical scale or zone of impact in which the phenomena considered produce a measurable impact. Thus, indicators relating to changes in land use and real estate, landscape restoration, fragmentation of natural areas, passage through surface water, population exposed to noise, air pollution, volume and composition of traffic, level of service, travel time and road safety are geographically limited to the road axis itself or to the adjacent area of impact zone I. Similarly, indicators

Table 2: Example of technical sheet: the beneficiary population indicator

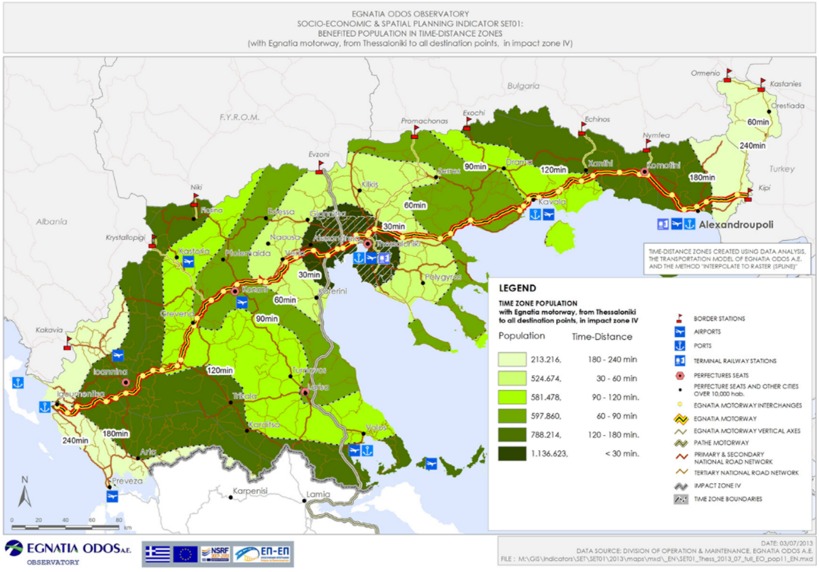
Definition	The indicator identifies the population potentially benefiting from the axis and which is defined as the population that is at a distance and/or time distance of (a) daily travel and (b) frequent travel from the seats of the prefectures and regions through which the axis passes		
Standard Format	The number of inhabitants of the area is determined based on the (time-) distance from the seats of the prefectures and regions in the existing road network		
	Table: beneficiary population by centre and (time-) distance		Map: beneficiary population by centre and (time-) distance
Units of Measurement	Population: Number of inhabitants	Distance (km): 50, 150, 300	Time distance: 45min., 60min., 90min., 3h
Spatial Reference	Zones II, III, IV $\kappa\alpha\iota$ V		
Measurement Frequency	Medium term: 5 Years		Long term: 10 Years
Feasibility	Estimation of the population accessible from an urban centre of the axis catchment area through the national road network and investigation of the prospects for functional interconnection between the various urban centres and different regions.		
Policy Objectives	Mobility - Accessibility		
Specifications	Comparative figures: Accessible population from TEN-T Accessible population from other motorways		
Data	Population of NSSG censuses at settlement level Settlements Road network Time-distance data of OD-B-8		
Sources	NSSG EGNATIA ODOS S.A.: Observatory (same measurements) EGNATIA ODOS S.A., Operation & Maintenance Division, Operation Directorate, Traffic Department EGNATIA ODOS S.A.: Observatory spatial database		
Problems	The time distance is a size that is not easily available for routes off Egnatia motorway. These paths require an assessment using GIS		
Comments	The distance and time distance are taken to study the following trends (a) the area of daily commuting around the county headquarters, which is a potentially a spatial functional unit, (b) the area of frequent travel mainly around the regional urban centres and (c) the area of wider functional interconnections around the regional urban centres. The indicator is also estimated using models such as the SASI model (Wegener, Bökemann 1998).		

Source: Adapted from Egnatia Observatory (2008)

related to socio-economic impacts, such as the beneficiary population, GDP growth and well-being levels, unemployment rate, urban population changes, urban hierarchy, accessibility of transport modes, accessibility to specific locations, coherence-fragmentation of settlements and intermodal transport, refer to a geographically wider area extending to zones of impact II, III and IV.

An example of how an indicator operates as a data model linking the real world with theory is the potentially benefited population, assessed first in relation to the distance on the road network and second in relation to the time/distance factor. The technical bulletin with the basic metadata of the indicator is given in Table 2.

Essentially, the factsheets accompanying each indicator include the necessary information and explanations to systematically extract the appropriate evidence and to ensure the reliability and comparability of measurements and results over the long term. Indicators refer to specific phenomena in a structured way and their role as 'data models' is to translate relevant empirical data into evidence to be used in the description, interpretation, and conclusions on the spatial impact of the Egnatia motorway. Results can be analysed and presented either for each indicator separately or in clusters of indicators



Source: Fourkas, Yiannakou (2015)
Notes: A full presentation of the results and visualization in tables, diagrams, and maps was provided at the website of the Egnatia Observatory that was available to the public until the beginning of 2023 and is currently under reconstruction as shown at the new Egnatia website https://egnatia.eu/en/homeen/. Furthermore, the new Egnatia website hosts a geoportal https://egnatiaodos.maps.arcgis.com/home/index.html with useful information.

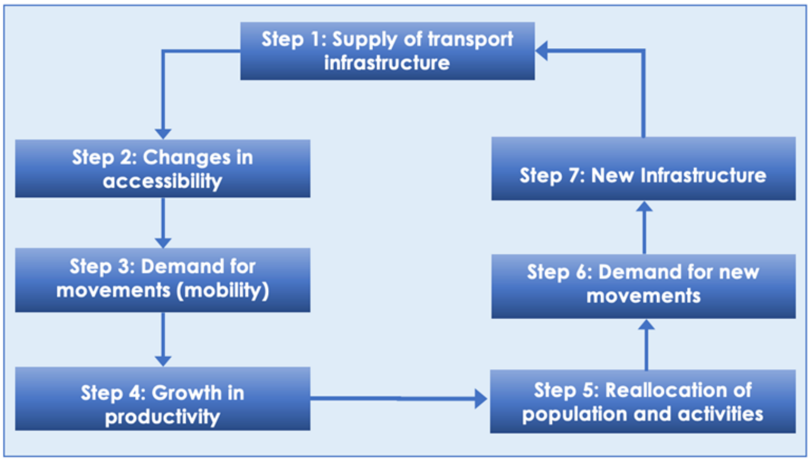
Figure 2: Egnatia motorway beneficiary population: time zones from Thessaloniki

which are constructed as new 'data models' of higher order to represent interconnected and complex phenomena according to the adopted theoretical framework. As an example, Figure 2 refers to the beneficiary population based on the distance from Thessaloniki, the main urban area along the axis.

2.3 Operation: the initial state

Following the completion of the pilot study, Egnatia Odos S.A. commissioned a study aiming to apply the system of indicators to assess the initial state of the zones of influence of the motorway (Kafkalas, Pitsiava 2004). This study was intended to become the model of the annual reports to be prepared by the observatory and for this purpose it was conducted in close cooperation with its staff. The object of the study was to develop and finalize the proposals, guidelines, and instructions originally formulated in the two previous studies, the feasibility study, and the pilot application so that the observatory would acquire a solid baseline before it began its full and normal operation. Some aspects of the study of the initial state are presented, with reference to key theoretical and methodological issues, including specifically how the appropriate groups of indicators mediate between the steps of the theoretical model on the one hand and with the pursued policy priorities on the other.

From an evolutionary perspective, the relationship between transport infrastructure and spatial structure depends on many agents, including public and private institutions and organizations, as well as collective and individual actors, the interplay of which exercise significant influence on how, when, and whether a potential impact will occur. These elements make it very difficult to find the correspondence between different kinds of territorial impact and specific characteristics of the transport infrastructure. However, it is possible to incorporate critical elements into theoretical models of the relationship between land use and transport change. There is a great variety of integrated land use transport models that contain a series of interlinked equations for predicting key variables related to economic activity, transport change, and land use patterns (Geurs, van Wee 2004). Figure 3 shows a seven-step (cyclical) model that satisfies the above criteria. This



Source: Adapted from Bruinsma et al. (1997)

Figure 3: A seven-step cyclical model of land use and transport interaction

is a simplified adapted version of a conceptual model on the relation between transport infrastructure and the spatial pattern of economic activities proposed by Bruinsma et al. (1997). A basic difference is that the transport cost is incorporated in Step 2, where accessibility expresses the generalized cost of travel.

As shown in Figure 3, transport infrastructure first and foremost affects accessibility and hence increases the economic potential of regions, producing a series of territorial impacts upon economic growth, the state of the environment, and land use patterns (Vickerman et al. 1999). This process is systematised according to the adopted model as follows: the supply of transport infrastructure (step 1) reduces the cost of transport and leads to an improvement in accessibility (step 2) that increases the demand for movement (step 3) and improves the productivity in the areas of its influence (step 4) triggering the reallocation of households and activities (step 5) and the generation of demand for new movements (step 6) which create pressures for the supply of new transport infrastructure (step 7).

In addition to the choice of an appropriate theoretical model, the elaboration of an evidence-based framework for the assessment of the territorial impacts of transport infrastructure upon spatial development presupposes the identification of relevant policy objectives and priorities. The adoption and formulation of policies is a dynamic process that has both territory-specific and time-specific components. In the case of the Egnatia Motorway, the spatial development and transport policy priorities were those stated in the official EU documents during the corresponding programming periods 2000-2006 and 2007-2013: the European Spatial Development Perspective (EC 1999), the Territorial Agenda of the European Union (Territorial Agenda 2007), the Green Paper on Territorial Cohesion (EC 2008), and the White Paper of European Transport Policy for 2010 (EC 2001). In summary, these policy priorities are:

- Parity of access means that policies should aim to close the accessibility gap between the different areas. This could be pursued through the allocation of new investment for the construction of new or the improvement of existing transport infrastructure.

- Territorial cohesion aims to confront socio-economic polarization and strengthen territorial cohesion through integrated multimodal and intermodal transport networks promoting polycentricity and a balanced system of settlements.

- The prudent management and protection of natural and cultural resources reflects the concern for the protection and improvement of the quality of the environment, addressing the environmental pressures that are generated by socio-economic conditions and the operation of the transport system

- The pursuit of social and economic cohesion is the aim of all sectoral policies. The assessment of progress towards this aim is reflected in policies aiming to close the gap in regional disparities as they are expressed by economic and social variables

After the formulation of the theoretical model and the identification of the main policy priorities, a critical task is to assess and possibly quantify the relationships between transport infrastructure and spatial development. Towards this aim, it becomes necessary to use clusters of indicators, which could operate as a mediating device linking the steps of the theoretical model with key policy objectives. In many projects, which focus on the territorial impact of transport system, different indicators have been tested (Andrikopoulou, Kafkalas 2000, Egnatia Observatory 2005, ESPON 2005, ESPON 2012, Fourkas 2006, Kafkalas, Pitsiava 2007, 2010). These efforts have been considered in the framework of the present approach to identify the kind of indicators that are appropriate to measure actual policy priorities according to the steps of the theoretical model. Based on the above considerations, the territorial impact assessment framework of the Egnatia Motorway Observatory is summarized in Table 3.

2.4 Assessment: the first ten years

At the end of ten years of continuous operation at the time of the official completion of the construction of the Egnatia motorway, Egnatia Odos S.A. commissioned an evaluation study to assess the contribution and prospects of the spatial impact observatory (Moutsiakis et al. 2014). More specifically, the aim is to determine how to assess the progress of implementation and the content of the Observatory's activities both in terms of the effectiveness of the resources it has and in terms of its contribution in promoting territorial cohesion and sustainable development in the wider geographical area along the road axis and vertical axes. In addition, the Observatory's prospects in the changing institutional and economic environment are examined, with the main orientation being to ensure its future viability. The development of the Egnatia Motorway Observatory and its integration into the administrative framework of the Egnatia Odos S.A. have been linked to the construction and development process of the motorway. Respectively, the spatial reference and the activities of the Observatory have focused on the system of the Egnatia Motorway and its vertical axes, supporting its operation and management and, in certain cases, the implementation of spatial planning at the local or/and regional level.

Despite the capacity of the Observatory to provide the evidence necessary for the evaluation of the socioeconomic and environmental conditions of the affected areas and to enable the improvement of spatial development planning, this potential was not fully realized. The main reason was problems of cooperation and/or compatibility with the involved decision-making authorities that either lack adequate expertise or rely on alternative sources for the collection and organization of information. The inability of the administration to use the Observatory as a source of reliable evidence and as a consulting service limits its potential contribution to the development of the regions affected by the Egnatia Motorway. However, the accumulated know-how and expertise have led to the creation of a data collection and impact assessment system with significant added value. Therefore, the Observatory has been established as a 'landmark' in the field of spatial analysis primarily for Northern Greece but also for the national territory (ESPON 2007, REGIO-MOB 2018).This fact constitutes the main feature of the new strategic orientation of the Observatory, which aims at the formulation and validation of its future potential as a tool to monitor the development trends in Northern Greece and the whole country in relation to the infrastructure and operation of the transportation system.

During the first ten years of operation, the Egnatia Observatory has accumulated a substantial amount of information, calculating several indicators on the socioeconomic and environmental impact of the Egnatia Motorway (Fourkas 2005, 2006, Giannakou et al. 2010). The results concerning socioeconomic impacts in terms of productivity, growth, and redistribution of activities and population, such as changes in GDP, market size, population density, urban hierarchy, and land use, were compatible with the theoretically expected impact due to the improvement of accessibility (Bröcker et al. 2002,

Table 3: Territorial impact assessment framework: theoretical model, policy priorities and impact indicators matrix

Steps/Objectives	Objective 1 Parity of access	Objective 2 Balanced development	Objective 3 Environmental protection	Objective 4 Social and economic cohesion
Step 1 Supply of Transport Infrastructure	supply indicators (i.e., length and density of road/rail network per surface and population)	composite indicators reflecting the potential use level of transport infrastructure (i.e., road density per surface in relation to the number of inhabitants per unit of road network)	Indicators expressing land changes and settlements' fragmentation due to transport development (i.e., land taken by transport development)	
Step 2 Changes in accessibility	indicators expressing accessibility levels (i.e., beneficiary population, travel time or the generalized cost of transport)			
Step 3 Demand for mobility	demand indicators (i.e., traffic volume --vehicle, passenger, and freight)		Indicators expressing the population exposed to potential annoyance (traffic noise/air pollution) due to new mobility patterns.	
Step 4 Growth of productivity				Indicators measuring economic variables (i.e., GDP per capita and activity rates, employment by sector of production, and unemployment rates)
Step 5 Reallocation of activities		socioeconomic characteristics of the various areas (i.e., employment per sector, GDP per capita, unemployment rates)	Indicators expressing the population exposed to potential annoyance due to changes in population and activity allocation.	Indicators measuring changes in population and activity allocation (i.e., population density and land use patterns)
Step 6 New demand for mobility	As in step 3		As in step 3	
Step 7 New transport infrastructure	As in step 1	As in step 1	As in step 1	

Source: Adapted from Kafkalas, Pitsiava (2010, 2013)

Bruinsma et al. 1997) as well as with the results of the ex post evaluations of similar projects (CSIL 2012). Some negative environmental impacts refer to the increase in air pollutant emissions and noise related to the generation of new traffic due to the increase in productivity in the vicinity areas mentioned above, as well as the negative externalities usually associated with the construction of large infrastructures. However, the overall environmental impact of the motorway is assessed as positive as the construction, in its largest part, led to the bypass of existing settlements and their statutory borders, a fact that resulted in a reduction of the percentage of population exposed to traffic noise and air pollutants, thus improving the quality of life in residential areas.

2.5 An example of value-added by the observatory: the SIMCODE-IGT project

The SIMCODE-IGT project (Spatial Impacts of Multimodal Corridor Development in Gateway Areas: Italy-Greece-Turkey) is a testimony to the value added of the Egnatia Observatory. The project aims to provide conceptual tools and an information base for evaluating the spatial impact of transport along the multimodal corridor linking South Italy, Northern Greece, and northwest Turkey in the broader context of European spatial development and transport policies (Kafkalas, Pitsiava 2007). Furthermore, the project aims to improve spatial cohesion and sustainability by allowing integration of transport policy priorities with spatial planning and spatial development efforts along the corridor and at the main gateways. To achieve this, the SIMCODE-IGT project uses spatial impact assessment to inform the formulation of policies promoting synergy between the priorities of transport infrastructure with those of spatial development and spatial planning.

In this context, the Egnatia Observatory with its system of indicators provides reliable data and updated information on many key aspects of spatial impacts. An example is the decoupling of freight transport demand, a composite indicator used to describe the relationship between economic growth (GDP) and total freight volume as the main factor responsible for freight-related externalities. This indicator is also related to the objective of the environmental protection policy (Objective 3, Table 3) and the increase in mobility and productivity (Steps 3 and 4 of the model Figure 3). When the GDP of a region increases at a much higher rate than the freight transport demand, the considered region appears to get a clear advantage from the expansion of its transportation task, indicating that it is becoming more efficient in utilising its existing transportation infrastructure and resources (Rodrigue 2020, Wang et al. 2021). This favourable condition prompts the consideration of strategic policy priorities that focus on improving efficiency in freight transport and promoting intermodality to optimise the movement of goods, thus leading to a more sustainable outcome (Kafkalas, Pitsiava 2010). However, before taking any decision, it is important to recognise the potential long-term implications considering the specificities of each region, because neglecting investment needed to promote efficient freight transport systems can hinder economic development and limit the competitiveness of the region in the long run (Kveiborg, Fosgerau 2007, Yang 2021).

3 Results: a methodological approach for adaptive spatial planning

Based on the lessons obtained and the insights inspired from the example of the Egnatia motorway spatial impact observatory, the extraction of evidence from data and its use as a knowledge base for the formulation of plans and the evaluation of their impact could be viewed as an adaptive process of basic relations linking theoretical models and planned interventions. A key insight is that in conditions where the emergence of unknown situations in the future is the most likely outcome, it is necessary to rely on flexible spatial planning frameworks that allow the recombination of the various elements and the adaptation of the respective plans (Getimis, Kafkalas 2002). The adaptive aspect of the approach implies that evidence should be used to enhance the flexibility and readiness of spatial planning to respond to unknown future conditions instead of pre-empting the future with pseudo-objective holistic solutions (Pitsiava, Kafkalas 2017). The proposed approach, which explores the path from data to plan, aims to strengthen the integrative and consensus building character inherent in spatial planning. The approach was given the symbolic name of IRIS, drawing parallels with the ocular diaphragm that regulates light intake and evoking the mythological connection to Styx water, known for testing truth, within Greek mythology, thus capturing the tension between raw facts and the extraction of evidence to accommodate multifaceted truths in the formulation of spatial plans.

The IRIS approach consists of several elements. It begins with the selection of a theoretical model that simulates the phenomena under study, such as the relationship between transport infrastructure and spatial development. The model represents a sequence of steps connecting these phenomena. On the other end of the process, there is the planned intervention, which aims to solve specific problems and align with policy priorities. The intermediate part of the process involves a data model that includes indicators that bridge the gap between the theoretical model and the plan. These indicators are selected to correspond with the steps of the theoretical model and provide the necessary evidence to formulate and evaluate planned interventions. The data model should remain flexible to accommodate a wide range of relevant phenomena and allow for selective use and addition of indicators based on the specific case.

Figure 4 visually delineates the fundamental elements of the IRIS approach, establishing a comprehensive framework capable of accommodating specific analytical components tailored to the unique context of each case. Within the context of the Egnatia motorway's spatial impact observatory, these specific elements have already been introduced in the research section and further elaborated upon in the subsequent discussion of the IRIS approach. This example serves as a demonstration of the key strength of the IRIS approach, which lies in its adaptability. It can be customised to suit various cases which may exhibit significant variations. This inherent flexibility makes the IRIS approach highly valuable for a broad spectrum of scenarios, as it can effectively address the inherent complexities and nuanced characteristics inherent to each distinct context. It should be noted that the initial idea of the bidirectional deductive/inductive path introduced by the IRIS model as the way to use evidence in spatial planning to bridge the gap between data and plans originates in the distinction made by Davoudi between the enlightening and the instrumental place of evidence (Davoudi 2012, 2015). She makes the distinction between a technical rational view of planning which perceives an instrumental place for evidence in the policy process that begins with the collection of often descriptive data and ends with a blueprint on the one hand and an enlightening rather than determining role of evidence in which policy is being informed by rather than being based on evidence.

At one end of the process is the choice of the theoretical model that simulates the real phenomena under study. For example, if the focus is on the relation between transport infrastructure and spatial development, the model should map the sequence of steps connecting these two sets of phenomena. Such a model, as the one used in the case of the Egnatia Motorway Observatory, can be presented as a series of steps as shown in Figure 3. At the other end of the process is the planned intervention aimed at the solution of specific problems and the pursuit of objectives corresponding to policy priorities. These are not always explicit and detailed but can be expressed in broad and generic terms and often refer to a long-term perspective of spatial development, such as the Europe 2020 strategy for smart, sustainable, and inclusive growth. For example, in the case of transport infrastructure, examined in the case of the Egnatia motorway, the above strategy is translated into guidelines to lay the foundation for how the EU transport system can achieve its green and digital transformation and become more resilient to future crises.

The intermediate part of the process is the data model needed to extract evidence from the data and bridge the gap between the theoretical model and the plan. This part consists of a system of indicators which are selected to correspond with the steps of the theoretical model, as was done in the case of the observatory of the Egnatia motorway. This system of indicators acts as a monitoring device which is used to collect and organise the appropriate data and extract the evidence needed for the formulation of planned interventions and the assessment of their impact in relation to both alternative plans and the pursuit of specific policy priorities. Given the complexity of the phenomena considered, the data model, as expressed by the indicator system, should remain flexible

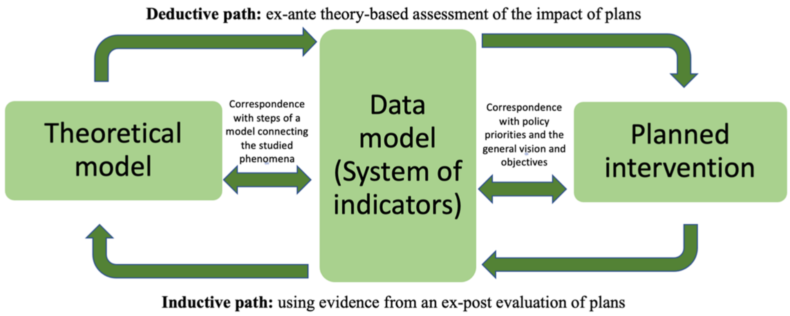


Figure 4: A generic scheme of the IRIS approach of adaptive spatial planning

for monitoring a wide range of relevant phenomena and should leave room for selective use and/or addition of indicators depending on the particular focus of interest on a case-by-case basis.

Theoretical models provide the background for insight and ideas on what indicators corresponding to the steps of the model should be included in the data model of the system of indicators to provide relevant evidence. Planned interventions provide the basis for the selection of the data model, i.e., those indicators that provide the appropriate evidence to measure the effectiveness of plans in promoting policy priorities. An example of this double correspondence is provided in Table 3 that presents the territorial impact assessment framework of the Egnatia motorway. The steps of the theoretical model for the phenomena studied are in the first column and the policies pursued through the plan are in the first row. The cells of the table were filled with the appropriate indicators that come from the intermediate data model of the indicator system that bridges the gap between the theoretical model and the planned intervention. What indicators are appropriate for the monitoring of a step, or a policy is a challenging issue that needs separate argumentation depending on each case examined.

The upper half of the process is the deductive path in the sense that it uses evidence for an ex-ante theory-based assessment of the impact of plans by providing insight into which parts of them and why they are expected to work or fail. This knowledge is crucial to enable the consensus required for the acceptance and implementation of the plans. When applied to projects already implemented, this path could help design and implement compensatory and complementary interventions aimed at minimizing unwanted effects. Given the fact that the deductive path depends on the adopted theoretical model simulating the real phenomena, there is always a danger to be used as a binding self-fulfilling prophecy instead of a flexible provisional solution to be tested. The bottom half of the process is the inductive path in the sense that it uses evidence from ex post evaluation of the spatial impacts of already implemented plans to test their effectiveness in the promotion of policy priorities. This knowledge of whether and in what way certain parts of the plan worked is potentially useful for subsequent plan-making of similar new projects or compensatory and complementary interventions to minimize any negative consequences. Given the fact that the inductive path does not depend on a theoretical model, simulating the real phenomena is susceptible to manipulation for the ex-post justification of the plans by presenting only the kind of evidence that proves their effectiveness.

The knowledge of what works and how effectively provides crucial insights that may be used to validate and/or adapt accordingly the initial theoretical model, the intermediate data model, as well as the policy priorities pursued by the plan. In this respect, the system of indicators in its capacity as a data model may be viewed as sensory organs which record changes in the environment and regulate the (re)organization of human activities within a territorial entity. This interaction has different outcomes which emerge in different time scales from the immediate to the very long term. An example of an immediate adaptive response is the diversion of traffic due to a bottleneck, while the increase in public green space or the expansion of city boundaries are examples of medium- and/or long-term adaptive responses. The inevitable inertia that accompanies the fixed assets associated with many planned interventions also plays a decisive role that orients spatial planning towards compensatory measures or regulatory mechanisms rather than to the destruction of existing and the building of new infrastructure.

It is important to note that while the IRIS approach provides a methodology and framework for adaptive spatial planning, its application and effectiveness may vary depending on the specific context and characteristics of each project. The general idea and principles behind the IRIS approach can be applicable to spatial planning projects that may differ in terms of their goals, geographical location, stakeholders involved, and available data. However, the specific implementation and the selection of indicators and data collection methods would require careful consideration and adjustment based on the specific project's requirements and context. Therefore, while the IRIS approach offers a valuable approach to enhance the flexibility and adaptability of spatial planning, it may need to be tailored and customised to suit the unique circumstances of each project.

4 Conclusion: adaptive spatial planning and the critical role of evidence

In the contemporary landscape of spatial planning, particularly in the wake of the digital era and the proliferation of big data, the use of evidence has become a crucial factor in the decision-making process. However, the complexity of determining the nature and extent of evidence required to devise a good plan remains an intricate challenge with no straightforward answer. Studies on what spatial planners do in this regard show that depending on each case, different data are collected, interpreted, and used as evidence, including qualitative characteristics such as views and expressed concerns of the local community and the interests of other stakeholders. Furthermore, these studies highlight a fundamental reality: The impartiality of decisions can become a subject of contention, irrespective of the volume and nature of the evidence employed. This arises from the absence of a distinct methodology that systematically justifies the hierarchy of priorities in the formulation of proposals. (Davoudi 2006, ESPON DIGIPLAN 2021, Lord, Hincks 2010). This intricate interplay between evidence, objectivity, and prioritisation unveils the multifaceted nature of contemporary spatial planning endeavours, inviting the exploration of new paradigms to balance data-driven insights with theoretical understanding and social consensus.

In this context, the IRIS approach introduces a comprehensive and integrative methodology that improves the efficacy of spatial planning processes. By establishing a link between theoretical models, policy objectives, and evidence-based decision-making, the IRIS approach addresses the complexities inherent in spatial planning. Using a system of indicators, this approach bridges the gap between theoretical models and planned interventions, ensuring a more informed and adaptable planning process. This integration of inductive and deductive paths empowers planners to make well-founded decisions by assessing the impact of plans before and after implementation. By tracking the correspondence between clusters of indicators, theoretical models, and policy objectives, the IRIS approach offers a methodical means to validate and refine plans. Its specific value-added lies in its capacity to combine scientific insight with political will, thus facilitating a more informed and consensual approach to spatial planning challenges. Furthermore, the IRIS approach can contribute to the development of adaptive governance frameworks in spatial planning. By continuously assessing impacts and incorporating feedback into the planning process, adaptive governance can enhance the resilience and responsiveness of spatial plans to changing circumstances.

The completion of the circular path ensures that both the deductive part and the inductive part contribute to the knowledge that enables the bridging of the evidence gap between data and plans. This is crucial for the critical relationship between scientific advice and political will that has been analysed elsewhere as the tension between an enlightening path that takes science into account in the formulation of plans and an instrumental path that uses science to effectively implement political decisions (Davoudi 2012, 2015, Kafkalas, Pitsiava 2010, Pitsiava, Kafkalas 2017). A more pessimistic view is that whenever there is a question of a confrontation between science and politics, the former is usually de facto reduced to the role of rationalising political decisions or switches to a pragmatic rationalism that allows the transition from knowledge to vision in terms of the real limitations and possibilities set by politics (Flyvbjerg 2003). The proposed IRIS approach resolves these issues through mediation of the indicator system, which acts as a data model that connects the steps of the theoretical model with the policy priorities pursued by the plan. In this way, the policy priority pursued by the plan is linked to the causality of the steps assumed by the theoretical model. However, it should be noted that the completion of the circular path could not happen simultaneously for the same plan. This becomes possible in the medium and long run by successive rounds of assessment of impacts and by comparison of many similar parts of many planned interventions.

In the context of the previous discussion, it is underlined that to bridge the distance from the present to the reality envisioned by the plan, the available data should be organised as evidence through theoretically informed 'data models' compatible with the dominant theoretical narrative of spatial planning. To the extent that spatial planning concerns an unknown future, the above adaptive approach does not guarantee the correctness of the decisions (Assche et al. 2017). The reason is that spatial organisation is a system of organised complexity, the future state of which, that is, the object of spatial planning, is formed through an evolutionary dynamic of functional and organisational differentiation and adaptation to constantly changing conditions (de Roo et al. 2020, Komninos 2018, Mehaffy, Salingaros 2014). However, what the IRIS approach can do is to improve the adaptability of the spatial planning process by providing the evidence necessary to improve the relevance and effectiveness of the plans. But, as we have seen, the identification of evidence presupposes both a practical interest to solve a problem and a theoretical approach to guide the attempt for its solution.

Thus, the question of the appropriate plan depends on the question of what should be considered as appropriate evidence to assess its relevance and effectiveness. Accordingly, the evolution of the main narratives of spatial planning, which can be seen as an evolutionary adaptation of spatial planning itself, reflects changes in the way reality is approached and how data are selected and interpreted to become evidence in the formulation of plans. An example offers the current situation where new digital technologies and applications dominate and, through generalised digital connectivity, provide new possibilities for data collection and processing in real time. The search for evidence takes advantage of access to data that allow the assessment of citizens' opinions and needs in the formulation of plans. Algorithmic techniques and the dematerialisation of many activities create expectations for better spatial governance and spatial organisation but are also accompanied by risks of increased surveillance and restriction of rights as they allow the collection and processing of big data beyond the limits of voluntary participation and consent of citizens. These trends create new expectations and risks that seem to be at the core of the future evolution of spatial planning.

References

Andrikopoulou E, Kafkalas G (2000) Chorikes Epiptoseis ton Evropaikon Politikon: i elliniki empeiria 1989-1999. (Spatial impact of European policies: The Greek experience 1989-1999). Ministry for the Environment, Physical Planning and Public Works & Aristotle University of Thessaloniki, ZITI publications

Assche K, Beunen R, Duineveld M (2017) Co-evolutionary planning theory: Evolutionary governance theory and its relatives. In: Gunder M, Madanipour A, Watson V (eds), *The Routledge Handbook of Planning Theory.* Routledge, New York, 221–236. CrossRef

Bottcher B (2006) The trans-European transport network (TEN-T): History, progress and financing. *Communications – Scientific Letters of the University of Zilina* 8: 51–54. CrossRef

Bruinsma F, Rienstra S, Rietveld P (1997) Economic impacts of the construction of a transport corridor: A multi-level and multiapproach case study for the construction of the A1 highway in the Netherlands. *Regional Studies* 31: 391–402. CrossRef

Bröcker J, Kancs A, Schürmann C, Wegener M (2002) Methodology for the assessment of spatial economic impacts of transport projects and policies. Berichte aus dem Institut für Raumplanung; 54. Technische Universität Dortmund, Dortmund. CrossRef

CSIL – Centre for Industrial Studies (2012) Ex-post evaluation of investment projects co-financed by the European Regional Development Fund (ERDF) and Cohesion Fund (CF) in the period 1994-1999: Ten projects observed. final report prepared by Centre for Industrial Studies (CSIL), milan, and DKM Economic Consultants, Dublin, on behalf of the European Commission, DG Regional and Urban Policy. https://op.europa.eu/en/publication-detail/-/publication/eaeb077b-ea0d-42a3-8e84-68c5f996537e/language-en/format-PDF/source-294703040

Davoudi S (2006) Evidence-based planning. *disP - The Planning Review* 42: 14–24. CrossRef

Davoudi S (2012) The legacy of positivism and the emergence of interpretive tradition in spatial planning. *Regional Studies* 46: 429–441. CrossRef

Davoudi S (2015) Planning as practice of knowing. *Planning Theory* 14: 316–331. CrossRef

de Roo G, Yamu C, Zuidema C (2020) *Handbook on Planning and Complexity*. Edward Elgar Publishing, Cheltenham. CrossRef

Dunlop C, Radaelli C (2015) Impact assessment in the European Union: Lessons from a research project. *European Journal of Risk Regulation* 6: 27–34

EC – European Commission (1994) Fifth periodic report on the social and economic situation and development of the regions. COM (94) 322 final, Brussels, 19 July 1994 (EU Commission - COM Document). http://aei.pitt.edu/15159/

EC – European Commission (1999) ESDP – European Spatial Development Perspective: Towards balanced and sustainable development of the territory of the European Union. Office for Official Publications of the European Community, Luxembourg. https://op.europa.eu/en/publication-detail/-/publication/a8abd557-e346-4531-a6ef-e81d3d95027f

EC – European Commission (2001) White paper: European transport policy for 2010: Time to decide – Policies. International Energy Agency, Paris. https://op.europa.eu/en/publication-detail/-/publication/043305f9-ebef-4534-aa5f-dd0206cbd1df/language-en/format-PDF/source-294698308

EC – European Commission (2002) Communication from the Commission on impact assessment. COM (2002) 276 final. European Commission. https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vikqgzdx74w7

EC – European Commission (2005) Impact assessment guidelines. SEC (2005) 791. European Commission. https://ec.europa.eu/transparency/documents-register/detail?ref=SEC(2005)791&lang=en

EC – European Commission (2008) Green paper on territorial cohesion. Turning territorial diversity into strength. Communication from the Commission to the Council, the European Parliament, the Committee of the Regions and the European Economic and Social Committee. Publications Office, Luxembourg. CrossRef

EC – European Commission (2009) Impact assessment guidelines. Sec (2009) 92). European Commission. https://community.oecd.org/servlet/JiveServlet/previewBody/103084-102-1-180246/European Commission (2009) Impact Assessment Guidelines.pdf

EEA – European Energy Agency (1998) Spatial and ecological assessment of the TEN: Demonstration of indicators and GIS methods. Progress report of the DGVII-DGXI-Eurostat-EEA working group of the SEA of the TEN. Office for Official Publications of the European Communities, https://www.eea.europa.eu/publications/GH-15-98-318-EN-C/at_download/file

EEA – European Environment Agency (2000) Are we moving in the right direction? indicators on transport and environment integration in the eu: Term 2000: executive summary. European environment agency; bernan associates

EEAC – European Environment and Sustainable Development Advisory Councils (2006) Impact assessment of european commission policies: Achievements and prospects. EEAC working group on governance, Brussels. https://www.oecd.org/-greengrowth/40033017.pdf

Egnatia Observatory (2005) Current conditions in the regions on the path of the Egnatia Motorway: Cohesion, mobility, balance, environment. 1st spatial impacts report, Egnatia Odos A.E., Thessaloniki, https://www.academia.edu/5066985/1st_Spatial_-Impacts_Report_of_Egnatia_Odos_Motorway_mobility_cohesion_balance_environment

Egnatia Observatory (2008) Technika Deltia Deikton tou Paratiritiriou tis Egnatias Odou (Technical Bulletins of Indicators of the Egnatia Odos Observatory). Egnatia Odos S.A, Thessaloniki

Egnatia Odos S.A. (2022) The project identity. Egnatia Odos S.A, Thessaloniki. Retrieved 10 November 2022, from https://egnatia.eu/en/projects/egnatia-motorway/h-tautotita-tou-ergou/

Ekbia H, Mattioli M, Kouper I, Arave G, Ghazinejad A, Bowman T, Suri V, Tsou R, Weingart A, Sugimoto S, R C (2015) Big data, bigger dilemmas: A critical review. *Journal of the Association for Information Science and Technology* 66: 1523–1545. CrossRef

Elgendy N, Elragal A (2016) Big data analytics in support of the decision making process. *Procedia Computer Science* 100: 1071–1084. CrossRef

ESPON (2005) Territorial impact of EU transport and TEN policies. Project 2.1.1, final report https://www.espon.eu/sites/default/files/attachments/fr-2.1.1_revised_0.pdf

ESPON (2007) Application and effects of the ESDP in the member states. Annex 5 territorial impact assessment (ESPON project 2.3.1) [final report]. NORDREGIO – Nordic Centre for Spatial Development. https://www.espon.eu/sites/default/files/-attachments/fr-2.3.1-full_rev_Jan2007.pdf

ESPON (2012) Territorial impact assessment of policies and EU directives: A practical guidance for policymakers and practitioners based on contributions from ESPON projects and the European Commission. ESPON 2013 Programme, https://www.espon.eu/topics-policy/publications/guidance/territorial-impact-assessment-policies-and-eu-directives

ESPON DIGIPLAN (2021) Evaluating spatial planning practices with digital plan data. Final report. https://www.espon.eu/digiplan

EUNET (2001) Socio-economic and spatial impacts of transport. EUNET-SASI - Final report. https://trimis.ec.europa.eu/sites/default/files/project/documents/eunet.pdf

Faludi A, Waterhout B (2006) Introducing evidence-based planning. *disP - The Planning Review* 42: 4–13. CrossRef

Flyvbjerg B (2003) Rationality and power. In: Scott C, Fainstein SF (eds), *Readings in Planning Theory*. Wiley-Blackwell, Hoboken, NJ, 318–329. CrossRef

Fourkas V (2005) Current conditions in the regions on the path of the Egnatia motorway: Mobility-cohesion-balance-environment [1st Spatial Impacts Report]. Egnatia odos s.a. https://www.academia.edu/5066985/1st_Spatial_Impacts_Report_of_Egnatia_Odos_Motorway_mobility_cohesion_balance_environment

Fourkas V (2006) Egnatia motorway observatory: Monitoring of spatial impacts of transport infrastructure. 3rd Congress on Transport Research, Thessaloniki, Greece. https://www.academia.edu/5067291/EGNATIA_MOTORWAY_OBSERVATORY_-MONITORING_OF_SPATIAL_IMPACTS_OF_TRANSPORT_INFRASTRUCTURE

Fourkas V, Yiannakou A (2015) Chorikes epidraseis tis Egnatias odou: Apotelesmata kai ektimiseis 2005-2015. (Spatial impacts of the Egnatia motorway: Results and estimates 2005-2015). 15 years of the Egnatia Observatory. Transport infrastructure policies and assessment – Monitoring of spatial impacts, Thessaloniki, Greece

Gandomi A, Haider M (2015) Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management* 35: 137–144. CrossRef

Getimis P, Kafkalas G (2002) Empirical evidence and comparative analysis of policy-making in the pursuit of innovation and sustainability. In: Heinelt H, Getimis P, Kafkalas G, Smith R, Swyngedouw E (eds), *Participatory Governance in Multi-Level Context*. VS Verlag für Sozialwissenschaften, Wiesbaden, 155–171. CrossRef

Geurs KT, van Wee B (2004) Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography* 12: 127–140. CrossRef

Giannakou A, Seitanidis S, Fourkas V (2010) Dierevnisi tis epidrasis tis Egnatias odou kai ton katheton axonon stin polykentriki choriki anaptyxi tis Voreias Elladas (A study of the impacts of Egnatia odos and the vertical axes upon polycentric spatial structure in Northern Greece). *Aeihoros* 13: 30–61. CrossRef

Giest S (2017) Big data for policymaking: Fad or fasttrack? *Policy Sciences* 50: 367–382. CrossRef

Günther WA, Rezazade Mehrizi MH, Huysman M, Feldberg F (2017) Debating big data: A literature review on realizing value from big data. *The Journal of Strategic Information Systems* 26: 191–209. CrossRef

Helming K, Diehl K, Bach H, Dilly O, König B, Kuhlman T, Pérez-Soba M, Sieber S, Tabbush P, Tscherning K, Wascher D, Wiggering H (2011) Ex ante impact assessment of policies affecting land use. Part A: Analytical framework. *Ecology and Society* 16: 27–43. CrossRef

Intezari A, Pauleen DJ (2019) *Wisdom, analytics and wicked problems: An integral decision making for the data age*. Routledge, New York. CrossRef

Kafkalas G, Giannakou A, Pitsiava M, Tsaboulas D, Foutakis D (1999) Paratiritirio Chorikon Epiptoseon Egnatias Odou. Erevna Skopimotitas gia ti Systasi kai Leitourgia (Observatory of spatial impact of egnatia odos. Feasibility research for establishment and operation). Aristotle University, Spatial Development Research Unit

Kafkalas G, Pitsiava M (2001) Paratiritirio Chorikon Epiptoseon Egnatias Odou. Pilotiki Efarmogi Systimatos Deikton (Observatory of spatial impact of Egnatia Odos. Pilot implementation of an indicator system). Aristotle University, Spatial Development Research Unit & Transport Engineering Laboratory

Kafkalas G, Pitsiava M (2004) Chorikes Epiptoseis Egnatias Odou. Ekthesi Katastasis Zonon Epirrois. (Spatial impact of the Egnatia Motorway. Status report on zones of influence). Aristotle University, Spatial Development Research Unit & Transport Engineering Laboratory

Kafkalas G, Pitsiava M (2007) Spatial impact of transport and territorial cohesion prospects: The SIMCODE-IGT approach. SIMCODE-IGT final conference, Thessaloniki

Kafkalas G, Pitsiava M (2010) The spatial impacts of transport infrastructure: A policy relevance approach with special focus on the environment. Regions and the environment, Winter Conference 26/11/2010, London

Kafkalas G, Pitsiava M (2013) Chorikes epiptoseis ton metaforon kai politikes proothisis tis viosimis chorikis anaptyxis. (Spatial impact of transport and policies promoting sustainable territorial development). *Aeihoros* 18: 94–115. CrossRef

Kaw JK, Anderson C, Soukup T (2020) Evidence-based planning and design. In: Kaw JK, Lee H, Wahba S (eds), *The Hidden Wealth of Cities: Creating, Financing, and Managing Public Spaces*. The World Bank, Washington, DC, 94–108. CrossRef

Komninos N (2018) Smart cities. In: Warf B (ed), *The SAGE Encyclopedia of the Internet*. SAGE Publications, Thousand Oaks, CA, 783–789. CrossRef

Komninos N, Kakderi C (2019) *Smart cities in the post-algorithmic era: Integrating technologies, platforms and governance*. Edward Elgar Publishing, Cheltenham. CrossRef

Kveiborg O, Fosgerau M (2007) Decomposing the decoupling of Danish road freight traffic growth and economic growth. *Transport Policy* 14: 39–48. CrossRef

Leonelli S (2019) What distinguishes data from models? *European Journal for Philosophy of Science* 9: 22–49. CrossRef

Leonelli S (2020a) Learning from data journeys. In: Leonelli S, Tempini N (eds), *Data Journeys in the Sciences*. Springer, Cham, 1–24. CrossRef

Leonelli S (2020b) Scientific research and big data. In: Zalta EN (ed), *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/sum2020/entries/science-big-data/

Leonelli S, Tempini N (2020) *Data journeys in the sciences*. Springer, Cham

Lord A, Hincks S (2010) Making plans: The role of evidence in England's reformed spatial planning system. *Planning, Practice & Research* 25: 477–496. CrossRef

McQuaid RW, Leitham S, Nelson JD (1996) Accessibility and location decisions in a peripheral region of Europe: A logit analysis. *Regional Studies* 30: 579–588. CrossRef

Medeiros E (2014) *Territorial impact assessment (TIA) – The process, methods, techniques*. Centro de Estudos Geográficos da Universidade de Lisboa (CEG), Lisbon

Medeiros E (2020) *Territorial impact assessment*. Springer, Cham. CrossRef

Mehaffy MW, Salingaros NA (2014) The biological basis of resilient cities. Ecologist – Informed by Nature. https://theecologist.org/2014/jan/25/biological-basis-resilient-cities

Moutsiakis E, Gavanas N, Kafkalas G, Pitsiava M (2014) Paratiritirio Egnatias Odou. Meleti Axiologisis kai prooptikon. Synthesi Apotelesmaton kai Symperasmata. (Egnatia Odos Observatory. Evaluation and foresight study. Synthesis of results and conclusions). Egnatia Odos S.A.

Msila V, Setlhako A (2013) Evaluation of programs: Reading Carol H. Weiss. *Universal Journal of Educational Research* 1: 323–327. CrossRef

Owens S, Rayner T, Bina O (2004) New agendas for appraisal: Reflections on theory, practice, and research. *Environment and Planning A: Economy and Space* 36: 1943–1959. CrossRef

Pitsiava M, Kafkalas G (2017) Planning for the unknowable: Impact of transport infrastructure and evidence-based spatial development policies. cities and regions in a changing Europe: Challenges and prospects. ASRDLF – ERSA-GR conference, Panteion University, Athens

REGIO-MOB (2018) Egnatia Motorway (traffic) Observatory. Interreg Europe. https://www.interregeurope.eu/good-practices/egnatia-motorway-traffic-observatory

Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. *Policy Sciences* 4: 155–169. CrossRef

Rodrigue JP (2020) *The Geography of Transport Systems* (5th ed.). Routledge, New York. CrossRef

Rogers PJ (2008) Using programme theory to evaluate complicated and complex aspects of interventions. *Evaluation* 14: 29–48. CrossRef

Succi S, Coveney PV (2019) Big data: The end of the scientific method? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 377: 20180145. CrossRef

Territorial Agenda (2007) Territorial agenda of the EU – Towards a more competitive and sustainable Europe of diverse regions. Agreed on the occasion of the Informal Ministerial Meeting on Urban Development and Territorial Cohesion in Leipzig on 24-25 May 2007. https://ec.europa.eu/regional_policy/en/information/publications/communications/2007/territorial-agenda-of-the-european-union-towards-a-more-competiptive-and-sustainable-europe-of-diverse-regions

TRIMIS – Transport Research and Innovation Monitoring and Information System (2022) Assembling a European network of monitoring centres for transport infrastructure. Retrieved 14 November 2022, from http://trimis.ec.europa.eu/project/assembling-european-network-monitoring-centres-transport-infrastructure

Vickerman R, Spiekermann K, Wegener M (1999) Accessibility and economic development in Europe. *Regional Studies* 33: 1–15. CrossRef

Voghera A, La Riccia L (2019) *Spatial Planning in the Big Data Revolution*. IGI Global, Hershey PA. CrossRef

Wang H, Han J, Su M, Wan S, Zhang Z (2021) The relationship between freight transport and economic development: A case study of China. 85: 100885. CrossRef

Wegener M, Bökemann D (1998) The SASI model. Berichte aus dem Institut für Raumplanung; 40. Technische Universität Dortmund, Dortmund. CrossRef

Weiss CH (1998) *Evaluation: Methods for studying programs and policies* (2nd ed.). Prentice Hall, Upper Saddle River, NJ

White H (2009) Theory-based impact evaluation: Principles and practice. Working paper 3, International Initiative for Impact Evaluation, New Delhi. https://www.3ieimpact.org/sites/default/files/2017-11/Working_Paper_3.pdf

Yang R (2021) Research on the correlation between freight transportation and national economic development. E3S Web of Conferences, 253, 01008. CrossRef