USING THE ANALYTIC NETWORK PROCESS FOR ADDRESSING A TRANSPORT DECISION PROBLEM

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ABSTRACT

One of the crucial issues for Decision Makers when considering transport choices is how to simultaneously optimize several criteria that take into account technical, economic, territorial and environmental constraints., The present paper proposes the application of the Analytic Network Process (ANP) methodology for supporting the decision-making process related to the implementation of the railway corridor in Italy specifically the trans-European railway axis from Rotterdam to Genoa (i.e. Corridor 24). In particular, the objective of the work is to rank the effects that a delay in the construction of the Italian portion of the corridor would have on the territorial system. The full range of possible effects have been identified and grouped into three clusters (socio-economic aspects, environmental aspects and transport aspects). The ANP model includes both subjective and objective elements which also have some interdependencies. The complexity of the case under examination made it necessary to consult iterative experts and manage the process through a specific focus group and different questionnaires. The most important aspects of the decision problem were discovered as a result of this application.

Keywords: Analytic Network Process, transport infrastructures, evaluation, Corridor 24.

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1. Introduction

Transport policy is a current and serious topic in both industrialized and developing countries. In the past, further transport investment in cities has been supported by arguing

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on the basis of growth allocation and, subsequently, as the main means to promote economic development and revitalization of depressed areas (Banister, 1994). This topic has now been broadened to embrace new aspects, mostly importantly, an, enhanced awareness of the issue of sustainability (Whitehead *et al.*, 2006). For these reasons, the necessity of decision support tools which are able to simultaneously consider different aspects of the problems related to transport planning is getting more and more evident (Jefferson, 1996).

There are several features of transport problems and models which must be taken into account when determining which analytical approach to use (Ortuzar and Willumsen, 2001). To start with, it is necessary to consider the *decision-making context*. This element involves the adoption of a particular perspective, and requires a choice of scope or coverage of the system of interest. It also helps to define requirements for the models to be used such as the variables to be included in the model whether given or exogenous. Second, the *availability of suitable data* has to be taken into account. The stability of the data and the difficulty involved in forecasting their future values must be considered In many cases the data available will be the key factor in deciding the modeling approach. Moreover, it is necessary to consider the *accuracy required*, the *state of the art in modeling* and the *resources available for the study,* with particular reference to the time involved and the level of communication with the decision makers and the public. Finally, the *data processing requirements* and the *levels of training and skill of the analysts* must also be taken into account.

Despite the fact that land use and transport systems are closely intertwined, the integration of planning between these systems is still far off for several reasons which include the controversy of the domain (many institutional and non-institutional stakeholders with divergent values and mandates), the complexity of the issues, and the high level of interdependencies. Different institutions that have responsibility in the domain often have competing mandates. “In this regard, in order to create agreement, it is tantamount to asking institutions to act in ways that are not consistent with their mandates and the interests of their immediate stakeholders” (Waddel, 2011). This is particularly evident in the case of the project of a Corridor, particularly in Italy.

The difficulties emerge around the definition of the concept of “corridor”. In the field of architecture the corridor concept and its performance characteristics are reasonably clear. Its primary purpose is to give access to a variety of different rooms, areas or activities. Functionally and economically, it is necessary to build as short a corridor as possible, while providing effective access to all accommodation requests. The corridor can be seen as a dynamic space but at the same time as a product to create a series of experiences. By contrast, corridors of development and infrastructure may need to perform in a variety of different ways that are so divergent as to create conflicts between them (Chapman *et al.*, 2003). The corridor concept in this sense is not easy to define. It is not always clear which are the territorial areas included in the corridor and, as a consequence, which are the political parties involved in the process. Normally, the corridor is seen as a "multifunctional backbone” that includes transport infrastructure for people and goods, high-level services (research, logistics, etc.), and the creation of spatial and environmental effects all within a framework of cross-regional and local policies. This very broad definition of "multifunctional backbone" covers a wide range of services to and from a specific territory where the development of infrastructure must be seen as a strategic driver for the transformation of that territory and not only as a project that meets the needs of a particular sector. The definition of a corridor is not a formalized category nor is it the outcome of a government decision; it is one of the many policies where strategies, clusters and alliances between the various players act (Fubini, 2008). The corridors can exist as an axis of infrastructure, economic development, urbanization and institutional development, but these four dimensions should be viewed as both qualitatively and functionally very different elements. The dimensions may coexist but they can also be seen as acting at quite different scales (Romein *et al.*, 2000). Although the term "corridor" clearly suggests the concept of connection and access, it may fail to adequately represent all aspects (subtle but crucial) related to the above four dimensions. There is also the problem of scale and scope that suggests a natural geographic shape, a linear rather than an institutional structure, and an idea of homogeneity rather than distinctiveness. While in infrastructure and institutional connections it is clearly desirable to be able to perform effectively, it's less clear how such high levels of consistency are "necessary" in terms of economic development or urbanization (Chapman *et al.*, 2003).

Therefore we think that the use of decision support tools, like the Analytic Network Process (Saaty, 2005; Saaty and Vargas, 2006), which are able to simultaneously consider different aspects of the problem, can help the stakeholders and especially the Decision Makers to reflect on the effects of a delay in the construction of the Rotterdam-Genoa section of the Italian section of the Rotterdam-Genoa corridor (i.e. Corridor 24). The whole corridor connects areas that are profoundly different when considering the four dimensions mentioned above and the effects they would have on the territorial system.

2. Context and objectives of the study

The goal of the trans-European railway axis (TEN-T) No. 24 from Rotterdam to Genoa (i.e. Corridor 24) is the interconnection of economic development, spatial, transport and ecological planning. From a European point of view, there is the need to strengthen links between countries to facilitate freight transport considering that difficulties arising from geographical context with orographic obstacles, administrative barriers and characteristics of the railway infrastructure are often not compatible with each other. The project area of Corridor 24 covers a number of the most important economic regions in Europe, crossing the Netherlands, Germany, Switzerland and Italy, and linking the North Sea port of Rotterdam and the Mediterranean port of Genoa with a catchment area of 70 million inhabitants and operating 50% (700 million tons/year) of the north-south rail freight (Figure 1).

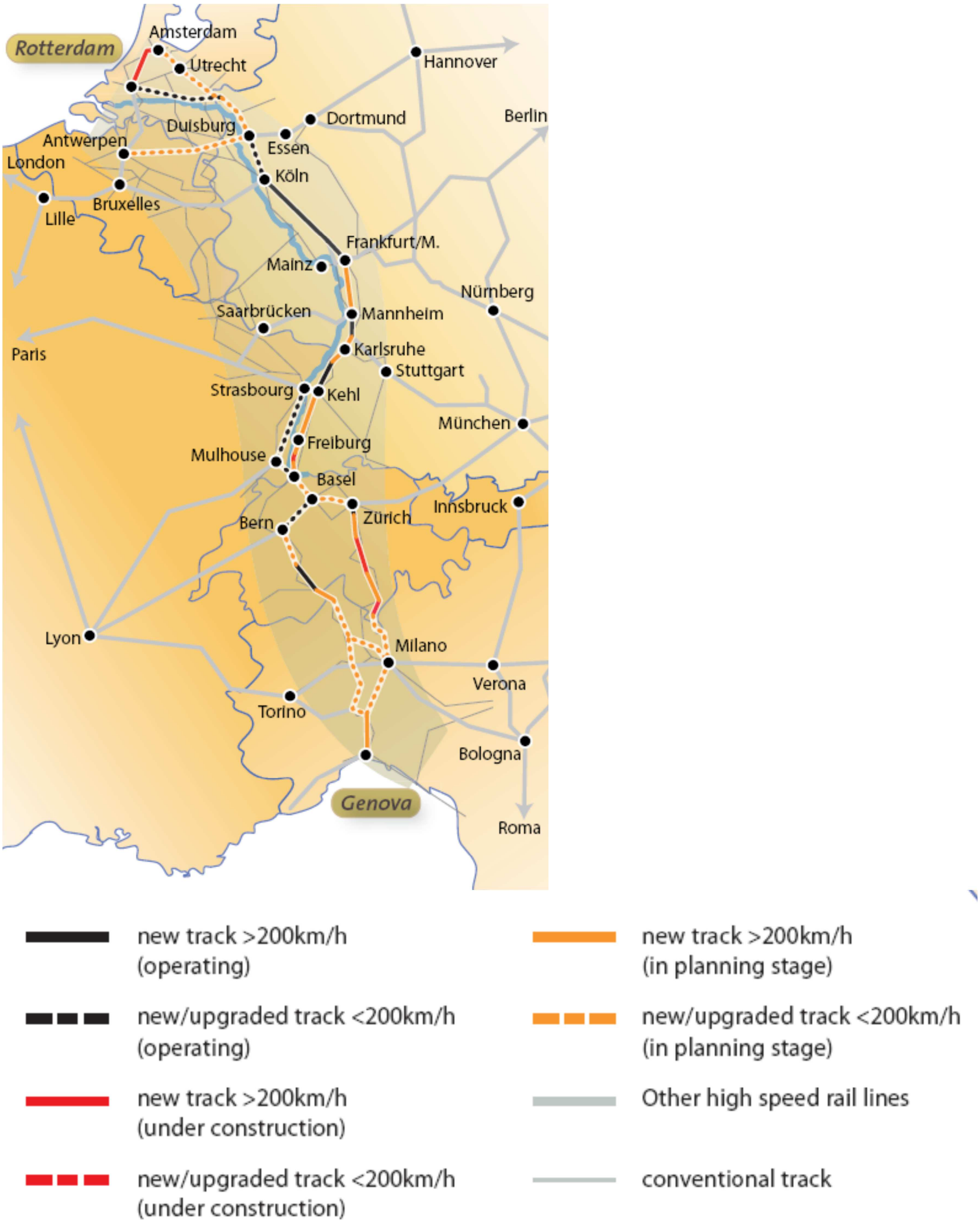


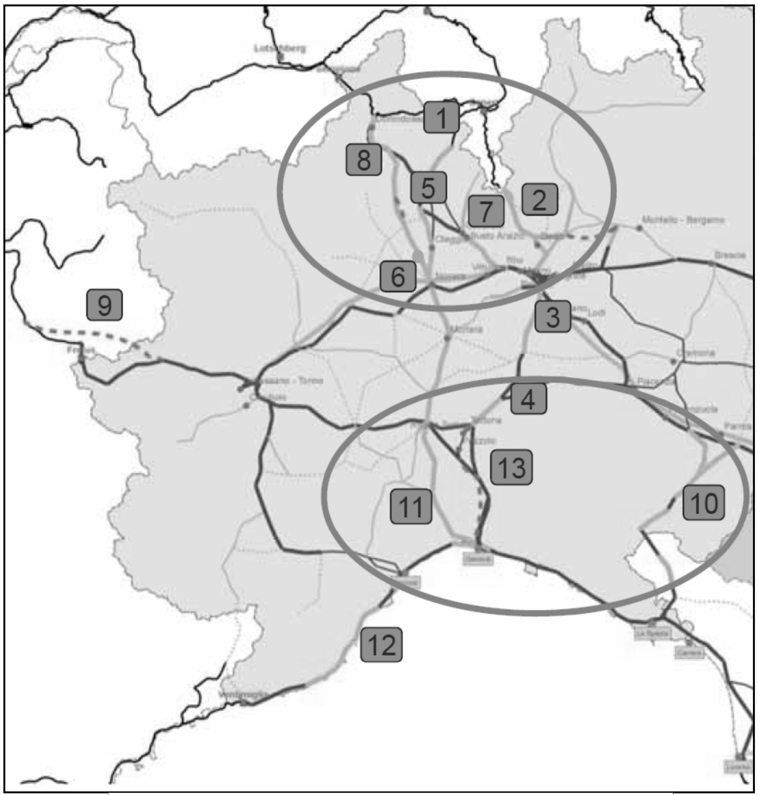
Figure 1 The trans-European railway axis Corridor 24 (source: www.code-24.eu)

The European Union's objective is to double by 2020 the capacity of rail transport on the axis in order to encourage a modal shift of freight by rail. The main projects relating to this objective are the Swiss rail tunnel Loetschberg (opened in 2007), the Gotthard tunnel (the last wall was torn down in October 2010 and the tunnel will be operational by 2017), and Mount Ceneri tunnel (which is expected in 2020). The overall objective is to jointly develop and accelerate the transport capacity of the entire corridor by ensuring optimal economic benefits and spatial integration while reducing negative impacts on the environment at both the local and regional levels. By focusing on regional aspects in the corridor area and joint development strategies, the project will strengthen the position of regional actors and stakeholders within the entire corridor.

There are still many problems that exist despite of the importance of this connection in terms of freight traffic and passenger transport These problems include infrastructure (as many sections do not have adequate capacity of functioning in the corridor), management, due to the presence of different transport services (freight, long distance, local traffic), and a lack of coordination and interoperability at the trans-regional level.

It is a priority to attain state of the art infrastructure and maintain the minimum quality standard along the corridor in order to continue the use of the network however this is currently not completely satisfactory. In Italy, the old and poor connection between the port of Genoa, the Lombardy Region and the Swiss border makes it necessary to transport goods using the road network with evident environmental and territorial problems. In fact, since many systems are implementing “knots systems”, the increase in speed must be great enough to accommodate the increase in the capacity required to produce benefits to all transport modality. In particular, in Italy, the bottlenecks mainly involve the access to Lotschberg and Gottardo railway tunnels, the doubling of the existing lines and their adaptation to freight, the improvement of some critical nodes (first of all the port of Genoa), and the overcoming of the Apennines barrier (“Terzo Valico dei Giovi”).

The obsolescence of railway lines and the lack of financial resources are not the only critical issues limiting the development of the Corridore24 in Italy; the capacity utilization of the logistic terminal in Milan, in the Lombardy region, which is now sufficient will become inadequate for the new European requirements by 2015 and, therefore the development of a North-West Italy intermodal transport network will be necessary to remain competitive in the European scenario (Figure 2).



1. **Laveno – Luino**, doubling works (preliminary design)
2. **Como – Seregno – Bergamo**, doubling and upgrading works (preliminary design)
3. **Pavia – Milano Rogoredo**, quadrupling works (preliminary design)
4. **Tortona – Voghera**, quadrupling works (design)
5. **Vignale – Oleggio – Arona**, doubling works (design)
6. **Nodo di Novara**, reorganization of the railway node (design)
7. **Gallarate – Rho**, upgrading and doubling works (design)
8. **Variante di Gozzano**, Work in progress from 2009
9. **New Line Torino – Lione**, in the desing phase, end by 2025
10. **Pontremolese**, line doubling (in contruction)
11. **Nodo di Genova**, line quadrupling Voltri-Sanpierdarena and 6-track line between Principe and Bringnole (in construction)
12. **Genova – Ventimiglia**, line doubling between San Lorenzo al Mare and Finale Ligure (in costruction)
13. **Terzo Valico dei Giovi**, works authorized for the first lot, expected work completion after 2019

Figure 2 North-West Italy planned railway infrastructure (source: OTI Nord Ovest, 2010)

Major bottlenecks, a lack of trans-regional coordination, diminishing consent among the involved population, and increasing difficulties because of doubts about financial resources still threaten the potential of the axis in Europe, limiting its economic and spatial development. The Italian situation however is particularly worrying because Italy lags behind in the implementation of the corridor with respect to the rest of Europe. The European routes will be finished at the latest in 2020, but in Italy the projects that have already obtained financial support risk not being completed by that deadline.

According to the studies conducted by the European Working Group of Corridor 24, in an optimistic view, Italy may be able to complete the planned works in the Alpine zone, but not those of Ligurian ports and the south Po Valley. In this case, the increased permeability of the North Italy would not be compensated by a port development, causing the "conquest" of Valley and the isolation of the Ligurian Ports from Europe. However, a pessimistic view, which envisions a general delay in the realization of the planned infrastructure (tunnels, railway lines, ports) is unfortunately considered more probable.

From this complex panorama the main issues causing the bottlenecks in the corridor emerge including public acceptance, noise, land management and landscape design, functionality of intermodal hubs and operational aspects as well as the management of planning processes and the financial issues related to major infrastructures. For all these reasons, removing existing bottlenecks requires co-operation across political, organisational and technical bodies, focussing on four main topics: i) railway and settlement development; ii) environmental issues; iii) integrated management of logistics; and iv) communication and stakeholder involvement strategies. Extensive collaboration along with the use of evaluation methodologies able to support the decision-making process have to be explored and tested in the areas of conflict regarding local planning competencies and over-regional spatial planning issues.

The construction of European transport infrastructures is a complex topic where new values have to be taken into account. It is not a specific question of localisms, nor is it merely an issue of moving goods and people. It does not simply affect only environmental, transport-related or town planning aspects. Tackling the issue of large-scale infrastructures involves dealing with a maze of decision elements which require new trans-disciplinary approaches. Currently, the fundamental issue connected to large-scale infrastructures seems to be related to the definition of the underlying agreements, rather than to the construction itself (Bertolini, 2001; Lami and Staffelbach, 2008).

In this context, the ANP could provide a very useful support in the decision-making process because it allows the different elements (both tangible and intangible) of the problem to be represented according to a network model, and it allows the judgements of experts as well as existing measurements and statistics to be considered in the analysis.
In territorial transformation processes (characterized by a long term nature), where different actors are associated in a dynamic context, some indefinite issues will need to be negotiated according to future evaluations and attempts made to mediate between opposing positions that can change during the decision process. Through the use of the ANP, it becomes possible to compare different objectives, interconnected among each

other, and measurable with different units of measure; furthermore, the analysis makes it possible to identify new definitions of the problem (Bottero *et al*, 2008).

This paper proposes the application of the ANP methodology for supporting the decision-making process related to the critical issues that could arise from a significant delay in the implementation of the Italian section of Corridor 24. The starting point of the ANP application is the idea that the possibility of not having properly upgraded the Italian railway lines when the Swiss tunnel Gotthard and Mount Ceneri will be working would bring the railway system in Piedmont and Lombardy to rapid saturation, and the Ligurian ports would lose competitiveness in Europe. In particular, the lack of a functional link between the port of Genoa and the railway network in the hinterland could relegate the Ligurian port to a marginal role with respect to the major ports of Northern Europe, which are organizing an efficient rail connection with their hinterland. In order to investigate this situation, this paper proposes to use the ANP not to assess different alternatives, but to examine and compare the main aspects of the problem and to rank them. It is an unusual use of the methodology, but particularly efficient in a case where there is a lack of exhaustive transformation scenarios and, at the same time, detailed information on key aspects of the decision problem is available. This application of the ANP is part of an Interreg IVB NEW Project, called “Code24”, involving 15 partners from 5 Countries for 4 years (2010 – 2013).

3. Development of the model

3.1 The ANP-based approach

Territorial transformation processes refer to a multidimensional concept that includes socio-economic, ecological, and technical perspectives, and thus leads to issues that are simultaneously characterized by a high degree of conflict, complexity and uncertainty. Particularly, when speaking about transport planning, many objectives have to be considered in the decision making process. These objectives range from the rationalization of the mobility system to the reduction of soil consumption, from the promotion of economic activities to the cut of air pollution due to traffic emissions, and from the endorsement of energy efficiency to the increase in the quality of public spaces.

The assessment of alternative scenarios of transport planning is therefore a complex decision problem where different aspects need to be considered simultaneously, taking into account both technical elements, which are based on empirical observations, and non-technical elements, which are based on social visions, preferences and feelings. In this context, the ANP method provides a very useful aid which allows the different elements of the decision problem to be represented while also considering their interdependent relationships. The network structure of ANP makes it possible to model the various aspects at stake without being concerned about what comes first and what comes next. This way of representing the problem, with fewer constraints than the structure imposed by the Analytic Hierarchy Process (Saaty, 1980), is more similar to real situations where the elements act in a non-hierarchical way. A very large and consolidated amount of literature concerning the ANP exists in different fields. With regards to transport planning, applications of ANP model have been used for selecting optimal routes and for designing new corridors (Piantanakulchai, 2005; Tuzkaya and Onut, 2008).

From a methodological point of view, the ANP requires a network structure to represent the problem, as well as pairwise comparisons to establish the relationships within the structure. In order to develop an ANP model, it is necessary to carry out five fundamental steps.

Step I: Development of the structure of the decision-making process
First the decision-making structure must be defined through the recognition of its main objective. The objective should later be divided into groups ("clusters") that are made up of various elements ("nodes"), and alternatives or options. Second, the relationships between the different parts of the network must be identified. Each element can be a "source", that is, an origin of a path of influence, or a "sink", that is, a destination of a path of influences. There are two possible structures for an ANP model, a "simple" network and a "complex" network. The "simple" network is a free-modeling approach, which is not supported by any guide or pre-determined structure. It consists of a network which has cycles connecting its components and a loop that connects a component to itself. The "complex" network or BOCR (Benefits, Opportunities, Costs, Risks) network allows one to simplify the problem by classifying issues in traditional categories of positive and negative aspects (Saaty and Ozdemir, 2008). The favorable concerns are called benefits, while the unfavorable ones are called costs; the uncertain concerns of a decision are the positive opportunities that the decision might create, and the negative risks that it could entail. Each of these four concerns utilizes a separate structure for the decision. A full BOCR is in some ways similar to a SWOT analysis. While the BOCR model is expected to catch all the aspects (positive and negative) of the decision in the present and future, the SWOT analysis focuses more on the external and internal elements of the problem (Wijnmalen, 2007).

Step II: Pairwise comparison
As in the AHP, a series of pairwise comparisons are made to establish the relative importance of the different elements with respect to a certain component of the network. In the case of interdependencies, components with the same level are viewed as controlling components of each other. The comparisons are made with the Saaty's Fundamental Scale. The numerical judgments established at each level of the network make up pair matrices. The weighted priority vector is calculated through pairwise comparisons between the applicable elements. This vector corresponds to the main eigenvector of the comparison matrix (Saaty, 1980, 2003). The eigenvector method yields a natural measure of consistency. Saaty (1980) defined the consistency index (*CI*) as in Equation (1):

$$CI = (\lambda_{\max} - n)/(n-1) \tag{1}$$

where $\lambda_{\max}$ is the maximum eigenvalue and n is the number of factors in the judgment matrix. Accordingly, Saaty (1980) defined the consistency ratio (*CR*) as in Equation (2):

$$CR = CI/RI \quad (2)$$

where *RI* is the consistency index of a randomly generated reciprocal matrix from the 9-point scale, with forced reciprocals. Saaty (1980) has provided average consistencies (*RI* values) of randomly generated matrixes (up to 11 x 11 size) for a sample size of 500. The consistency ratio *CR* is a measure of how a given matrix compares to a purely random matrix in terms of the consistency index. A value of the consistency ratio $CR < 0.1$ is considered acceptable. Larger values of *CR* require the decision-maker to revise his judgments.

Step III: Supermatrix formation

The supermatrix elements consider the interdependencies that exist among the elements of the system and allow a resolution to be made. It is a portioned matrix where each sub-matrix is composed of a set of relationships between and within the levels, as represented by the DM's model (Step I). The supermatrix obtained in this step is called the initial supermatrix, and it contains all the eigenvectors that are derived from the pairwise comparison matrixes of the model. The eigenvector obtained from a cluster level comparison with respect to the control criterion is applied to the initial supermatrix as a cluster weight. The result is the weighted supermatrix.

Step IV: Final priorities

In this step, the weighted supermatrix is raised to a limiting power, as in Equation (3), in order to converge and to obtain, as stated in the Perron-Frobenius theorem, a long-term stable set of weights that represents the final priority vector.

$$\lim_{k \to \infty} W^k \quad (3)$$

In the case of the complex network, it is necessary to synthesize the outcome of the alternative priorities for each of the BOCR structures in order to obtain their overall synthesis; for this operation different aggregation formulas are available (Saaty, 2005).

Step V: Sensitivity analysis

The fifth and final step involves carrying out the sensitivity analysis on the final outcome of the model in order to test its robustness (Saaty R.W., 2003). With particular reference to the application of the ANP proposed in this paper, the ANP is not used as a method to determine a priority list of the different alternatives in the decision problem, but as a structured procedure that is able to support the analysis in the identification of the principal aspects to consider in order to come to a decision (Bottero and Lami, 2010).

This choice is due to the current issue in the decision process where despite the importance of developing the Corridor 24 being officially shared by all government's levels, the planning choices are struggling to find real implementation. Therefore it is not possible to affirm that there are real alternatives of intervention. What is clear instead is a general concern regarding this stalemate in Italy compared to the actions in the rest of Europe. In order to translate these concerns into concrete elements, a decision has been made to apply the ANP methodology in order to achieve real choices for infrastructural and track interventions In other words, in the present study the ANP model has not been applied with the aim of ranking different options in the context of the development of the Corridor 24. Instead, the overall object of the analysis is to determine a priority list of the effects that a delay in the construction of the Italian portion of the corridor will have on the territorial system. In this sense, the ANP consists of a simple network where the different elements and their reciprocal relationships are represented and linked with the aforementioned goal (Nekhay *et al*., 2009). The model has been developed by means of a specific focus group where seven experts in the different fields (most of whom are currently involved in the "Code24" European Project) worked together to compile the pairwise comparison matrices.

3.2 Structure of the network

In the case considered in this paper, the development of the model involves a cluster and node comparison. In fact, as already mentioned, the objective of the performed analysis is not to find the best solution or scenario for the construction of the transport network, but to identify what the critical issues are that can arise from a delay (or failure to complete) of the Italian section of the European Corridor 24.

The full range of effects related to the delay in construction have been identified and grouped into three clusters, namely socio-economic aspects, environmental aspects and transport aspects. These aspects represent the main issues of the decision problem under investigation. The first cluster refers to the consequences that a delay in the construction of the infrastructure could have on the social and economic system, including the real estate market, employment, the attractiveness of the region, and the volume of trade. As far as the environmental aspects are concerned, the analysis takes into consideration the problems that could result from a failure to complete construction of the new railway connection which would leave a large part of the traffic on the road network The environmental effects include a variation of the environmental quality (air and noise pollution), energy consumption, and use of the soil. Finally, the transport aspects refer to the adverse consequences that could be expected on the infrastructural system, including road congestion, the costs of transports, the freight travel time and the reliability of the services. The nodes are explained in Table 1.

Table 1
Clusters and nodes of the model

Clusters	**Nodes**	**Description**
Environmental aspects	Increase in acoustic emission	The increase in noise is due to the passage of a large amount of trucks.
	Increase in air pollution	The increase in air pollution is due to the road congestion, particularly in urban areas.
	Increase in energy consumption	The energy consumption is related to the use of private motor vehicles.
	Increase in soil consumption	The necessity of new roads causes an increase in the consumption of soil.

Table 1 (cont'd)
Clusters and nodes of the model

Clusters	Nodes	Description
Socio - Economic aspects	Decrease in property values	The decrease in market value is due to the peripheral effect due to the lack of good connections.
	Lack of employment effect	The reduction of the existing jobs or, at least, the absence of new jobs, is related to less interest by companies for this area.
	Lower level of attractiveness	The companies, factories, offices prefer in general a very well connected location and for this reason they will invest in different areas.
	Reduction of trade	The reduction is due to the increase in transport costs and to extra time of travel .
Transport aspects	Congestion of road network	The congestion of the road network is due to the increased passage of the trucks without an effective alternative by rail.
	Increase in costs of transports	The increase in costs of transport is expected due to the costs of fuel and toll.
	Increase in freight travel time	The increased passage of trucks and t consequently the congestion of roads causes an increase in freight travel time.
	Less reliable service	The risk of an incident is greater in the road transport than in the rail transport, so the freight risk of freight damage is increased and the service is less reliable.

Once the elements of the decision problem were set up, the relationships among them have been established. Finally, all the elements in the clusters have been connected to the goal of the evaluation that has been organized in an autonomous cluster. Figure 3 represents the decision network of the problem under examination.

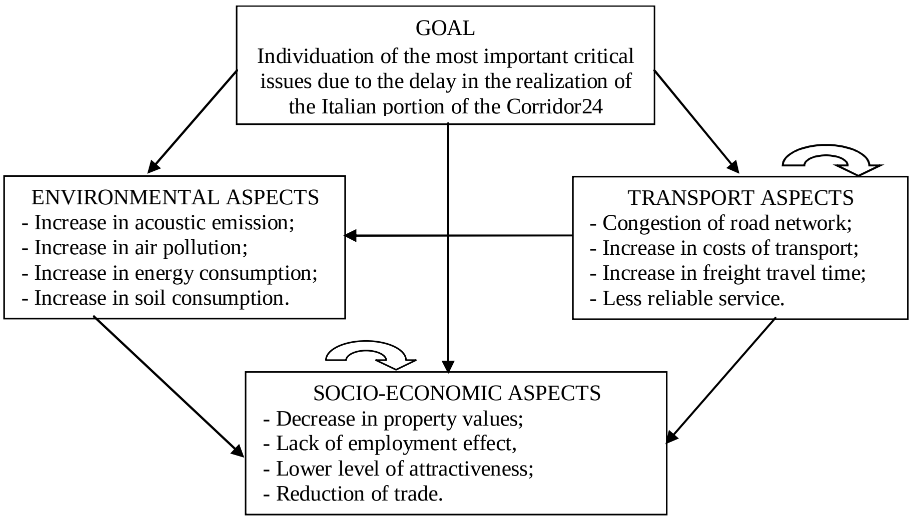


Figure 3 Decision network of the problem

3.3 Pairwise comparison

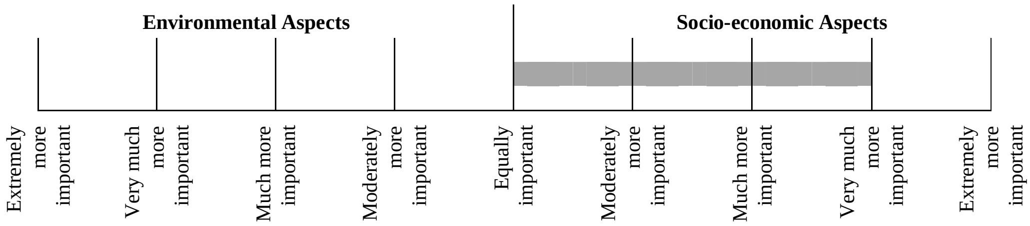
According to the ANP methodology, after having structured the decision network, the second step of the analysis consists in creating the pairwise comparison matrices. It is important to highlight that there are two levels of pairwise comparisons in the ANP, the cluster level, which is more strategic, and the node level, which is more specialized. The model has been developed by a specific focus group where experts in the different fields worked together. The focus group included different experts in the fields of transport infrastructures, environmental assessment, urban planning, economic evaluation and social sciences. The focus group had the dual purpose of helping to structure the decision problem taking into account the feedback and suggestions coming from the experts, and to compile the pairwise comparison matrices in order to come to a coherent result. We first asked every expert to write down their individual judgments for each question. The given judgments were then illustrated and discussed in the focus group until a shared weight was achieved. According to the ANP methodology, in pairwise comparisons, a ratio scale of 1-9, that is the Saaty's fundamental scale, is used to compare any two elements translating qualitative variables in numerical values and *vice-versa* (Table 2). The main eigenvector of each pairwise comparison matrix represents the synthesis of the numerical judgements established at each level of the network (Saaty, 1980).

Table 2
Saaty's fundamental scale

Value	Definition	Explanation
1	Equally important	Two decision elements equally influence the parent decision element.
3	Moderately more important	One decision element is moderately more influential than the other.
5	Much more important	One decision element has more influence than the other.
7	Very much more important	One decision element has significantly more influence over the other.
9	Extremely more important	The difference between influences of the two decision elements is extremely significant.
2, 4, 6, 8	Intermediate judgment value	Judgment values between equally, moderately, much, very much and extremely.

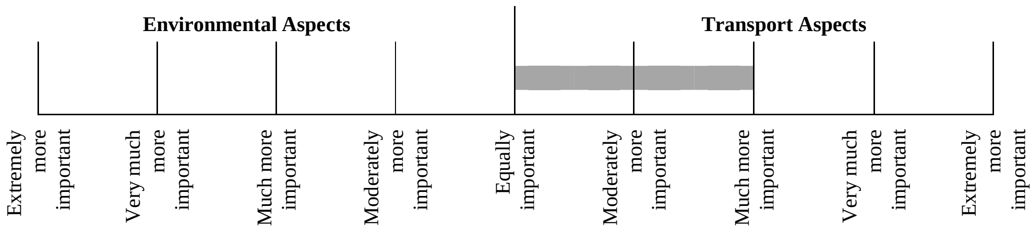
In the presented application all the calculations have been implemented using the *Super Decisions* software (www.superdecisions.com).

The questions that were generated considering the pairwise comparison at the clusters level were similar to the following: Among the "*Critical issues due to the delay in the realization of the Italian portion of Corridor 24"*, which of these two aspects do you think is more important? To what extent?



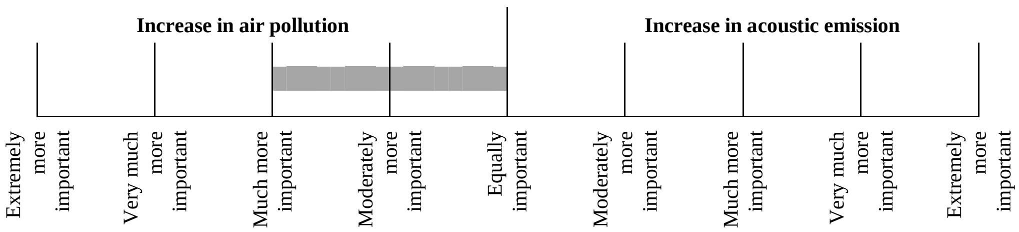
In this context, the weight that has been assigned to the socio-economic aspects reflects the economic expectations attributed to the construction of the corridor, such as the fear of becoming peripheral in the European context or the decrease in the capacity of attracting new economic activities. These expectations are considered much more important than the environmental issues.

Another example of a question generated at the clusters level is as follows: Among the "*Critical issues due to the delay in the realization of the Italian portion of Corridor 24"*, which of these two aspects do you think is more important and how much more?



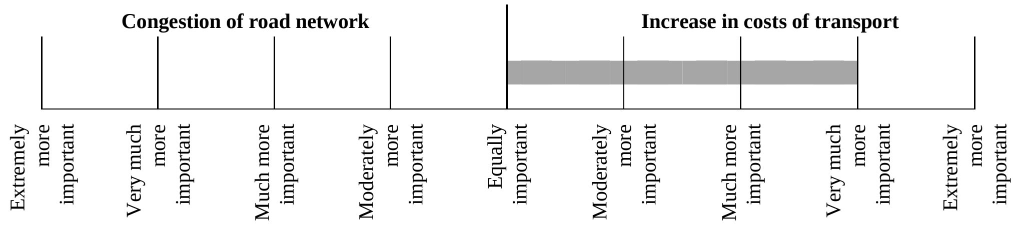
The weight that has been assigned to transport aspects is much more important than the environmental aspects. This reflects the opinion that the implementation of the links in Europe is fundamental.

Once the cluster comparisons have been conducted, it is necessary to study the problem in depth through the analysis of the elements. The questions that were generated considering the pairwise comparison at the nodes level were similar to the following: with reference to the environmental aspects, among the "*Critical issues due to the delay in the realization of the Italian portion of Corridor 24"*, which of these two elements do you think is more important and how much more?



In this case the weight that has been given to the air pollution reveals the general opinion that the atmospheric quality is more important than the acoustic one, even if, according to the sector literature, the increase in acoustic emissions can be seen as the cause of the main social costs due to the presence of a transport infrastructure.

Another example of a question generated at the nodes level is as follows: with reference to transport aspects, among the "*Critical issues due to the delay in the realization of the Italian portion of Corridor 24*", which of these two elements do you think is more important and how much more?



According to the evaluation performed, the increase in cost of transport is considered much more important than congestion of the road network by the focus group. This is because the increase in cost is related to the congestion of road network. In fact, if there is congestion, there will be also an increase in transport time and therefore an increase in cost of transport due mainly to fuel expenses. In the development of the model, a great deal of attention was given to check the consistency index of the pairwise matrixes. In the full range of cases this index was less than 0,1 in order to ensure the acceptability of the model.

3.4 Final results

From the cluster level comparison it is possible to derive the cluster matrix, which represents the importance of the general aspects of the decision problem (Table 3). In the case under examination, the socio-economic aspects were given the highest importance (0,649), followed by the transport aspects (0,280) and finally by the environmental aspects (0,071).

Table 3
Cluster matrix

	Goal	Environmental Aspects	Socio-economic Aspects	Transport Aspects
Goal	0,000	0,000	0,000	0,000
Environmental Aspects	0,071	0,000	0,000	0,152
Socio-economic Aspects	0,649	1,000	1,000	0,606
Transport Aspects	0,280	0,000	0,000	0,242

The totality of the eigenvectors that are derived from the pairwise comparison matrixes of the elements of the model forms the unweighted supermatrix (Table 4). The abbreviations used in this table refer to Figure 3.

Table 4
Unweighted supermatrix

		Goal	Environmental Aspects				Socio-economic Aspects				Transport Aspects			
		G	E1	E2	E3	E4	S1	S2	S3	S4	T1	T2	T3	T4
Goal	G	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Environ-mental Aspects	E1	0,083	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,100	0,000	0,000	0,000
	E2	0,225	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,225	0,000	0,000	0,000
	E3	0,619	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,675	0,000	0,000	0,000
	E4	0,073	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Socio-economic Aspects	S1	0,054	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,166	0,000	0,000	0,000
	S2	0,168	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	S3	0,389	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,834	0,750	0,750	0,000
	S4	0,389	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,250	0,250	1,000
Transport Aspects	T1	0,304	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,080	0,000
	T2	0,082	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,732	0,000
	T3	0,192	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	T4	0,422	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,188	0,000

The cluster matrix is then applied to the unweighted supermatrix as a cluster weight and the result is the weighted supermatrix (Table 5).

Table 5
Weighted supermatrix

		Goal	Environmental A.				Socio-economic A.				Transport A.			
		G	E1	E2	E3	E4	S1	S2	S3	S4	T1	T2	T3	T4
Goal	G	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Environ-mental	E1	0,005	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,020	0,000	0,000	0,000
	E2	0,016	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,045	0,000	0,000	0,000
	E3	0,044	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,134	0,000	0,000	0,000
	E4	0,005	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Socio-economic	S1	0,034	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,133	0,000	0,000	0,000
	S2	0,109	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	S3	0,252	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,666	0,750	0,535	0,000
	S4	0,252	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,250	0,178	1,000
Transport	T1	0,084	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,023	0,000
	T2	0,022	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,208	0,000
	T3	0,053	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	T4	0,117	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,053	0,000

Finally, the weighted supermatrix is raised to a limiting power in order to converge and to obtain a long-term stable set of weights that represents the final priority vector (Figure 4).

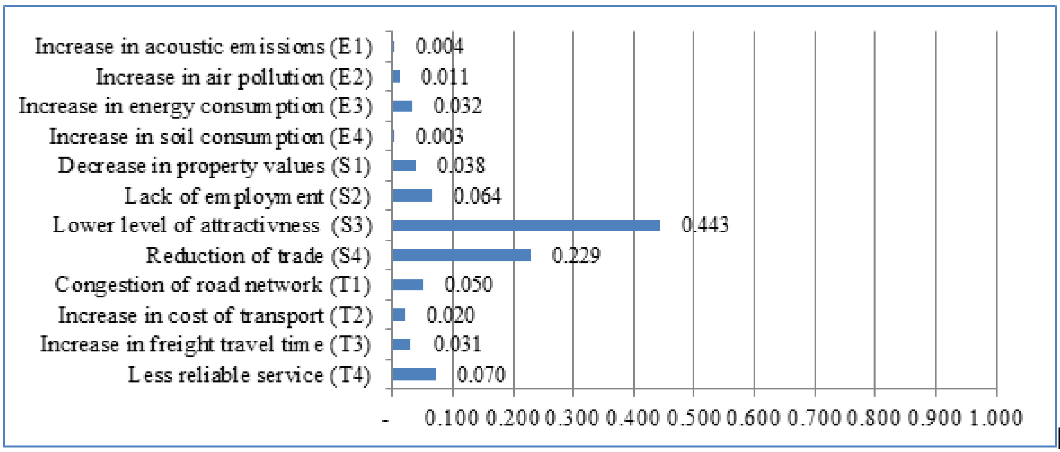


Figure 4 Final priority vector of the elements of the model

4. Discussion of the results and conclusions

The results of the ANP model as shown in the priority vector of Figure 3 highlight some interesting findings that can be summarized as follows. The most important effect that the delay in the realization of the corridor could produce is the "lower level of attractiveness" element (0,443), which belongs to the "socio-economic aspects" cluster. This effect is approximately as important as all the other elements combined. The second effect in the priority list is the "reduction of trade" element (0,229) in the "socio-economic aspects" cluster. It is possible to say that the two aforementioned elements are independent but strongly interrelated in determining the potential threats on the territorial system. The third element in order of importance is the "Less reliable service" element (0,070) which is part of the "transport aspects" cluster. It is important to note that the reliability of service has been considered by the experts in the focus group more important than the freight travel time and the costs of transport. It is also important to mention the fact that the elements belonging to the "environmental aspects" cluster have been given a very low importance. This can be explained in two different ways. To start with, it is possible to suppose that the freight volume will decrease because of the segregation effect due to the absence of the corridor axis. Secondly, the environmental effects are not a crucial point in the decision problem under examination because they would also be very high in the case of the construction of the corridor, considering the presence of the high speed rail.

The aforementioned considerations show that the results of the technical focus group reflect the concerns of the overall political class about the role that Italy could play in the international context. In fact, even if the project under examination refers to a transport infrastructure, the most important effects that one could expect from the delay in the construction of the corridor have a socio-economic nature and are not related to transport aspects or spatial planning considerations. This is consistent with other technical transport studies within the "Code24 project" that focus on the fact that North-West Italy is late compared to the rest of Europe in its expected conclusion of the work along the Corridor 24 (2020). It is possible to suppose at the strategic level, three extreme and provocative scenarios at that time (Carrara and Arnone, 2011):

1. Work not finished: Italy gets "isolated", with loss of accessibility to the economic system of the Pianura Padana; the Ligurian ports are just ports of the Pianura Padana; with loss of competitiveness of Italy;

2. "Alps" work finished, "Ligurian" work not completed: Italy gets "conquered". This could represent an increased permeability of the Alps; Northern ports enlarge their hinterland in the Pianura Padana and Ligurian ports are isolated from Europe;

3. All work finished: Italy becomes a"gateway of Europe", with an increased connection between Italy and Europe and a greater competitiveness of the Ligurian ports (well linked to the inland) in Europe.

In terms of scientific contribution, the developed model has offered a creative way of combining many detailed criteria in an evaluation study and synthesizing them to obtain a priority list of the most important effects that a delay in the construction of the infrastructure could produce on the territorial system. Moreover, the ANP-based application succeeded in bringing together a heterogeneous decision-making group made of specialists coming from different fields of expertise related to transport activities and forcing them to discuss and to evaluate the criteria of the model.

The ANP methods proved to be suitable in dealing with decision problems related to transport planning for several reasons. To start with, the methodology allowed the most important elements of the decision problem to be highlighted through a transparent and traceable decision-making process thus facilitating deliberation. Second, the methodology supported communication with the DMs and granted a mutual understanding. More generally, it can be said that the ANP can be usefully applied within the context of the stakeholders-driven or institutional approach to transport project evaluation. Policy makers can use the findings resulting from the application as input for designing formal decision-making processes geared towards including stakeholder's objectives in transport project evaluation (De Brucker *et al.*, 2004). Apart from the aforementioned advantages that are a result of the application of the ANP in complex decision environments, one of the most significant strengths of the adopted methodology is represented by the fact that the DM gains more awareness of the elements at stake while structuring the model and thus learns about the problems while solving them (Bottero *et al.*, 2010).

There are still a number of opportunities for expanding the study and for validating the obtained results. First, it would be of scientific interest to implement the ANP model on the whole corridor, including organizing different focus groups with all the partners of the Code24 project. Second, even though the use of fuzzy logic in AHP and ANP methodologies is quite controversial, future research could explore this approach in the development of the model. In particular, the fuzzy logic could be useful in a group decision making context for the aggregation of the different preferences. It could therefore be very interesting to investigate the use of fuzzy numbers in the pairwise comparison process (Liu and Lai, 2009) in order to tolerate vagueness and ambiguity in the evaluation. Finally, the application of the ANP model could be enriched by specific visualization tools that are of great importance for presenting and communicating the results of the analysis to Decision Makers and the interest group (Lami, 2011).

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