

# AHP-Aided Evaluation of Logistic and Transport Solutions in a Seaport

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Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/63686>

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## Abstract

The chapter reports on the application of the analytic hierarchy process (AHP) to a strategic decision in the transport sector, concerning the reconfiguration of the railway infrastructure of the seaport of Trieste. The proposed solutions should not only solve some technical and operational problems of the terminal, but they could allow the port to be included in the Trans-European Network-Transport Programme (TEN-T), promoted by the European Union and aimed to develop the Trans-European Networks of Transport. Accordingly, the selection of the solution with the most promising potential to satisfy the goals of the TEN-T policy is a fundamental stage of the project. The case study is an actual AHP application to an evaluation process concerning a pre-feasibility study of strategic solutions in the logistics and transport fields. Some practical aspects regarding the application of the AHP and the building of the model, when several stakeholders are involved in the decision process, are highlighted and discussed.

**Keywords:** Logistics, intermodal transport, railway, seaport, analytic hierarchy process (AHP)

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## 1. Introduction

The Trans-European Network-Transport Programme (TEN-T), promoted by the European Union, is aimed to develop the Trans-European Networks of Transport, which include the major priority projects for road and combined transport, waterways and seaports, and the European network of passenger and freight trains. In this context, the North Adriatic Ports Association Studies project (NAPA) was developed, which focuses on the future develop-

ment projects of the Northern Adriatic seaports: they are considered as fundamental points of interconnection between different transport systems. Each port has therefore conducted specific research as part of NAPA Studies. As far as the Port of Trieste is concerned, its current infrastructure, layout, and operations were deeply investigated and the bottlenecks, which could negatively affect the role of the port within the network, were identified. Several institutions and subjects are interested in the progress of the port infrastructure and consider the NAPA project an opportunity for developing concrete solutions that could redefine the place of the port in the European network. A set of technically feasible alternatives was found that encompass the reconfiguration of the railway infrastructure and operations.

Three main stakeholders are involved in the decision process: the port authority, the Italian railway infrastructure manager, and the Region Friuli Venezia Giulia. They are all interested in the development of the port but pursue different goals. On account of the complex setting, the multi-criteria evaluation of the solutions has been considered as an important stage of the overall project aimed at supporting the final decision. Indeed, multi-criteria methods give the opportunity to include in the evaluation of the project solutions several points of view and effects, some of which cannot be easily translated into economic values. The opportunity to understand the points of view of each stakeholder and involve them in the evaluation process is key features of some methodologies. On these grounds, the analytic hierarchy process (AHP), which enables a transparent process and the explicit representation of the decision-makers, was selected to support the analysis and evaluation. By involving the key stakeholders and some experts in such activities, it was possible to build a valid and useful model that allowed to select the most effective alternative with respect to the goals of TEN-T policy.

After a short presentation of the background of the NAPA project, the main aspects of the discussion and decision to be made about the Port of Trieste are introduced. In Section 4, the multi-criteria methods are presented with specific reference to strategic decisions in the transport sector and the AHP is briefly outlined. The section then describes the application of the AHP in the specific situation and the procedure that was followed to interact with the stakeholders. The results of the application are reported and discussed in the Section 5. Some practical aspects that emerged during the process are eventually highlighted in the Section 6, which precedes the conclusions.

## 2. Background of the project

The Port of Trieste is located in the northern Adriatic, which is a strategic position at the intersection among important maritime routes and motorways of the sea and the European corridors, Adriatic-Baltic, and Mediterranean (**Figure 1**). Therefore, it may play an important role (European gateway) for long distance traffic flows between the Far East and the markets of Central and Eastern Europe.



**Figure 1.** Map of European transport corridors.

The port already offers regular sea side and direct connections with China, the Far East, Singapore, Malaysia, Albania, Slovenia, Croatia, Greece, Turkey, Egypt, Lebanon, and Israel. From the land-side perspective, it is connected with the production areas and industrial North-East Italian and Central Europe, with different destinations, such as Germany, Austria, Czech Republic, Hungary, Switzerland, and Luxembourg, serving a very interesting economic area. In 2015, the port handled 57.12 million tonnes; therefore, it is the first port of Italy for the handling of goods in tonnes (source: port authority).

Regarding land-side infrastructure, the Port of Trieste has a long tradition in good rail connections and it is linked to the main Italian railway network through the Trieste Campo Marzio marshalling yard where all operations of train composition and de-composition are concentrated. The port is connected to Trieste Campo Marzio by means of three openings (**Figure 2**, Varco II, Varco III, Varco IV circled in red), but currently only one of them (Varco III) is in operation. Moreover, insufficient curvature radii and a critical general layout of the marshalling yard cause excessively complex and time-consuming shunting. The whole rail terminal has been identified as the main bottleneck for railway traffic increase inside and outside the port not only for the present conditions of the infrastructure, but also for its management.

The main reference document for planning and development is the Master Plan of the seaport. Starting from the analysis of the existing weaknesses and strengths, and in relation to a strategic vision and traffic increase forecasts, the Master Plan identifies a list of actions to be implemented in the port area. They include the extension/expansion of the existing facilities in the area of wharfs ("Moli") V, VI, and VII, and the realization of a new Logistic Platform, which is a modern and functional multipurpose terminal.

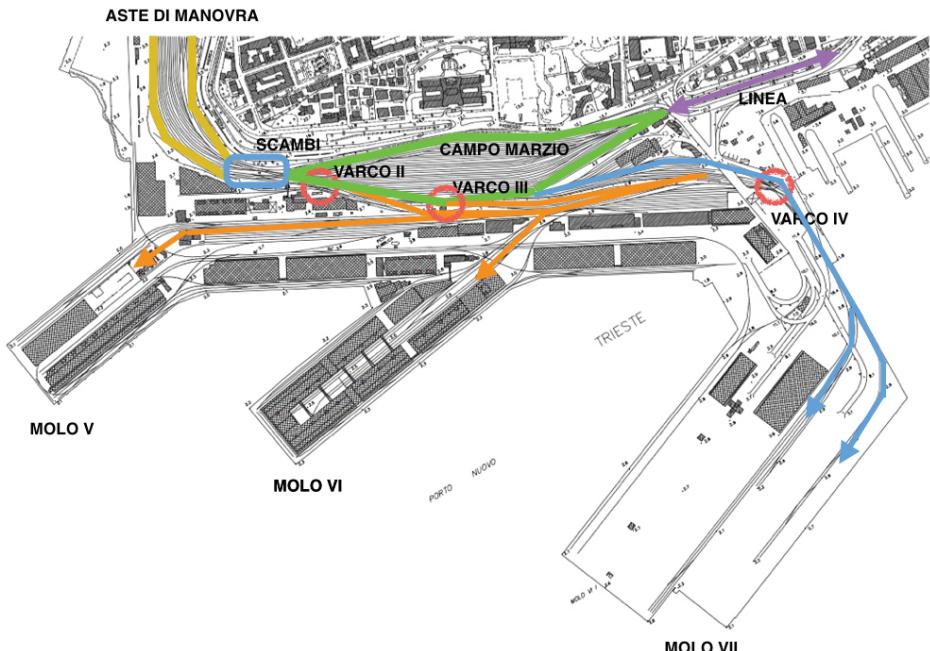


Figure 2. Layout of the seaport of Trieste.

In this context, the North Adriatic Ports Association Studies project (NAPA) was developed, which aims to support future development projects of the Northern Adriatic ports, thus contributing to the development of seaports as points of interconnection between different transport systems. In 2012, the NAPA carried out a market study on the potential handling capacity of containers in the ports of Koper, Ravenna, Rijeka, Trieste, and Venice. The five NAPA ports, in fact, intend to develop container traffic, becoming a multi-port gateway for Asian and Central and Eastern Europe economies. Each port has, therefore, conducted specific research as part of NAPA Studies. As far as the Port of Trieste is concerned, its current infrastructure, layout, and operations were deeply investigated and the bottlenecks, which could negatively affect the port's role within the network, were identified. A set of different feasible solutions was found that encompass the reconfiguration of the railway infrastructure and operations, in order to make possible the composition and movement of trains longer than those currently possible inside the port, ensuring efficiency improvement of the operational activities, particularly for containers, and, consequently, traffic increase.

These improvements are also required to meet the railway infrastructure requirements for the core network within the European Union's Regulation No. 1315/2013 [1] on "Union guidelines for the development of the trans-European transport network" (art. 39 "at least 22.5 t axle load, 100 km/h line speed and the possibility of running trains with a length of 740 m").

### 3. The decision process

Different solutions for the reconfiguration of the port infrastructure were proposed, and the main aim of the decision process was then to compare the feasible alternatives and to identify the best project for the Port of Trieste in consideration of the EU's goals and the subjects who are interested in the improvement of the facility. Three main decision-makers are involved in the decision process: the port authority, the Italian railway infrastructure manager—Rete Ferroviaria Italiana (RFI)—and the Region Friuli Venezia Giulia. They are all interested in the development of the port, but they pursue different goals.

The port authority has the primary task of defining the port strategies, planning, coordination, promotion, and control of port operations and other commercial and industrial activities in the port. The authority is also responsible for the ordinary and extraordinary maintenance of the common areas within the port and for the general services to port users. RFI has the main task to develop, manage, and maintain the railway network. It is also responsible for the commercial access and use of the infrastructure by transport companies. The Region Friuli Venezia Giulia has the competence in the regional development, transport planning, and port regulation. Accordingly, RFI may be responsible for railway design and construction, the Region for transport network planning, and the port authority for the port development.

On account of the complex setting, the evaluation of the solutions has been considered as an important stage of the overall project aimed at supporting the final decision. As stated before, the main goal of the assessment activity was to identify the best technical solution to improve the railway infrastructure both in the Port and in Campo Marzio station. Within NAPA Studies project, a team of experts has been built in order to support the analysis and evaluation process. The experts were able to estimate the performances of the alternatives against the main criteria included in the EU Regulation for this kind of interventions, and to support the decision-makers throughout the assessment.

The first step was the identification of the alternatives. In particular, three new projects were proposed and a “do minimum” alternative was also taken into consideration. In summary, the candidate solutions are the following:

“Do minimum”: The alternative refers exactly to the actual situation in which only planned maintenance activities are considered; of course, long trains cannot be composed nor circulate in the system;

Alternative “650 m”: The project allows the composition and circulation of trains 650 m long; it includes a new intermodal terminal between Campo Marzio yard and the Port area to be used by Molo VII container terminal; the solution was promoted by RFI;

Alternative “750 m A”: The project allows the composition and circulation of trains 750 m long. The composition and de-composition of longer trains is made up through a set of shunting movements of shorter trains using the existing openings; long trains cannot enter the port directly;

Alternative "750 m B": The project allows the composition and circulation of trains 750 m long. In this case, an additional opening should be realized to allow the direct long train movement from and to Molo VII, while 650 m trains may use the other openings and reach Molo V and VI with simpler shunting operations.

The alternatives were analyzed with particular reference to the goals of TEN-T policy, and it was decided to investigate the methods that could be suitable to support the evaluation process ensuring transparency and participation. The methodological aspects and the resulting choice are discussed in the next section.

## 4. The methodology and the AHP model

### 4.1. Methodological aspects in the evaluation of transport projects

#### 4.1.1. Generalities

The evaluation of solutions is a key activity within feasibility studies concerning transport projects. Study guidelines and regulations have traditionally focused their attention on the so-called "technical and economic feasibility"; in this context, evaluation has been based on the technical, financial, and economic contents or effects of a project, and more specifically, on economic efficiency [2]. With this respect, financial methods have been adapted and used in order to judge the economic efficiency by comparing the cost of the resources employed to produce and manage the infrastructure, and the economic benefits that could be derived from it. This evaluation approach is grounded on the assumption that it is rational to choose the solution that is the best according to one criterion: the economic advantage of the stakeholders.

A standard methodology of this kind is the cost-benefit analysis (CBA), which is focused on the welfare change of the community that bears the costs and gains the advantages of the transport infrastructure and service. CBA is widely used for infrastructure projects on account of the public expenses expected to realize and run them [3]. In the standard CBA, the capital and running financial costs and other effects (e.g., on the environment, on the community's mobility etc.) are converted into "social opportunity" costs or revenues. Different synthesis indicators, which are based on the monetization of the effects and their inter-temporal discount (e.g., the economic net present value), can be used to evaluate the economic performance of a project solution (see [4]). The methodology can clearly support the selection of the "best" alternative in a set in that the solutions can be ranked according to their economic performance.

Even if the CBA takes into account a single criterion of evaluation, the methodology aims to assess different types of outcomes, which is always appropriate to projects in the transport sector (see [5]). Indeed, some effects (e.g., the environmental costs) can be reasonably translated into monetary terms and then aggregated into a single measure of economic efficiency. Nonetheless, the methodology becomes complicated and less transparent when it comes to assessing other effects of transport infrastructures (in particular, the "intangible" ones). In addition, some criticism about the principle of welfare theory and the monetization approach,

and the need to introduce different dimensions of evaluation have encouraged the use of methods that can explicitly take into consideration several evaluation criteria [6–8].

The methods of multi-criteria decision analysis (MCDA) can support decisions in which several aspects, points of view, or decision-makers are relevant. Projects of transport infrastructures have generally more than one goal to achieve which are advocated by different interest groups or stakeholders. Indeed, they are typically the subject of “strategic” decision processes that involve several participants with different roles in and power over the process and the final decision. In these multi-actor decision processes, the participants, explicitly or implicitly, promote their interests and often represent those of other subjects or groups (see, e.g., [9, 10]); in the following, the term “stakeholder” will be used to indicate subjects or groups that participate or are represented in the decision process.

According to a relevant article by Banville et al. [11], the multi-criteria methods are particularly appropriate for the introduction and the use of the stakeholder concept in supporting decisions, so that different viewpoints can be explicitly and clearly adopted. In particular, the concept of stakeholder can improve the initial stages of decision-making, namely problem analysis, identification of the alternatives and of the evaluation criteria. Different stakeholders have different perceptions of the problem that is targeted by the project, its solutions and their outcomes on the mobility system, the community, and the environment; they may appreciate such aspects from different perspectives, and therefore, the levels of importance of the evaluation criteria may vary among them. Bristow and Nellthorp [3] confirmed that MCDA can be more effective than CBA to capture and assess environmental and social impacts, while other authors [7, 12] concluded that MCDA is suitable to taking into explicit account public opinion and making a transparent and participative decision.

MCDA methods give the opportunity to include in the evaluation of the project solutions several points of view and effects, some of which are not easily converted into economic values. They have been successfully applied to decision processes concerning transport systems and are promoted within guidelines on feasibility studies (see, e.g., [13]). A good number of articles have been published that present applications of MCDA to infrastructural projects (e.g., [14–16]) and transport plans or policies (e.g., [12]). Several studies confirm the above-mentioned advantages of MCDA with respect to economic-based methods, but, in line with official guidelines, they usually suggest to carry out both analyses to have a complete picture of a project's effectiveness and efficiency (see, in particular, [7, 8]). As for ports, the studies pay particular attention to logistic and locational effects of these infrastructures and highlight the necessity to involve the port authority and users, governmental institutions, and community stakeholders in the decision process [17, 18].

Traditionally, the stress has been posed on the notion that any action performed on a transport system would involve public or private costs in exchange of benefits to the system's users or external to the system. In addition, in many cases, the decision concerns the choice of one item within a set of pre-defined alternative solutions. Accordingly, the decision process and the supporting MCDA methodology have often been applied in the framework of a “rational” decision process with the following main features:

The subjects who take part in the process have specific (and possibly stable) roles;

The process can be structured in a sequence of steps;

There is a clear distinction among decision-making, analysis and evaluation activities;

The object of the decision can be described through a set of properties or attributes that can be individually analyzed and evaluated.

Several authors have proposed guidelines for a structured application of MCDA, which should make the methodology more straightforward and, in the case of projects involving the public interest, like in the energy and transport sectors, could favor the transparency of the process (see, e.g., [15, 19]). The proposed structures or procedures can be more or less detailed but, typically, they include the following steps:

definition and structuring of the problem;

identification and development of the alternative solutions;

definition of a set of criteria for the evaluation;

identification of the stakeholders' system of preference;

evaluation of the alternatives and recommendation to the decision-maker(s).

It is commonly accepted that the MCDA process is non-linear and can be subject to several refinement cycles, in particular when several actors are involved. As previously remarked, the participants to decision processes concerning transport projects have usually different roles and decision power that can be broadly subsumed under the following categories:

actual decision-makers (who can take the final or other key decisions);

stakeholders or their representatives (who can have more or less powerful influence on decision-makers);

analysts and experts (who may be consulted to support the whole process or to provide highly technical information on specific topics).

In common practice, there is a clear distinction between the decision-makers and the subjects who support (or "aid") the decision by means of their technical or scientific expertise. Some authors, however, have made a clearer distinction between "experts," who provide technical advice on specific topics (e.g., experts who carry out mobility analysis), and analysts, who analyze, model and facilitate the decision process [20–22]. Furthermore, it has been remarked that the analyst can effectively support the decision-makers if there is an interaction with them, so that the products of the analysis (specially the models) are understood and validated.

As previously noted, decisions concerning transport projects or plans are the result of a multi-actor process in which diverse stakeholders can exercise their influence or decision power with different strength, in different stages and on different objects of the process.

For instance, a public institution can promote a project solution since the pre-feasibility study and decide to fund it, but it cannot take the final decision about its actual implementation. The clear determination of the actual objective of the decision, the involved stakeholders, and their role in the process are prerequisites to taking into account the key stakeholders' viewpoints in the application of the evaluation method, and to promoting their participation in the analysis and evaluation activities.

Some studies have indeed underscored the importance of including the stakeholders and their objectives at the beginning of the MCDA, so that it is possible to relate them to the evaluation perspectives, the criteria used in the model and their levels of importance [10, 23, 24]. Furthermore, it has been remarked that using the MCDA methods that enable to add them to the model explicitly, may improve the transparency of the whole exercise [25, 26].

In the case study discussed in this article, the analytic hierarchy process (AHP) was used because it offers some features that can facilitate the inclusion of the above-mentioned aspects in the decision aiding process. The AHP [27] has been applied since the 1980s to support the evaluation and selection of alternative project solutions or plans in the transport field. The effective hierarchical representation of a decision problem and the ability to evaluate quantitative and qualitative properties of the alternatives are just two of the most notable features of the method. Its key steps can be explained by the analyst to the decision-maker with limited effort, establishing a solid ground for the mutual understanding and validity of the evaluation process [28].

The evaluation of the alternative infrastructural solutions of the port railway system was carried out by means of an AHP model, which offered an explicit representation of the main stakeholders, the evaluation criteria, and the alternatives. The inclusion of the stakeholders in the hierarchy, which has been used in some previous studies [29], allows to take into consideration their judgments in regard to the elements of the lower level (dimensions of evaluation and criteria). The experts of the project team performed the evaluation of the alternatives' performance against the criteria. This is in line with other studies, which affirm that the experts' contribution to the decision process improves the technical soundness of the solutions and can take into account the viewpoints of the users of the transport system [30, 31]. The model and the results are discussed in the next section.

## 4.2. The implementation of the AHP method

### 4.2.1. *The main features of the evaluation*

The development of the NAPA project and the key role of the evaluation have been discussed in Sections 2 and 3. The evaluation stage can be conceived as a process with specific objectives, resources, and expected results. The relevant characteristics of this process are the following:

overall goal: The project is aimed at finding a configuration of the railway infrastructure in the port that can pursue the goals of TEN-T policy;

expected output: The result of the evaluation process is the identification of the project solution that will be submitted to the EU for funding;

object of the evaluation: The candidate solutions are given and mutually exclusive (alternatives);

key stakeholders: There is a limited set of stakeholders who can exert a significant influence on the final decision (submission of the project solution);

role of experts: The project team is entitled to support the evaluation stage and provide the technical expertise to assess the performance of the project solutions.

These aspects have significant effects on the way in which the evaluation is performed and the AHP model is built. In the AHP (see, e.g., [32]), the decision problem is structured as a functional hierarchy of connected elements (or “nodes”). The overall goal was located in the top level (focus of the decision) and is broken down into elements that are used to analyze its properties, assess their importance for the decision-makers and gauge the level at which such properties are found in the available solutions (located at the bottom level). Each element of a level can be connected to one or several elements of the lower levels; stated differently, the elements connected to an upper node (“parent node”) share the property represented by that node: it is then possible to judge the relative “priority” (or “importance”) of the elements with respect to the property. Relative priorities can be obtained by direct rating or, as suggested by Saaty [33] and in all those cases in which direct assessment is not viable, by pairwise comparing the elements of a level against the parent node. The child nodes of a level that are connected to a parent node can be grouped into a “cluster”; the elements in a cluster should not have priorities that differ by orders of magnitude, and a cluster can contain all or only a number of the nodes of a certain level. Finally, the connected hierarchy enables to synthesize the priorities of the alternatives with respect to the overall goal.

#### *4.2.2. The evaluation model*

The hierarchy built in the case study consists of four levels (**Figure 3**):

first (top) level: overall goal of the decision;

second level: main stakeholders;

third level: criteria of evaluation;

fourth (bottom) level: alternatives.

The upmost node represents the overall goal of the evaluation process, which was stated as “Select the port project alternative that can achieve best the objectives of EU’s TEN-T policy.” It is worth noting that the sentence is fairly simple and contains the key aspects of the evaluation:

the evaluation is aimed at selecting a candidate in a given set of alternatives;

the evaluation solutions are evaluated on the basis of their potential to implement TEN-T policy.

The overall goal was validated by the members of the project team on the basis that it complies with the main objective to be achieved in the NAPA project. The project team identified the stakeholders that can exert major influence or power on the implementation of the project (see Section 3):

the Regional Government of Friuli Venezia Giulia (FVG), because of its planning and control role over strategic projects in the regional territory;

the Port Authority of Trieste (APT), which plans, co-ordinates, promotes, and monitors port operations;

the Italian Railway infrastructure manager (RFI), which has the responsibility for the planning and management of the railway infrastructure.

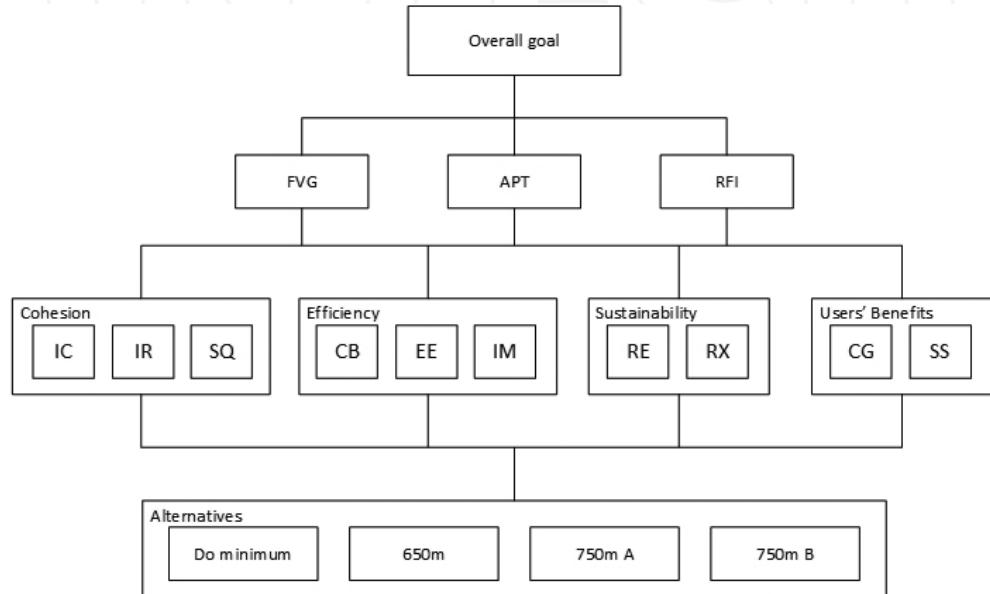


Figure 3. Hierarchical model built to support the evaluation.

These “key stakeholders” were explicitly introduced in the hierarchy, and representatives of them were interviewed to elicit the levels of importance of the criteria used in the evaluation. The explicit introduction of the stakeholders in the model is not strictly necessary to use their judgments for weighing the criteria. Nonetheless, it makes their importance or influence over the main goal more transparent, and the input of their judgments of importance, with regard to the elements of the lower levels, easier and clearer. As for the importance of the three stakeholders with respect to the overall goal, after some discussion within the project team, it was decided to assign them equal weights and analyze the sensitivity of the overall priorities to variations of their values.

The third level of the hierarchy is made up of the criteria used for the evaluation. They are grouped into four clusters that represent the four dimensions of evaluation directly related to the EU's objectives for TEN-T. It is worth remarking that TEN-T policy proposes four "categories of objectives": cohesion, efficiency, sustainability, users' benefits. Each of them is a dimension of evaluation that includes a set of "general objectives" with a common policy goal and are valid for any kind of project concerning the transport network (independently from the transport mode, location, type of action). The general objectives are then translated into "specific objectives" in light of the particular action to be carried out in a portion of the network. The categories of objectives are briefly introduced in the following points [1].

Cohesion can be carried out through the improvement of the accessibility of all EU's regions, the reduction of quality gaps that can affect the infrastructure and a stronger interconnection of long-distance, regional, and local traffic flows.

Efficiency aims at assuring the continuity of flows and the interconnection and interoperability of transport networks and promotes intermodality and economic efficiency in the production of transport service.

Sustainability aims to provide a transport network that can reduce externalities, preserve sensitive areas, and reduce emissions.

The users' benefits should take into consideration the needs of the users of the transport system including their safety and security.

The categories were used as clusters to group the criteria that are specific to transport projects that aim to improve the Adriatic-Baltic and Mediterranean corridors within the TEN-T network. They were selected by the project team among the criteria proposed in the "Baltic-Adriatic Core Network Corridor Study" [34] taking into account those directly connected with freight multi-modal transport. The criteria aim to evaluate the performances of a project alternative in regard to the aspects that are reported here below. It can be noted that all the criteria are aspects to be improved by means of the implementation of the project.

#### 4.2.3. Cohesion

Interconnection of flows (IC): The development of the interconnectivity of the transport network between long-haul sections and long-haul/short-haul sections.

Standard and quality of the infrastructures (SQ): The improvement of the quality and standards of the transport infrastructure with the aim of complying with the technical requirements (for the railway transport: line speed, train length, axle load).

Regional integration (IR): the development of the accessibility of European regions with particular reference to the most peripheral ones.

#### 4.2.4. Efficiency

Removal of rail and road bottlenecks (CB): The reduction or removal of existing transport bottlenecks in the network or, conversely, the creation of a new bottleneck.

Intermodality (IM): The optimal integration and interconnection of different transport modes, with particular reference to the connections to ports, airports, and rail-road terminals.

Economic efficiency (EE): The promotion of economically efficient and high-quality transport and the efficient use of existing infrastructures.

#### 4.2.5. Sustainability

Reduction of emissions (RE): The reduction of emissions and noise from the transport activity.

Reduction of externalities (RX): The reduction of external costs of transport and protection for environmentally sensitive areas.

#### 4.2.6. Users' benefits

Congestion (CG): The reduction of congestion in the transport network.

Safety and security (SS): The enhancement of safe, secure and high-quality transport standards, for both passenger and freight.

The criteria were then presented to the representatives of the stakeholders within the project team who considered them valid in the specific context. The hierarchical structure enables to relate the set of criteria to the solutions and the key stakeholders. It can be noted (**Figure 3**) that the key stakeholders are connected to the clusters and the criteria. This feature of the model can be practically implemented by means of the supporting software tool that was chosen: SuperDecisions [35]. In this way, it is straightforward to input in the model the stakeholders' pairwise comparisons of importance:

between the clusters;

between the criteria with respect to their cluster.

The relative weight of each criterion is then the synthesis of the judgments of all three stakeholders on both clusters and criteria.

The fourth level includes the four alternative solutions that are described in Section 3, namely:

"Do minimum";

"650 m": project which allows trains 650 m long;

"750 m A": project which allows trains 750 m long, mode A;

"750 m B": project which allows trains 750 m long, mode B.

The alternatives have been analyzed by the project team's experts and they can be characterized and judged with respect to all the criteria. However, considering that the association of the criteria with specific measures of performance is not viable at this stage of the project, it was decided to elicit the alternatives' priorities by pairwise comparing them against the criteria.

The execution of the model produces the overall priority of the alternatives: it is then possible to rank them or identify the most effective. Nonetheless, it can be noted that the criteria of the model do not include a measure that accounts for the investment cost. In fact, as already remarked, the criteria represent the positive outcomes that are expected from the implementation of the solutions. As suggested by Saaty (cf. e.g., [32]), the cost of each alternative was introduced after the evaluation of the overall performance. This approach allowed the stakeholders to focus their attention only on the effects of the alternatives when they judged the weights of the criteria. Eventually, the benefit-cost ratio was used to obtain a measure of resource spending efficiency: the alternatives could then be ranked, from best to worst, in decreasing order of the ratio.

#### *4.2.7. The evaluation activity*

The evaluation activity was based on two methodologies:

- face-to-face interview with the representatives of the key stakeholders to assess the weights of the clusters and criteria;
- group discussion within the experts of the project team to evaluate the performances of the alternatives against the criteria.

The first consisted of the following stages:

- preparation of the interview;
- first-pass interview;
- consistency check and second-pass interview (if needed);
- input data to the model.

Two members of the project team, one of whom assumed the role of facilitator, conducted the interviews. As a first step, the main contents and objectives of NAPA project were recalled and the goals of the evaluation process were remarked. Secondly, the procedure of multi-criteria evaluation was presented, and the categories of objectives and the criteria were introduced and illustrated. Before the assessment exercise, its main steps were introduced with the help of the propositions reported below:

*"In order to obtain the overall evaluation of each alternative, it is necessary to establish the level of importance ("weight") of each criterion in regard to the main goal: the higher the weight of a criterion, the higher will be that criterion's contribution to the overall performance of an alternative."*

*"The levels of importance are derived from pairwise comparison of the criteria. For each pair of criteria (C1 and C2), you will be asked two questions:*

*Considering criteria C1 and C2, which is more important with respect to the main goal (or are they equally important)?*

*How much more important is that criterion?"*

The second judgment was based on the verbal scale proposed by Saaty that was briefly introduced to the respondents. Each stakeholder's evaluations were recorded in two different tables (see **Tables 1–6**): one for the pairwise comparisons of clusters and one for pairwise comparisons of criteria within a cluster. The results were then input to the software SuperDecisions for the consistency check.

The assessment of the alternatives' priorities against the criteria was the product of group discussions that involved the technical experts of the project team. Their contribution to the decision process assured a good level of technical soundness to the evaluation and the inclusion of the viewpoints of the port users and the promoters of the solutions.

## 5. Results and discussion

The results of the evaluation activity are reported in **Tables 1–16** starting with the data collected from the face-to-face interviews (**Tables 1–6**). Each of the three interviews with the key stakeholders' representatives produced two tables: the first shows the results of pairwise comparisons (in terms of importance) between clusters (or "categories of objectives"); and the second shows those between criteria of a cluster. The notation " $A > B$ " means that the element A is five times more important ("moderately more important") than B, while the notation " $A < B$ " means that the element B is five times more important than A, and " $A = B$ " means that A and B are equally important. The tables show the measure of inconsistency produced by the software for the pairwise comparisons between three or more elements; Saaty remarks that inconsistency can be acceptable if it is not  $>10\%$ .

Cluster i		Cluster j
Cohesion	<6	Efficiency
Cohesion	<3	Sustainability
Cohesion	4>	Users' benefits
Efficiency	4>	Sustainability
Efficiency	8>	Users' benefits
Sustainability	6>	Users' benefits
Inconsistency		0.08062

**Table 1.** Pairwise comparisons of clusters by FVG.

Only for stakeholder FVG, a second pass interview was necessary, due to the high inconsistency obtained after the first pass. Arguably, this situation can be attributed to the more limited

knowledge of the NAPA project and its relation with TEN-T policy that the FVG's representative had with respect to the other two interviewees. Indeed, while APT and RFI had been involved in the NAPA project at an early stage, FVG was consulted only after the complete definition of the four alternatives. A second possible reason can be the fact that the consultation with FVG was the first of the three, and therefore, the two interviewers could improve their command over the interview flow in the second and third sessions.

The results of the pairwise comparisons of the alternatives against the criteria are reported in **Tables 7–16**. A total of 60 comparisons were made by the experts of the project team, which were based on the alternatives' features and expected performances in regard to the criteria. The grounds of the experts' judgments are briefly reported in the following paragraphs.

Cohesion		Efficiency			Sustainability			
IC	5>	SQ	CB	<3	IM	RE	=	RX
IC	<3	IR	CB	<7	EE		Users' benefits	
SQ	<7	IR	IM	<5	EE	CG	3>	SS
<b>Inconsistency (cohesion)</b>							0.06237	
<b>Inconsistency (efficiency)</b>							0.06239	

**Table 2.** Pairwise comparisons between the criteria of a cluster (FVG).

Cluster i		Cluster j
Cohesion	3>	Efficiency
Cohesion	5>	Sustainability
Cohesion	>7	Users' benefits
Efficiency	3>	Sustainability
Efficiency	5>	Users' benefits
Sustainability	3>	Users' benefits
<b>Inconsistency</b>		0.04381

**Table 3.** Pairwise comparisons of clusters by APT.

Interconnection (IC—**Table 7**). The candidate solutions do not have any significant effects in terms of the improvement of the interconnection between long-haul and short-haul sections of the Adriatic-Baltic and Mediterranean corridors.

Standard and quality of the infrastructures (SQ—**Table 8**). Both solutions "750 m A" and "750 m B" comply with the European standard, because they allow the 750 m-long train operations without disruptions, while "650 m" and "Do minimum" alternatives do not. In fact, "650 m" could deal with long trains but with an important increase in track occupancy and conflicts in the port.

Cohesion		Efficiency			Sustainability			
IC	<7	SQ	CB	<3	IM	RE	3>	RX
IC	<4	IR	CB	<7	EE	Users' benefits		
SQ	4>	IR	IM	<6	EE	CG	7>	SS
Inconsistency (cohesion)						0.07348		
Inconsistency (efficiency)						0.09609		

**Table 4.** Pairwise comparisons between the criteria of a cluster (APT).

Cluster i		Cluster j
Cohesion	<3	Efficiency
Cohesion	=	Sustainability
Cohesion	5>	Users' benefits
Efficiency	3>	Sustainability
Efficiency	5>	Users' benefits
Sustainability	3>	Users' benefits
Inconsistency		0.04324

**Table 5.** Pairwise comparisons of clusters by RFI.

Cohesion		Efficiency			Sustainability			
IC	<5	SQ	CB	7>	IM	RE	=	RX
IC	3>	IR	CB	5>	EE	Users' benefits		
SQ	7>	IR	IM	<3	EE	CG	<3	SS
Inconsistency (cohesion)						0.06239		
Inconsistency (efficiency)						0.06239		

**Table 6.** Pairwise comparisons between the criteria of a cluster (RFI).

Regional integration (IR—**Table 9**). “Do minimum” keeps the present configuration of the port railway infrastructure essentially unchanged, and some local studies have observed that it presents some weak points that affect the accessibility to other European regions (e.g., Central and Northern Europe). The other three solutions certainly improve the situation and “750 m B” should have a slightly better performance because it allows a direct connection (without decomposition) between the Port and the main network for long trains.

Removal of rail and road bottlenecks (CB—**Table 10**). The present infrastructure presents several bottlenecks (e.g., the limitation in the number of trains that can be dispatched to the network) that can be reduced by the new projects. However, the alternative “750 m B” is more effective than “650 m” and “750 m A” with this respect, because it may allow a higher number of long trains thus reducing the number of trains given the demand flows.

<b>Interconnection</b>	
650 m	= 750 m A
650 m	= 750 m B
650 m	= Do minimum
750 m A	= 750 m B
750 m A	= Do minimum
750 m B	= Do minimum
Inconsistency	0.00

**Table 7.** Comparisons between the alternatives (IC).

<b>Standard and quality of the infrastructures</b>		
650 m	<5	750 m A
650 m	<5	750 m B
650 m	3>	Do minimum
750 m A	=	750 m B
750 m A	7>	Do minimum
750 m B	7>	Do minimum
Inconsistency		0.02752

**Table 8.** Comparisons between the alternatives (SQ).

<b>Regional integration</b>		
650 m	=	750 m A
650 m	<3	750 m B
650 m	5>	Do minimum
750 m A	<3	750 m B
750 m A	5>	Do minimum
750 m B	7>	Do minimum
Inconsistency		0.02752

**Table 9.** Comparisons between the alternatives (IR).

<b>Removal of rail and road bottlenecks</b>		
650 m	>3	750 m A
650 m	<3	750 m B
650 m	>5	Do minimum
750 m A	<5	750 m B
750 m A	>3	Do minimum
750 m B	>7	Do minimum
Inconsistency		0.04381

**Table 10.** Comparisons between the alternatives (CB).

<b>Intermodality</b>		
650 m	<7	750 m A
650 m	<9	750 m B
650 m	<5	Do minimum
750 m A	<3	750 m B
750 m A	>4	Do minimum
750 m B	>6	Do minimum
Inconsistency		0.08974

**Table 11.** Comparisons between the alternatives (IM).

<b>Economic efficiency</b>		
650 m	<7	750 m A
650 m	<9	750 m B
650 m	=	Do minimum
750 m A	<3	750 m B
750 m A	>7	Do minimum
750 m B	>9	Do minimum
Inconsistency		0.03410

**Table 12.** Comparisons between the alternatives (EE).

Intermodality (IM—**Table 11**). The infrastructure layout introduced by the alternative “650 m” may pose several problems to land-sea intermodal transport because the new terminal is quite far from the sea; therefore, the internal road traffic would increase causing potential congestion within the port road network. In this regard, the layout of “Do minimum” is better than that of “650 m”; nonetheless, “750 m A” and “750 m B” increase the capacity of the railway

infrastructure and improve the current layout. "750 m B" is better than "750 m A" as it gives the opportunity to manage without disruptions trains 650 m-long too.

Economic efficiency (EE—**Table 12**). The alternatives "750 m A" and "750 m B" can make the port more attractive to freight forwarders that need to send their goods to Central and Northern Europe, because of the train capacity increase, their compatibility with European standards and the reduction of unproductive times (due to operational disturbances, for instance). "750 m B" is more flexible than "750 m A" as it allows to operate 650 m-long trains too without disruptions.

Reduction of emissions (RE—**Table 13**) and reduction of externalities (RX—**Table 14**). The performances of each alternative with respect to the two criteria are similar, even if the first one is mainly related to the infrastructure's operation and the second one to its layout and land use. The "Do minimum" alternative is the worst against both criteria, and the "750 m B" is the best because it can assure a larger modal shift from road to railway than "750 m A" and "650 m." These last two are similar with respect to RE, while the layout of "750 m A" is slightly more beneficial than that of "650 m" as far as external costs of transport are concerned.

<b>Reduction of emissions</b>		
650 m	=	750 m A
650 m	<3	750 m B
650 m	5>	Do minimum
750 m A	<3	750 m B
750 m A	5>	Do minimum
750 m B	7>	Do minimum
Inconsistency		0.02752

**Table 13.** Comparisons between the alternatives (RE).

<b>Reduction of externalities</b>		
650 m	<3	750 m A
650 m	<5	750 m B
650 m	3>	Do minimum
750 m A	<3	750 m B
750 m A	5>	Do minimum
750 m B	7>	Do minimum
Inconsistency		0.04381

**Table 14.** Comparisons between the alternatives (RX).

Congestion (CG—**Table 15**). The alternative “750 m B” can produce the most valuable results in terms of reduction of congestion in the port and in the surrounding area as it can significantly increase modal shift from road to railway transport. A similar effect is expected from “750 m A,” though to a less extent. “650 m” introduces some additional movements of the trains within the terminal that imply just a slight improvement of train circulation with respect to “Do minimum,” which is the worst.

Safety and security (SS—**Table 16**). The modal shift that is expected from alternatives “750 m A” and ‘750 m B’ will provide benefits in terms of safety and security of freight and, because of the reduction in the number of trucks on the network, passengers. “650 m” has a slightly lower performance than the aforementioned two, but it is surely better than the current situation.

<b>Congestion</b>		
650 m	<5	750 m A
650 m	<7	750 m B
650 m	3>	Do minimum
750 m A	<3	750 m B
750 m A	7>	Do minimum
750 m B	9>	Do minimum
Inconsistency		0.06164

**Table 15.** Comparisons between the alternatives (CG).

<b>Safety and security</b>		
650 m	<3	750 m A
650 m	<3	750 m B
650 m	5>	Do minimum
750 m A	=	750 m B
750 m A	7>	Do minimum
750 m B	7>	Do minimum
Inconsistency		0.02752

**Table 16.** Comparisons between the alternatives (SS).

**Table 17** (second column) displays the overall priorities of the alternatives that were obtained from the execution of the model. The alternative “Do minimum” is the worst of the four: in fact, congestion and bottlenecks are just the most evident problems that the current infrastructure causes and that triggered the project. In addition, the present configuration of the railway infrastructure of the port would not allow its inclusion in the TEN-T system. This same

consequence would follow if the alternative “650 m” were implemented, as it does not comply with the European TEN-T’s standards. Further, the layout and track circuits of this solution would increase the congestion in the port terminal. Conversely, the two alternatives “750 m” assure seamless integration of the port in the Baltic-Adriatic and Mediterranean corridors, the removal of the current bottlenecks and higher economic efficiency. Still, the solution “750 m B” is more flexible than “750 m A” because it enables to operate trains 650 m- and 750 m-long without increasing the occupancy of tracks or delaying train dispatching.

In order to evaluate the sensitivity of the alternatives’ priorities to changes in the stakeholders’ weights with respect to the overall goal, some different combinations of weights were tested. The interval of variation was set between 0.2 and 0.6, as these were reputed the minimum and maximum relative levels of importance of the key stakeholders that could be acceptable in the context of the decision. Even if there were some changes in the values of priorities, the overall ranking proved to be stable.

As a final step, the estimated capital costs of the alternatives were taken into consideration (**Table 17**, third column). The benefit-cost ratio, namely the ratio between an alternative’s overall priority and the normalized capital cost, was used as an indicator of efficiency. **Table 17** (fifth column) shows the results: the alternative “750 m B” keeps the first position, while “Do minimum” gains two positions. In fact, this second alternative has a cost that is eight times lower than the capital cost of “750 m B,” but B’s expense is repaid by its high level of overall benefits. The value of the ratio is low for “650 m,” and this seems to suggest that it should not be taken into consideration in the future stages of the project.

At the conclusion of the evaluation, the results were illustrated and discussed with the decision-makers, who approved the proposal of further investigating and refining the technical contents of solution “750 m B,” in order to seize opportunities for funding it.

Alternatives	Overall priority	Estimated investment cost (M€)	Normalized cost	B/C ratio
Do minimum	0.064	6.5	0.046	1.38
650 m	0.136	38.5	0.275	0.49
750 m A	0.276	45.0	0.321	0.86
750 m B	0.524	50.0	0.357	1.47

**Table 17.** Overall results.

## 6. Practice implications and lessons learned

The analysts who support the decision process usually face several practical problems concerning the development of the model and the interactions with the actors involved in the process. In the specific case, the activity was limited to the evaluation stage, which is part of a larger decision process; nonetheless, there were some issues related to the presence of several stakeholders and the need to translate the solutions’ specific technical features into the criteria,

which represent properties that are more general but are strictly connected with the key objectives.

The key stakeholders had different roles (see Section 3), were involved in the project at different stages, and their representatives had different levels of expertise and knowledge of the problem. Such situation is not infrequent in strategic transport decisions and should be carefully managed. The opportunity to have an open and informative discussion with the stakeholders, and the quality of the information obtained can be delicate aspects. The case study confirms that it is necessary not only to identify the key stakeholders but also to individuate their representatives and involve them at an early stage of the evaluation process. However, the authors of this study observed that there is a relation between the interest and role of the stakeholder in the process (in particular, if a stakeholder is the promoter of one or more solutions) and the quality of the information retrieved from their representatives.

The interview of the actors is a key activity in multi-actor evaluation and should be carefully planned and, possibly, tailored to the respondent role (expert, policy maker etc.). In the specific, a structured interview was arranged only for the key stakeholders, while the experts were consulted in the context of group discussions within the project team. On the one hand, the interview allowed the respondents to focus their attention on the topics and their actual contribution to the evaluation; on the other, they did not always feel at ease with making comparisons between pre-determined criteria and asked for examples that could better describe their practical meaning. Not surprisingly, the representatives of the stakeholders involved in the NAPA project had less problems in the assessment.

The last observation is also valid for the experts of the project team. Still, some methodological issues were highlighted. Firstly, even if the separation between stakeholders' weighting of criteria and experts' judgment of the alternatives' performance was considered in line with the "political" and technical contents of the evaluation, an open discussion involving both figures could have been effective in exchanging viewpoints and circulating information. Secondly, the need to subsume many technical features of the solutions under broad criteria was considered arguable. In some cases, the association of the characteristics (such as track configuration, capacity, transit times, etc.) with a specific criterion was not immediate; further, this approach seemed to negatively affect the transparency of the evaluation. The opportunity that AHP offers for using both pairwise comparisons and direct measures could have been seized, and it could have satisfied some experts who stress the difference between "objective" and "subjective" measures of performance. However, this would have implied an additional effort to select the measures of performance that were meaningful for a criterion and non-redundant; in addition, the development stage of the project could not assure that the needed data were available. On these grounds, it was decided to employ the original methodological solution, based on pairwise comparisons. The last issue that was raised by the experts concerned the possible interdependencies among several factors (criteria or features), which were not considered in the AHP model. It was acknowledged that the model was a simplified representation of the problem: other methods that can deal with interdependencies, such as the analytic network process [36], should be used if a more refined evaluation was needed at the cost of a greater intellectual effort and a broader participation of experts and stakeholders.

## 7. Conclusion

The evaluation process satisfied the participants to the NAPA project concerning the development of the Port of Trieste: the objective of the evaluation was achieved, and the result was useful for the next stages of the project. The AHP allowed the implementation of a multi-criteria model in which the most important elements of the evaluation (key stakeholders and criteria aligned with EU's TEN-T policy) are plainly represented. This made the model transparent and easily understandable by the participants. An early involvement of the key stakeholders, who provide information that is essential to the assessment, can surely improve the quality of the evaluation, which depends on the knowledge of the problem and, perhaps less importantly, on the level of expertise in the technical field. The AHP may offer a representation of the decision problem that is too simplified in some cases; in particular, when interdependencies between elements of the problem cannot be overlooked. However, it is essential to consider if the improvement in the accuracy of the model is worth the increase in model complexity and in the amount (and quality) of the information that is required to produce reliable results.

## Acknowledgements

The study here presented has received funding from the European Union—Trans-European Transport Network (TEN-T), Commission Decision 2013-EU-21017-S, under the grant agreement “Development of North Adriatic ports multimodal connections and their efficient integration into the Core Network (NAPA STUDIES).”

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