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A spatial decision support system for strategic urban re-development. The case study of Turin Central Station, Italy

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ABSTRACT

The development of urban and territorial projects requires more effective and supportive visioning and forecasting evaluation methods. Traditionally, MCE (Multi-criteria evaluation) theory aim at foreseeing early warning signals and place them in the context of planning and designing a new or existing project. However, this evaluation lack of visualisation which are essential for assessing other design aspects, such as aesthetical conditions, etc. More recently, spatial decision support tools (e.g. Idrisi) based on the integration of MCE and Spatial Analysis have been usefully adopted for helping decision making processes on a the basis of “visible” rather than “discursive” design conditions. The problem with these tools is the hierarchical structure of decisions underlying the MCE when applied to complex urban regeneration and sustainable development problems.

This paper discusses the potentialities of a new tool, based on the linking of MCE applications with the ANP (Analytic Network Process) technique that makes possible to systematically deal with all kinds of dependencies and feedback in a decision making problem. Some assumptions of this new support system will be explored on a practice level by developing and combining some analyses of a strategic infrastructural re-development area in Turin (Italy).

Key words: Analytic Network Process, Multicriteria Evaluation, Urban transformation, Space Syntax

1 INTRODUCTION

In the past ten years, Urban Designers have used new analytical tools for understanding city mechanisms, improving planning practice and possibly foreseeing some successful changes. This has been possible because spatial-related data have become more available, GIS-based software have acquired tools easier to use and more performing. Today a new generation of young researcher, process consultants, negotiators, consensus builders, design professionals combine and integrate many different techniques and become more familiar with the use of integrated urban information.
However this new software-based analyses and practices are very heterogeneous all over the world and it is difficult to path a common methodology that has been supportive for decision-making experiences. Brail (Brail & Klosterman 2001), who studied the successful raising of Transport Modelling System in USA, says that three factors are required for computer-based tools to be widely used in practice:

- a shared commitment to a well-defined methodology
- extensive government support
- the ability of available tools to provide needed outputs for a substantial user community

Besides this software-based revolution, there is lack of planning experiences that combine the relations between spatial organisations, social life and planning decisions in an analytical tool. Multicriteria Evaluation (MCE) tools could be an attempt to synthesise, hence support the activities of all actors involved in such planning processes. MCE tools support a wide range of planning problems and this has lead to its widespread adoption by planners, community groups, and decision makers. MCE literature and experiences are making a wide use of integrated tools and methods to support decision making, combining AHP - Analytical Hierarchy Process (Saaty, 1980), GIS spatial analysis functions and other analytic output provided by Space Syntax analysis.
Indeed MCE will combine useful evaluation criteria draw from Space Syntax and Functional Mix analytical methods. Moreover, due to the limitations in specific complex decision problems of the AHP model, this Paper suggests a new spatial decision support system based on the integration of MCE and the ANP - Analytic Network Process (Saaty, 2006). The result of these studies could effectively help stakeholders on the basis of “visible” rather than “discursive” design conditions (Roccasalva, Corsico 2004).

Specifically, the paper is structured as follows.
Next section introduces MCE, Space Syntax analyses, Functional analyses, and the ANP methodologies, from a theoretical viewpoint. Some explorative trials will be also produced in the form of images in order to start making the new support system more discussable and understandable.
Section 3 presents the case study and the construction of the ANP network model in the prospective of being applied in a real strategic infrastructural re-development railway stations area in Turin (Italy).
Finally, section 4 will provide some conclusion and future research perspective in the field.

2. METODOLOGYCAL CONTEXT

It is clarifying hence important to give one of the most common definition of MCE as *a decision-aid and a mathematical tool allowing the comparison of different alternatives or Scenarios according to many criteria, often contradictory, in order to guide decision makers towards a judicious choice. (*Roy 1996)
The most successful asset of MCE tools are the capacity to give a clear support to the stakeholders bias which says: "*if I don't see your point of view I hardly can conceive hence believe it*". In fact, MCE is keen to weight simultaneously all decisions and consequences on a viewable platform. However most of MCE are not supporting small scale analysis of urban development probably because MCE was originally designed in a Planning and landscape research environment and evolved on large scale issues, targeting wide areas, regions o even countries. Instead, this paper is investigating the opportunity of adapting some MCE-based analytical tools to answer important urban issues at a very detailed scale, supporting Urban Design policy making.
Based on practical studies and researches conducted at KTH Department of Urban Studies of Stockholm (Roccasalva 2005), it is important to distinguish between two preliminary operations that experts require to set ahead of any urban analysis:

- decide about the suitable MCE procedure to adopt according to the objectives
- decide about the spatial related criteria or constraints to manipulate with MCE tools and functions.

About the first operation, MCE literature has an extensive set of examples which are following the rules of Urban Forecasting theory (Van der Heijden 1996) and Scenarios building procedures (Roccasalva, Corsico 2004). In few words, there exist specific procedures that have to be adopted in accordance to:

- what answer has to be searched
- the long term or short term objectives (discrete or continuous MCE objectives)
- the modes of actors engagement into the analytical process

About the second operation, all practitioners must be aware of the multidimensional nature of urban and territory–related problems and, consequently, the multidimensional data that can be "translated" for a MCE tool. In fact, if choosing urban criteria and constraints is a problem, on the other hand it is crucial how to relate spatially all the suggestions, opinions, assumptions, notes, proposal in order to translate actors and expert's choices in design principles. In this regards the urban space Consultancy of Turin LAQ -TIP (High Quality Lab -Territorial Integrated Projects has experienced more difficulties but also advantages in adopting a set of urban criteria rather than choosing a likeable predicting procedure. Indeed, which are the most useful criteria for evaluating public space in an urban transformations analysis? For example, factors as walking patterns, living trends and behaviour model can be efficient criteria in the decision process and have related spatial consequences.
Focusing on this second operation, the following section will discuss a set of criteria which are driving towards a MCE application environment.

2.1 Interpreting criteria for an evaluation: Space Syntax and Functional mix

The dynamics that goes on between buildings, the relationship between the form of

urban fabric and how people meet and move, is LAQ-TIP main target. The interaction between the physical environment we live in and the activities that take place in its surroundings must be investigate and measured because it is a useful assessment criterion. For example, all practitioners agree that if open spaces can be observed from different perspectives, it encourage people to occupy them and enhance comfort and security. This criterion is related to physical/visual accessibility. Planners can maximise opportunities for meeting, seeing, and hearing of people through simple planning criteria, such as arranging paths (biking or walking) in strategic spaces that are mutually visible from the users and the passer by.

One of the most well grounded analyses that are able to study these spatial public space criteria is developed by Professor Bill Hillier. Hillier et al. (1984) place-making method, “Space Syntax”, studies the relationship between the physical and social environment. Forms could carry social information useful to foresee their possible uses or development. Using Hillier’s highly mathematical approach, it becomes possible to understand the social dimensions of complex geometrical networks. The result of this analytical theory is a set of performance indices of public space configuration which can be assumed as criteria for a MCE application.
For example, Space Syntax methodologies produce criteria as *Connectivity*, *Visibility* which could be simplify as a measure of open visible space. These criteria rank public spaces in accordance with their geometric shapes e configuration.
Among the other useful evaluation criteria that Space Syntax can provide, *Spatial Integration* (SI) is one of the most useful for different urban issues. In general terms, *Spatial Integration* is measured to determine the average depth of a space to all other spaces in the system. An integrated space, according to Bill Hillier, “*contains the best possibility for the encounter of other people and for the transformation of strangers to humane citizens.”* The SI maps produced are easy to understand for the public and the decision-makers (see figure 1).

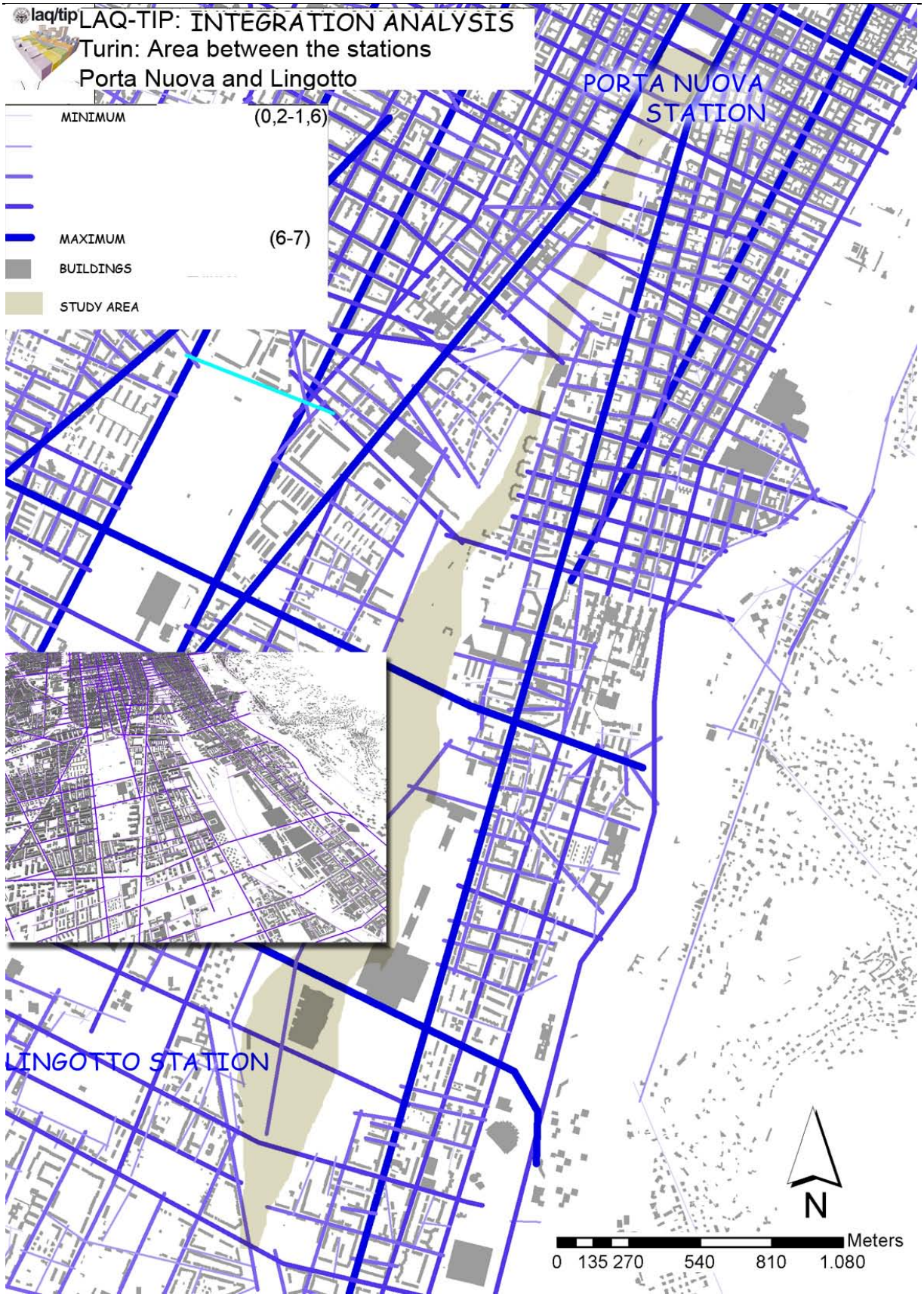

Figure 1 Spatial Integration Map. It shows the predictable movements allowed in a specific form of urban fabric.

The Spatial Integration maps show a set of lines, each with a different values and thickness. These lines represent the public spaces according to a process which reduce convex space of the city structure in axial lines. In simple terms, the analysis syntheses the open visible public space according to the predictable linear movement that could occur; then all linear movement are calculated to draw a set of indicators. SI gives the quality of movements that could be predicted according to a give form of the city structure.
Due to its ability to be measurable and comparable, this method allows to asses alternative Scenarios of urban forms. For example, this method might help to choose the optimum allocation of scarce resources in environmental matters but also determine how spatial changes will affect existing patterns of pedestrian movement, economic vitality, as well as social activities, retail vitality, crimes and so on.

Another important analysis is concerning the interface between indoor/outdoor activities which is mutually influential and useful as interpreting criteria for urban evaluations. In this regard, the LAQ-TIP is caring on some trials that could analyse city functions and probably combine them in a MCE environment.
For example, with an analysis called “Mixité”, the LAQ-tip research office studies the Functional Mix (FM) present within each blocks of a city structure. Indoor FM has a great influence on quality, quantity and intensity of outdoor social activities and therefore it can be considered as another useful urban criterion together with SI. The quantity/quality of cities functions are crucial and as William Whyte says *crowding and pleasure are inextricably bound up… part of what attracts people to the street is the pleasure of the congestion (*Whyte, 1980). Also Christopher Alexander warns about *the dangers of approaching city design in ways that do not allow for a rich diversity of cross connections between activities and spaces (*Alexander 1965).
The data used to detect FM, rely on a tax database which is detailed and constantly up to date by the Public Authorities. The analytical procedure is highly complex and implies the use and combination of different software for processing data and consequently arranging to be visualised on a GIS platform. The final result shows the functional mix with a gradient of one single colour (red). The more a block is red, it indicates that a higher mix of activities is available within it and therefore it is likeable to have active outdoor public space (see Figure 2).

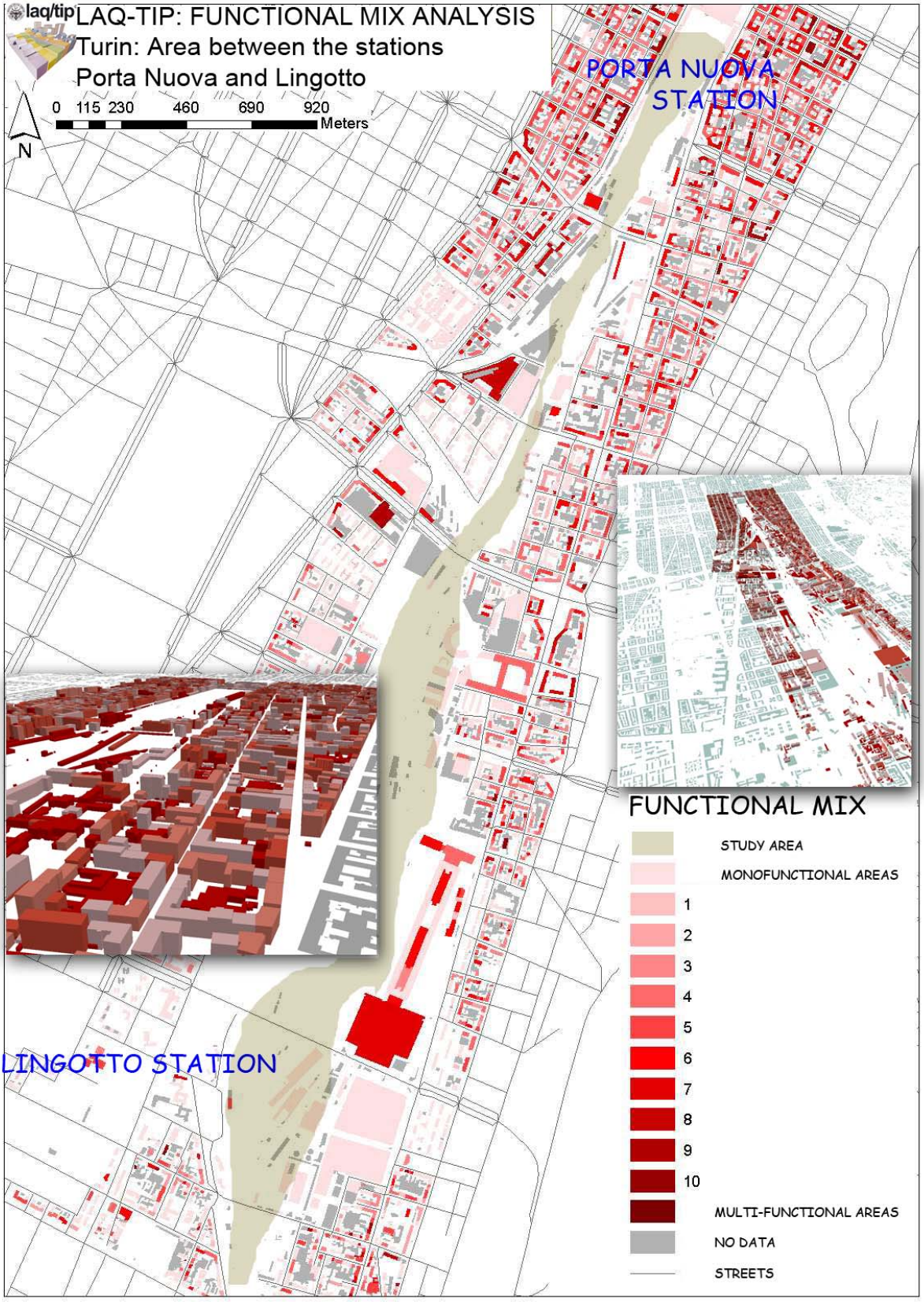

Figure 2 Functional Mix Map. It highlights the mono or multi functional areas of a city structure.

2.2 The Analytic Network Process

The Analytic Network Process – ANP (Saaty, 2006) is an evolution of the Analytic Hierarchy Process – AHP, which is able to consider all the dependences and feedback in a decision problems context. It considers not only the importance of the criteria to determine the alternatives' ranking (as in a hierarchy), but also the importance of the alternatives themselves to determine the weight of the criteria. A hierarchy is a linear top down structure while a network spreads out in all directions and involves cycles between clusters and loops within the same cluster.
The ANP model consists of control hierarchies, clusters, elements, interrelationship between clusters, and interrelationship between elements. The ANP allows interactions and feedback within and between clusters and provides a thorough framework to include cluster of elements connected in any desired way to investigate the process of deriving ratio scales priorities from the distribution of influence among elements and clusters.
Taking into consideration the very high number of operations involved in the analysis, the general ANP network can be subdivided in different control nodes. In fact, any decision has several favourable and unfavourable issues to consider. The positive issues are called "Benefits" while the negative ones are called "Costs". The uncertain issues of concern are the positive "Opportunities" that the decision might create and the negative "Risks" that it can entail. Each of these four aspects of concern utilizes a separate structure and the network of interdependencies that belongs under each benefit control criterion, and ending with a risks control structure.
The BOCR (benefits-opportunities-costs-risks) approach allows simplifying the structure of the analysis by making a top-level network and some subnets containing control criteria. Usually the structure in this subnet is a hierarchical one (Lombardi et al., 2007). Section 3.3 will show how to build an ANP model (BOCR version) with reference to the case study of the strategic infrastructural re-development railway stations area in Turin, taking into account the Space Syntax results.

3. CONTEXT CASE STUDY

3.1 The case study

The case study is related to a large strategic redevelopment area between Turin central railway station (Porta Nuova) and Lingotto railway station (around 300.000 square meters).
Porta Nuova represents the central core of the Turin and Piedmont railway system. This station has a high number of passengers (about 70,000 per day) due to its structure as head station, together with the high number of convoys trains that come and go from the station (about 179 starting trains/per day).
This research investigation rises up from the need to develop Porta Nuova and Lingotto stations from a transport view point. At the same time the Town Council aim at completing the Master plan project that has revolve completely the potential and the future of Turin mobility by placing underneath the whole levels of transport systems. This process has allowed to reconnect most districts at the ground level and to build new urban area and consequently new urban identities. In view of this, it is necessary to draw attention to the development of the railway areas between Porta Nuova and Lingotto and the impact on the surrounding urban environment.
The railway system will be improved with a railway link placed underground which creates the conditions for an overall urban reorganisation of the city structure over

ground. The Turin transportation system it is the fundamental element which connect the metropolitan areas from the north to south (Lombardi and Roscelli, 2004; Lami et al., 2005). The construction of this network system constitutes the necessary conditions to offer a structural response to the problems of metropolitan mobility from the sustainable development point of view, but in order to be efficient it must be integrated with coherent urban and transport policies that encourage the use of the network.

From this point of view, it becomes crucial to focus the territorial organisation on the stations, not only along the railway link axis, but also in the whole metropolitan area (Lami, 2007). Under this scenario the reorganisation of the stations and their reference areas therefore becomes of strategic importance, and makes them places of great urban gathering of quality with the presence of activities and functions that are coherent with the levels and roles of the different stations, as well as with a general re-qualification of the urban environment. It is with respects to this reference layout that the reflections on the Porta Nuova District and the surrounding area play a role (Lombardi, 2007).

3.2 Building the implementation of new Decision Support System

Some of the criteria presented above have been developed on the base of a real case studied (see figure 1-2). These analyses have been supporting, but separately, the design decision process as interpreting factors.
Space syntax analysis (see figure 1) has show the potential mechanisms of pedestrian flows according to the new and the present form of the city structure between the railways area. This analysis has encouraged some connection showing an improvement of integration quality between some quarters of the studied area. Integration is a quality for the urban environment and it has intuitive influences on the economic activities of the area, the success of urban spaces in terms of uses and the comfort of pathways for movements.
The Functional mix analysis (see figure 2) has shown the areas where there is a more vibrant urban environment in terms of pedestrian encounters, social activities, economic vitality and related consequences. In Porta Nuova transformation development, Functional mix represents a useful criterion for targeting those areas where there is a segregation of a single activity and where it is likely to find a lower urban quality. In this case, urban quality might lack in terms of safety public places or comfortable pathways due to a specific monothematic use of places in space and time.
The belief of this paper's investigation is that MCE can embody all the criteria and constraints discussed above (spatial integration and functional mix). MCE works with the rules of raster analysis, which means that it is needed to overlap a Space Syntax map (spatial integration) and functional mix map for synthesis both output in a common analysis (see figure 3).

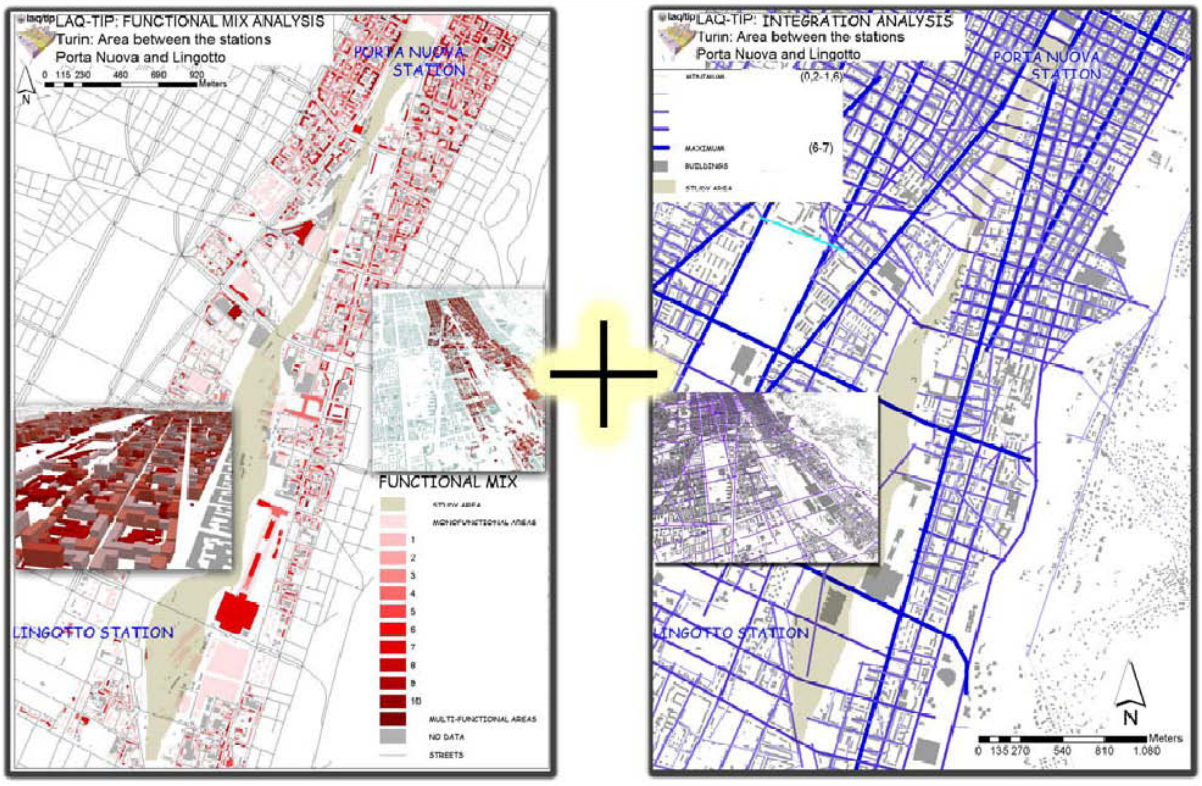

Figure 3 the aim of this paper is to combine different useful evaluation criteria and their analysis in a comprehensive process. The image helps to understand this process which is still in progress.

The integration between Functional Mix criteria and Spatial Integration is possible on a MCE tool as, for example, Idrisi. The counteract between SI and FM might allow to foresee many strengths and critical points in the performance of a urban public space configuration as it has been experiences in most urban transformation analyses carried on by the LAQ-TIP consultancy. The viewable result will detect one or more areas were criteria and objectives of all decision makers are feasible or concurring to optimal design proposal (see figure 4).

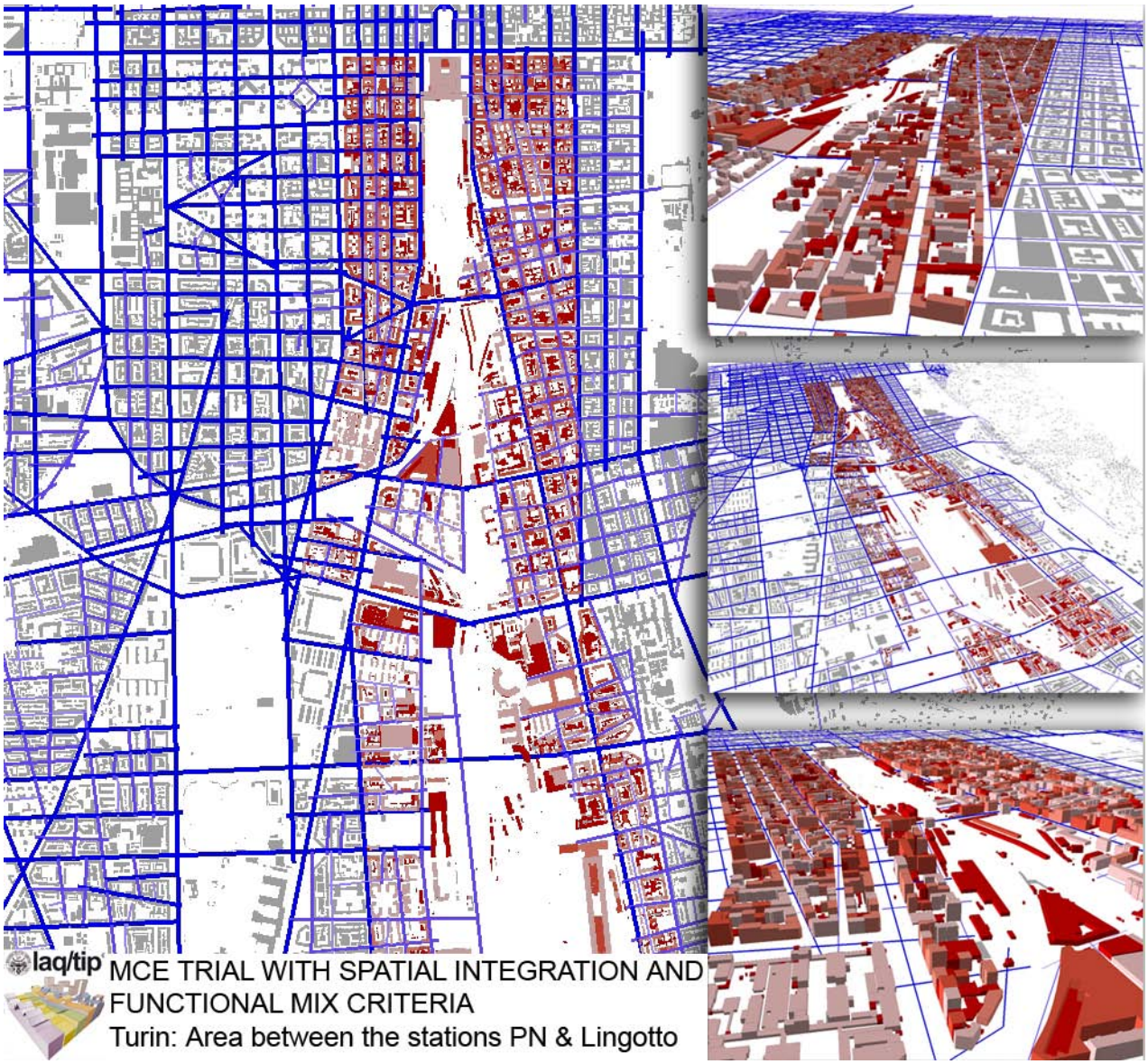

Figure 4 an ideal combination of SI and FM criteria with a MCE tool. The image help decision makes to learn about optional decision and the consequences of specific design policies.

The general assumption is that spatial integrated space has a high functional mix. The new urban form generated by the correlation of these analyses in a MCE environment might contrast the traditional way of designing urban space and provide a more coherent design decision.

Finally the two criteria can be weighted and assessed but not yet with an ANP environment. In fact, using MCE applications as the AHP model, it is possible to

weight criteria according to one or multiple objectives with a precise hierarchy of decisions which does not give space to feed back. In complex design process this system will need to be integrated with the assets of the ANP model which will be described later on.

3.3 Modelling of the case study

This paragraph illustrates the modelling of the case study using the BOCR version of the ANP (see paragraph 2.2) and the results from the Space Syntax analysis, presented in the previous paragraph. Full application of the ANP model has not been developed yet. This will be shortly done once a focus group has been gathered.
A BOCR model includes all the followings: benefits, opportunities, costs, and risks involved in making a decision (Figure 3).
In the present case, the ANP is used to select the best transformation scenario for the large urban area between Porta Nuova and Lingotto railways stations in Turin. Four alternatives are considered as follows:

- A.1 To fill up the track from Porta Nuova to Lingotto and to replace the Lingotto station
- A.2 To replace the Lingotto station
- A.3 To built a new "bridge station" on the track at Lingotto
- A. 4 To do nothing

The BOCR model for the Porta Nuova-Lingotto case study includes four subnets, working as control criteria: Economic, Transport, Urban aspects and Social aspects.
The components of the model are illustrated in Table 1. It may be important to note that the urban aspects cluster has been defined and articulated through the application of the Space Syntax illustrated in the previous paragraph 3.2. For instance, the "functional mix" element in the urban aspects cluster included inside the Benefits of Table 1 comes from Figure 1.

BOCR model

Table 1. The BOCR components: clusters and elements. In red, it is possible to highlight some direct or indirect factors which can be measure and evaluated with the analytical method presented in section 2.

BOCR	Clusters	Elements in clusters
Benefits	Economic	Increasing Piedmont Region's site values
	Transport	Direct connection between exhibition quarters
	Urban aspects	Direct connection with the underground
		"Visibility", hence measure of open visible space
		Increasing of connectivity
		Revitalization of the area
	Social aspects	Synergy with the transformations being carried out
		Functional mix
		Correspondence to Local Community expectations
Opportunities	Economic	Possibility of neighbouring areas' revaluation
		Starting point for the area's development
	Transport	Possibility to create an intermodal transport pole
	Urban aspects	Possibility to connect along the ground two big courses
		Increase of pedestrian permeability
		Connection between two parts of the town
		Direct access to the Lingotto building
		Creation of a services axis from Palavela building to the Lingotto station
	Social aspects	Improvement of environmental quality
		Increase of social interaction
Costs	Economic	Operational costs
		Construction time
	Transport	Difficulties in operating during the construction stage
		No possibility to connect with the underground
	Urban aspects	Changes in the railway system
		No connectivity
		Distance from hospitals
Risks	Economic	Maintenance cost
		Low investment return
	Transport	Difficulty to create an intermodal transport pole
		Interference with the rivers
	Urban aspects	Interferences with overpasses
		Low integration with the urban context
		Risk of increasing criminality in residential area
		Restraints in the use of the railways surface

Next steps of the ANP application will require:

- The determination of relative weights of the components from focus group participants. This will be based on pair wise comparison as in the standard AHP. Pair wise comparisons of the elements are conducted at each level with respect to the relative importance of a control criterion or a cluster. In the assessment process, Saaty (1980; 2000) suggested a scale of 1–9 when comparing two components.
- The numerical judgments established at each level of the network will provide pair matrixes.
- At the end of the assessment process, the elements in a cluster will be prioritized with respect to the elements of all those clusters that have an influence on it.
- In a similar way, a pair wise comparison will allow to establish the importance of the alternatives with regard to each criterion.
- At the end of the weighting process, the priorities will be inserted in a matrix called “Unweighted Supermatrix”; then the priorities are multiplied by the weight of the cluster. This provides the “Weighted Supermatrix” which is used to obtain the final priorities of all the elements (Saaty, 2000). The priorities for the alternatives are a ranking of the different urban transformation scenarios for the area under study.
- The last step of the procedure will require a sensitive analysis, to evaluate how the results are stable with reference to the weights of both elements and clusters.

4. CONCLUSION

This paper has illustrated and discussed feasible criteria for assessing and designing urban space and it has indicated a way to combine many factors in a comprehensive evaluation process.

Moreover these analyses could provide information and support for development a new design support system which also accounts the process of ANP, here structured according to the “complex” network form (Saaty and Vargas, 2006).

The conjoint use of the two analytical techniques, both belonging to the MCE family of methods, represents an innovation in the field of urban renewal evaluation. Specifically Space Syntax results can help to define conditions and aspects for urban development in a ANP experiment where it is important to set up a focus group, choose decision making processes, provides weights for the different criteria in order to give a clear picture of urban and territorial issues of the case study.
The study is currently in progress and the results obtained so far are exploratory but have allowed decision makers to sustain objectively a very large number of assumptions, spatial decisions, and allocation of new functions or new streets for a real case studied.

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