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A Public Participatory GIS and Multi Criteria Decision Analysis framework for the Evaluation of Transport Scenarios

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ABSTRACT (ENG)

The decision-making process of transport projects is very complex, especially for public administrations which have to take into account often incomparable criteria of judgment. In addition, in order to achieve a good social sharing and robustness of the decision, policy makers have to include in the process not only the transport planning experts but also the stakeholders of the community.

The purpose of this study is to propose an evaluation framework that supports the decision making process able to allow public participation in the assessment of transport design scenarios while at the same time ensuring a high level of technical quality of the final decision. The framework will include a method to analyze monetary and non-monetary parameters that will be easily understandable for all decision makers. It will be based on the application of Multi Criteria Decision Analysis (MCDA) techniques, an evaluation process that can take into account different quantitative and qualitative objectives and criteria; in order to favor public participation, the implementation of this technique will take advantage of Geographic Information System (GIS) for its ability to easily represent the impact of spatially based alternative project scenarios. Different case studies will be analyzed in order to assess the level of implementation of the three main ingredients of the framework: Multi Criteria Analysis, GIS and Public Participation.

ABSTRACT (ITA)

Il processo decisionale di valutazione dei progetti di trasporto è molto complesso, soprattutto per le pubbliche amministrazioni che si trovano a dover prendere in considerazione criteri di giudizio spesso non comparabili fra loro. Inoltre, al fine di raggiungere decisioni robuste e con una buona condivisione sociale, i responsabili politici devono includere nel processo decisionale non solo gli esperti della pianificazione dei trasporti ma anche le parti interessate della comunità.

Questo studio ha lo scopo di proporre un framework di valutazione che supporti le scelte decisionali, in grado di permettere la partecipazione pubblica nella valutazione di scenari di progettazione dei trasporti ed al contempo garantire un elevato livello di qualità tecnica della decisione finale. Il framework includerà un metodo che consentirà di analizzare parametri monetari e non, e che sia di facile comprensione per tutti gli attori del processo decisionale. Si baserà sull'applicazione di tecniche di Analisi Multi Criteriale, una procedura di valutazione in grado di prendere in considerazione differenti obiettivi e criteri quantitativi e qualitativi; allo scopo di favorire il coinvolgimento pubblico, l'attuazione di questa tecnica sarà integrata in un ambiente GIS (Geographic Information System) caratterizzato dalla capacità di rappresentare facilmente gli impatti spaziali di scenari di progetto alternativi. Saranno analizzati diversi casi di studio per valutare il livello di attuazione delle tre componenti principali del framework: l’Analisi Multi Criteriale, l’uso del GIS e la partecipazione pubblica.

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1. BACKGROUND

1.1. WHY SHOULD WE SEEK CITIZEN PARTICIPATION?

Citizen Participation is Citizen Power: *It is the redistribution of power that enables the have-not citizens, presently excluded from the political and economic processes, to be deliberately included in the future. It is the strategy by which the have-nots join in determining how information is shared, goals and policies are set, tax resources are allocated, programs are operated, and benefits like contracts and patronage are parceled out. In short, it is the means by which they can induce significant social reform which enables them to share in the benefits of the affluent society (Arnstein, Sherry R., 1969).*

According to Weirner et al (2002), a *Community* can be defined by physical closeness to others and the sharing of common experiences and perspectives. It's a synonymous of neighborhood, village, or town, although communities can also exist in other forms—communities can thus be virtual. *Citizen participation refers to community engagement*. Roots of such process can be found among the political and professional elite (Kearns, 1995), but more recently the concept has moved to the commitment of people who decide how their local community or neighbourhood should be managed and planned. In fact, an active public engagement is able to improve the effectiveness of the neighborhood renewal projects, both in the development of personal and community skills and the achievement of tangible regeneration objectives, particularly in deprived neighborhoods (Beresford e Hoban, 2005).

The overall objective of citizen participation is to enable people to reach a large number of advantages in engaging actively in their communities with the aim of improving local services and the fabric of their area. This concept ranges from very different methods to the recent exploitation the new Information and Communication Technology (ICT) through the Internet: if properly designed, these tools may allow people to make better planning decisions, promoting better communication, design and analysis in the decision process.

What is the rationale behind governments and decision makers strengthening their relations with citizens?

OECD (2001) recognizes three main reasons that lead to support public involvement:

1. Stronger government-citizen relations ensure an effective implementation, as citizens become well informed about the policies they have taken part during their development.

2. Greater trust in government information creates greater acceptance for political outcomes, avoiding the raising of social movements opposing to planning decisions, since issues are (frequently) place-based and so are participants (with the easy development of NIMBY - Not In My Backyard - syndrome).

3. Stronger active participation makes government more transparent, encourages more active citizenship in society and supports citizen engagement in the public sphere, leading to a stronger democracy.

1.2.HOW DO WE SEEK PUBLIC INVOLVEMENT?

Empty ritual versus real benefits: *Public participation is important in community planning, but has been practiced in ways that range from evasion to full empowerment. This range may be seen as a ladder of increasing participation. On the lowest rung, citizens are (sometimes) provided with requested information. At the top rung, the public has a full voice in the final decision, usually through a community organization (Weirner et al, 2002).*

Seeking citizens' participation means that decision making process has to be oriented to encourage useful initiatives to improve approaches and ways to involve people. Relations among citizens and decision makers cover a spectrum of several types of interaction that broaden from a basic level of citizen information throughout awareness initiatives, to consultation and active participation, processes in which the influence citizens can exert on policy-making rises (Figure 1).

Since 90's, the traditional participation methods have been criticized by many for several reasons (Healey, 1998). This is due to the fact that public participation in decision-making has traditionally tended to be accomplished by a series of meetings; these meetings often provide an atmosphere in which decision-makers are considered the authoritative holders of all the knowledge, skills and information. Often in these meetings, the decision-makers are positioned on a stage with the public generally in a lower and less favourable physical and psychological position.

INFORMATION

One-way relationship in which the administration produces and provides information for citizens. In this relation there are integrated both "passive" access to information (on request) and "active" measures by the public authorities aimed at disseminating information to citizens about decision already taken;

CONSULTATION

Two-way relationship in which citizens provide a feedback of the administration information. This relation is based on the definition, given by the administration, of the subject on which the views of citizens are seeking and it requires them to be informed. (The answers of the citizens in general are predetermined by the government through multiple choice - questions with closed options);

DELIBERATIVE PARTICIPATION

The government engages citizens in a consultation process (the citizens are invited to vote on issues before the final response

ACTIVE PARTICIPATION LED BY GOVERNMENT

The Government starts a consultation process but retains decision-making powers

ACTIVE PARTICIPATION LED BY THE CITIZENS

The citizens are actively involved in decision-making processes, alongside government. Citizens' decisions become binding: citizens share the ownership and responsibility for results.

FIGURE 1: TYPE OF PUBLIC INVOLVEMENT IN THE DECISION PROCESS BY OECD (2001)

As a result, most of people "almost never emerges as a leading player in the development process" (Healey et al., 1988). In such kind of processes, public participation is limited to the right to get informed, through an information campaign or the right to object through the local political representatives. The ability to define the interests, to determine the order of the day, assess the risks, recommend solutions and take part in the final decision is instead largely precluded to the public. Even if there’s a consultation process, meetings are very often conflicting, they can be dominated by the minority groups, and it is often difficult for non-technical to understand issues because the whole process very often involves a highly technical and legal jargon. We can finally say that while citizen information is an objective pursued by most of governments and decision makers, consultation still remains a process developed with very true differences in countries, while citizen involvement with an active participation is still rare and often undertaken on a pilot basis.

The importance of public participation in policy and law making is nowadays recognized. Several documents have been developed by major European intergovernmental organizations to support and strengthen it and although some of these documents are not legally binding, they lay down standards, principles and best practices which should be considered in initiatives on national level (Hartay, 2001):

- The European Commission developed the *White Paper on European Governance* (2001) which highlights five principles of 'good governance' (openness, participation, accountability, effectiveness and coherence) which led in 2002 to the adoption of the General principles and minimum standards for consultation of interested parties by the Commission (EC Principles and Minimum Standards, 2002) emphasizing the importance of providing clear consultation documents, consulting all relevant target groups, leaving sufficient time for participation, publishing results and providing feedback.
- The Article 10 of Lisbon Treaty prescribes that: "Every citizen shall have the right to participate in the democratic life of the Union. Decisions shall be taken as openly and as closely as possible to the citizen." Moreover, in 2009 the European Parliament adopted a resolution on the perspectives of Developing Civil Dialogue under the Treaty of Lisbon, which reinforces the significance of consultation and calls on EU institutions to adopt binding guidelines concerning the appointment of civil society representatives,

methods for organizing consultations and their funding, and calls on them to maintain registers of actives CSO.

- The issue of participation is addressed also in several recommendations of the Council of Europe (Recommendation CM/Rec, 2007; Recommendation CM/Rec, 2010; Recommendation Rec, 2001)
- Another fundamental document is the European Charter of Local Self-Government (1988) which is the first internationally binding treaty that guarantees the rights of communities and their elected authorities and establishes the principle of subsidiarity.
- Although it does not have a mandatory nature, it is also worth to mention the Code of Good Practice for Civil Participation in the Decision-making Process (2009), which defines the sets of general principles, guidelines, tools and mechanisms for civil participation with the intent that it will be implemented at local, regional and national level.

With a view to overcome the inhibiting effects of traditional public involvement policies, Beresford and Hoban (Beresford and Hoban, 2005), suggest several measurer that should be taken into account, on the basis of an analysis of existing experience identified barriers in the way of people's participation in initiatives (Table 1).

TABLE 1: MEASURES TO IMPROVE PUBLIC INVOLVEMENT (BERESFORD AND HOBAN, 2005)

MEASURE	**REASON**
Support citizens' empowerment	helping citizens to develop new confidence, skills and understandings
Reaching out to people and groups with lived experience	rather than expecting them to 'come to you'
Establishing accessible and 'user-friendly' structures and processes; enabling involvement on both an individual and group/collective basis. Supporting the development of specific black and minority ethnic initiatives, groupings and organizations	in order to enable equal involvement for all individuals and groups
Helping to establish a sense of ownership	to encourage the trust and confidence of others
Recognizing and clarifying power relations	being clear about aims and possibilities
Linking participation with change making	make people understand that their involvement will lead to a change
Enabling and working towards the independence of the participatory scheme	so that it can be adapted in situation involving different participants, organizations and agencies.
Understanding and working for change in the benefits system	not restrict people's opportunities to get involved and make their contribution.
Supporting the development of independent groups and organizations of people	to provide a continuing platform for the development of their own ideas, perspectives and activities
Building monitoring, evaluation and follow-up into participatory schemes	so that their lessons can be learned
Working to negotiate, not assuming agreement	Since people are not always a homogeneous group; they may have competing concerns and goals
Providing opportunities for the exploration and negotiation of different views and interests	People may have competing concerns and goals.
Improved access to existing experience	to collate this experience and to make it available to those who wish to draw on it, whether as researchers, organizations or local people.

Since 90's examples from different communities in the United States of America have reported positive results on all sides of the decision-making process in the use of public involvement (Schiffer, 1995). In Europe, citizen involvement follows different schemes among the countries;

procedures may be regulated in legally binding documents (laws, regulations) or in documents with no binding measures (codes, standards) (Hartay, 2011). The United Kingdom is one of the countries which more experimented consultation procedures and tools at a local level; it is nowadays more focused on dissemination of good practices rather than improving the implementation. At national level most of consultation procedures take place during the policy making of ministers or departmental bodies, while no involvement is usually provided for parliament decisions. At a more wide European level, since 2008, the CIVITAS ELAN project promoted the mobilization of citizens by involving the cities of Ljubljana (Slovenia), Ghent (Belgium), Zagreb (Croatia), Brno (Czech Republic) and Porto (Portugal); the vision of the project focus on the concept that decision makers are becoming more aware that the problems and challenges of modern society can no longer be solved within narrow professional and political circles: in democratic societies, people's views and responses whether they find new solutions acceptable should be considered side by side with professional decisions (CIVITAS ELAN, 2012).

Also the Sustainable Urban Mobility Plan Guidelines (SUMPS, 2011) promote both stakeholder and citizen involvement, since it legitimizes the plan and enhances its quality by developing a more effective and efficient plan. A particular attention should be put in the involvement of stakeholders, using different formats and techniques with each category (authorities, private businesses, civil society organizations, or all of them together). In SUMPS Citizens are seen as sub-group of stakeholders and their involvement ensures the legitimacy and quality of decision making, while being also a requirement given by EU directives and international conventions.

1.3. WEB-GIS PUBLIC INVOLVEMENT

Online Participation *The internet and World Wide Web are generating radical changes in the way we are able to communicate. Our ability to engage communities and individuals in designing their environment is also beginning to change as new digital media provide ways in which individuals and groups can interact with planners and politicians in exploring their future. (Hudson-Smith, 2002).*

The opening of decision processes through the use of Web-based approaches can help to push public involvement further up in the participation scale, as defined by Weidemann and Femers (1993). The use of internet, instead of conventional meetings, has the potential to break down barriers to participation by removing some psychological elements which affect citizens when they express their views at meetings. Graham (1996) argued that the Internet would “generate a new public sphere of interaction support, debate, democracy and new forms of computer culture to support a revival of social and cultural life of the city." Unlike traditional methods, new forms of participation are beginning to evolve, and the experience from North America suggests that there are many advantages in web-based participation (Howard, 1998). One of the main advantages is that planning meetings are not limited by geographical location. Access to information about the issues under discussion is available from any place with access to the web. Information is also available at all times of the day avoiding the problems associated with the organization of meetings in the evening. The concept of "access 24/7" (in other words, 24 hours a day, 7 days a week) opens up opportunities for more people to take part to a public consultation. With a web-based system, the public is behind the screen of a computer with an Internet access that allows them to comment and express themselves in a relatively anonymous way and that does not include a debate as in the traditional method in which you have to support your opinion facing a group of strangers.

Considering that most of the public concern about the impacts of projects on their surroundings involves spatial entities, the use of Geographic Information Systems (GIS) on the Internet has a great potential for easing public involvement. Actually in the past, GIS have been accused of being an elitist technology, giving more power to those already in possession of knowledge and depriving the general public, which most of the times lacks these direct forms of access to information (Monmonier, 1996; Pickles, 1995). Monmonier (1996) argued that public access to GIS technology could actually evolve into a wrong decision because he believed that the audience armed with a GIS, but not the able to use the system properly, could become vulnerable to attacks of the defenders (or detractors) of a given project. Also in more recent years Carver (2001) raised two key issues about public use of GIS, i.e. one relating the public access to the Internet and the other relating to training in the use of GIS: even if some of this arguments can appear highly overcome nowadays, public access to GIS must be provided through carefully designed interfaces and controlled measures to prevent misuse. In the mid-1990s, a series of examples that made use of GIS technology in the field of public participation have been developed. One of the main objectives was to give the public a greater degree of involvement in planning issues and access to relevant tools, data and information to enable more informed participation in decision-making. Usually most of the programming documents tend to be long and difficult and quite often contain some proposals of political type in the form of a map as an insert at the end of the document, in an attempt to display the proposed spatial policies. Most of the people who want to engage in the planning system want to know which policies affect the way they live and work. Therefore, a more appropriate method to examine what policies affect them may be to focus on the map and extract the relevant policies of a particular location. Providing access to interactive online planning documents can help the audience to focus on particular places, rather than wade through a long document to find the policies that may have implications for their lives.

Starting from Arnstein's (1969) well known ladder of citizen participation, scholars from the Leeds group (Carver, 2001; Kingston, 2002a) argue that online participation can be structured in different levels of involvement (Hudson-Smith,2002): it starts at its bottom with passive online service delivery till getting to the top of virtual worlds where, at least in principle, many more actors or users can be involved than in decision support systems (Figure 2).

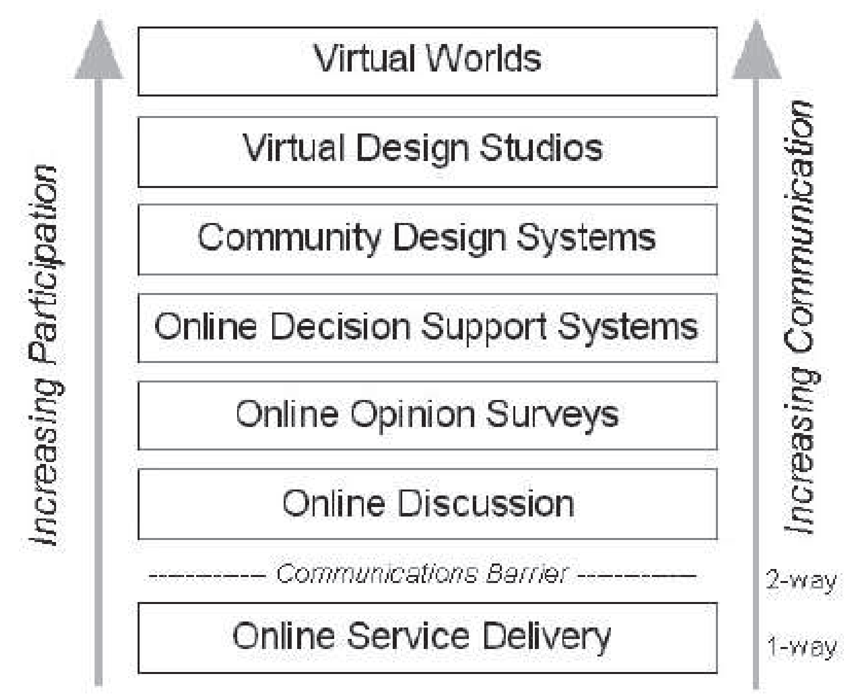


FIGURE 2 AN AUGMENTED LADDER OF E-PARTICIPATION (HUDSON-SMITH,2002)

1.4. KEY ISSUES AND STRUCTURE

The key issue of this thesis is to provide a methodological framework supporting decision-makers to select transport projects that are both widely accepted by citizens and with a high technical profile. This kind of approach will contribute to technical quality of transport planning decisions while ensuring transparency and citizen participation in shared decisions. The decision process will benefit of a method for the evaluation of transport planning scenarios which will allow the assessment of non-quantifiable parameters while being easily understandable for both decision makers and stakeholders. Three main components are identified as the basis of a framework for this kind of approach, and that can be found at different level of implementation:

- PUBLIC PARTICIPATION DURING THE PLANNING PROCESS
- USE OF GIS TECHNIQUES TO REPRESENT THE IMPACTS OF DIFFERENT ALTERNATIVE SCENARIOS
- USE OF MULTI CRITERIA DECISION ANALYSIS TO ENCLOSE THE DIFFERENT POINT OF VIEWS OF STAKEHOLDERS AND CITIZENS

The dissertation is structured in 5 chapters. This first chapter illustrates background and motivations and research questions are presented. The second chapter presents an analysis of the state of the art of Multi Criteria Decision Analysis techniques in transport planning and their integration with Geographic Information System (GIS). In the third chapter a framework for the use of MCDA, GIS and Citizen Participation and their integration in transport project scenarios is presented. The fourth chapter is a compendium of case studies where different alternative scenarios have been evaluated and where the three basic elements of the framework can be found at different degrees of implemention. The case studies presents have been included in five articles already published in international confefrence proceedings. Finally, in the last chapter conclusions and a discussion on overall results and future development of research are presented.

2. LITERATURE REVIEW

2.1. MULTI CRITERIA DECISION ANALYSIS (MCDA) IN TRANSPORTATION PLANNING

The choice among various project scenarios is a critical problem with which authorities and planners have to deal frequently; in the case of the design of a transport system, in particular, they often have to face a large number of stakeholders whose interests may easily come into conflict. The decision-making process generally aims to find the solution that maximizes the welfare of the community involved in terms of economic, political and social equity benefits (Medaglia et al., 2008). Territorial and transport planning often include accessibility of people to opportunities and services as a primary goal. The use of adequate accessibility indicators can be considered a valuable support tool in transport planning aimed at the territorial cohesion (Geurs & Van Wee, 2004, Gutiérrez et al., 1998, Halden, D. 2003).

Cost-Benefit Analysis (CBA) is an assessment technique used to predict the effects of a project, program, or investment by verifying whether the society obtains a benefit or a net cost. It is a tool to support public decision because, through the calculation of the benefits and costs associated with realization of projects, it highlights the best proposal among several design alternatives. It is based on the identification of the costs and benefits only in monetary terms. The variables considered by this analysis are therefore financial (monetary) and social (monetized). Though still widely used, this type of traditional assessment is nowadays considered quite obsolete, since it is not able to grasp all the possible impacts of planning policies (Browne D., Ryan L., 2011) and for its intrinsic inability to include the distributional inequalities of the projects.

Multi criteria decision analysis techniques (MCDA) can help analysts and decision makers when priorities have to be identified on the basis of different criteria. The use of these techniques in fact allows the sorting of project alternatives basing on a series of objectives and constraints; multidimensionality is a special characteristic of the issues related to sustainable development and this makes MCDA particularly suitable to address planning and design of sustainable transport.

In recent years, MCDA has been widely used in the evaluation of territorial policies, due to the complexity of the issues and the inadequacy of traditional methods to capture all the possible impacts of policies and planning, such as in the case of cost – benefit analysis (Browne & Ryan., 2011). Furthermore, through the application of MCDA methods the decision maker can obtain a ranking or at least a classification of the different alternatives. According to Turcksin (Turcksin et al. 2011), the most common multi criteria decision analysis techniques used in transport sector are variants of the multiattribute theories, such as Analytic Hierarchy Process (AHP, Saaty, 1980), Analytic Network Process (ANP, Saaty, 1996), Multi Attribute Utility Theory (MAUT) and outranking methods like PROMETHEE and ELECTRE (Roy, 1968). According to studies conducted by Macharis and Bernardini (2015), the main fields of application of multicriteria analysis techniques in transportation planning process range in several areas: environmental assessments (Tuzkaya, U.R., 2009); location analysis (Cantarella & Vitetta. A., 1994); strategic decisions (Keshkamat et al., 2009); evaluation of freight and passengers transport policies (Bielli et al, 1996, Bernardini A., Macharis C., 2011); transport technologies (Tzeng & Tsaur., 1993, Yedla & Shrestha, 2003, Tzeng et al., 2005, Ludin & Latip, 2007); infrastructure projects (Hugonnard & Roy, 1983, Jakimavicius & Burinskiene, 2009); design of transport systems (Tsamboulas & Mikroudis,2000; Medda & Nijkamp, 2003).

A fundamental advantage of MCDA technique is it can be used as a tool for the assessment of transport planning in the context of an institutional approach and with the presence of various stakeholders (De Brucker et al., 2011) since it provides a mechanism for expressing different participants' preferences and objectives for generating a compromise solution; MCDA offers a structured environment for investigating the intensity and sources of conflicts among different participants and improve communication and understanding among multiple decision makers, which, in turn, pave the way for converging preferences and building a consensus in such a way that a minimum conflict solution can be generated (Boroushaki and Malczewski, 2010).

2.2. GIS BASED MCDA

Normally, multi criteria analysis assumes that there is spatial homogeneity of the alternatives taken into account; this consideration, however, is not realistic in the case of transport projects and in general in all the cases in which the alternatives have also a geographic dimension, since the assessment of criteria varies in space, and therefore their classification, sorting or selection, is also dependent on the spatial distribution of people affected by the project (Malczewski, 1999; Laskar, 2003). A spatial multicriteria analysis therefore provides, for the evaluation of the alternatives, both value judgments and spatial data (Malczewski, 1999). Once established a method of evaluation of alternatives, the next step is therefore to find a tool capable of analyzing the quality and quantity of spatial data that are required in the design of a transport system.

According to Witlox (2005), because of the large amounts of spatial data and the complexity of their relationships, decision makers need to make use of IT tools, such as softwares which allow high-performance geospatial analysis, web mapping and image processing. In the field of transport design, GIS software can be considered valuable tools, since they are able to handle data and spatial information with a high precision (Sikder, 2009). The introduction of a decision support system that can store, manage and process large amounts of data can greatly simplify the combination of the evaluation of decision-making procedures. GIS software are widely used for the solution of transport-related issues, but often the procedures that characterize the design of a system, even if present in these software, are complex and fragmented, and show the limits in the analyses that also involve value judgments (Malczewski, 1999; Eldrandaly et al., 2005). For this reason, in recent years, a number of studies have dealt with the development of support systems for spatial decisions (Spatial Decision Support System - SDSS) or otherwise functional and complete integration forms of MCDA models and GIS tools. The effort to integrate GIS and MCDA can be associated with the current proliferation and development of the GIS (Malczewski 2006a). In the last years, in fact, the system evolved from an expert-oriented technology towards a new user friendly oriented one. This has spurred a movement in the GIS community towards the use of this technology to increase the degree of democratization of decision-making through public participation and collaboration. Malczewski (2006a) suggested that it is in the debate on the relation among “GIS and society” (Pickles 1995) that we can see the real potential of the construction of GIS – MCDA systems to facilitate collaborative decision process. GIS based Multi Criteria Decision Analysis is potentially able to offer a flexible problem solving technique in which participants can explore, understand and redefine a decision problem (Feick e Hall, 1999, Jankowski e Nyerges, 2001, Kyem, 2004, Malczewski 2006a, b). It can be defined as a process that transforms and combines geographical data (criteria from the map) and value judgments (preferences of decision makers) in order to obtain relevant information for decision making (Eastmen et al., 1995, Malczewski, 1999).

According to different scholars (Goodchild et al., 1992, Jankowski, 1995, Malczewski, 1999) there are three type of integration between GIS and MCDA: loose coupling, tight coupling and full integration. In the loose coupling approach, the files are simply exchanged between the two systems; the processes are then executed in two separate software. GIS software is used for a feasibility study, with the selection of the criteria and their scores which are then exported to a multicriteria analysis algorithm. The multicriteria algorithm is used for the evaluation and the results are exported again to the GIS for displaying.

In the tight coupling strategy, there is a single data model or operator and a common user interface. A more complete integration can be achieved with the creation of user-specified routines through the use of specific programming languages that can then be added to the existing set of the GIS package commands: the multi-criteria analysis is then developed within GIS software and data exchange is avoided.

The ultimate goal of such integration is to build the consensus among the different decision makers and stakeholders by generating a shared solution that best represents the preferences of all participants (Boroushaki and Malczewski, 2010).

The integration between GIS and MCDA is widely used in land suitability analysis, site planning and control and other environmental issues (Pettit & Pullar, 1999; Gonçalves Gomes &Pereira Estellita Lins, 2002; Massei et al., 2013).

There are different examples that use pairwise comparison from Analytic Hierarchy Process to evaluate the weights of each decision criterion and superposition functions, which are very similar to the weighted summation technique. In the transport sector, some examples of integration can be found with particular reference to the AHP-ANP technique (Sadasivuni et al., 2009, Piantanakulchai & Saengkhao, 2003).

2.3. COUPLING BETWEEN GIS AND WEB

The birth of the Internet introduced new trends in mapping and greater democratization of the spatial data and maps. In a Web environment with GIS capability the map becomes dynamic, interactive and accessible to a wider number of users as a visual communication tool.

Through the Internet, GIS systems may face and develop democratization on the accessibility of spatial data and the transparency of decision-making: in this way the technology can contribute to greater democratic participation in planning processes (Carver 1999, Carver e Peekham 1999 Dragićević 2004 Dragićević e Balram 2004, Miller 2006).

The coupling between GIS and the Web has improved the shared use of GIS in three directions (Plewe 1997; Green and Bossomaier 2002; Peng and Tsou 2003):

1. Access and dissemination of spatial data. Peng e Zhang (2004) underline the potential of GIS to interoperate spatial data and high quality graphic outputs, proposing the Geography Markup Language (GML), a data codification and transmission mechanism, the Scalable Vector Graphics (SVG), to improve the quality of the reproduction on the web and the Open GIS Web Feature Service (WFS), a mechanism with some specifics to improve accessibility and recover of spatial data.

2. Exploration and geo - visualization of spatial data. The improvement of the analysis of spatial data and their display is deepened by Evans (Evans et al., 2004) and Dragićević and Balram (2004). Evans designs a Web GIS that allows the public involvement in the management of radioactive waste; decision-makers can explore digital maps and give their opinions on the choice of the criteria in relation to managing problems. The authors analyze the ability of decision makers towards the GIS tool and the system; they also analyze the way in which the geographical information has an impact on decisions in the case of NIMBY (Not In My Back Yard) syndrome. Dragićević and Balram develop a Web GIS that uses the Delphi method for the analysis of experts' opinions in planning procedures. Experts can represent their views on the conservation of natural resources by placing annotations on the map using polygons, points and lines. The maps created provide the basis for structuring the debate and achieving different levels of agreement.

3. Their elaboration, analysis and modeling. The introduction of a prototype of integration among Web GIS and analytic tools (WGAT, Tsou, 2004) provides a combination of data archive, visual information and analysis services to process data in remote. Sakamoto e Fukui (2004) develop a decision support system that uses a multicriteria optimization and structural fuzzy model tools for visual analysis and mapping of the results. The tool provides an intuitive interface for classification by importance of the criteria rather than an ordinal number. This makes modeling possible for both technical users and not.

2.4.WEBGIS-MCDA

Web GIS MCDA: *Implementing GIS within the World Wide Web environment and integrating its capabilities with multicriteria decision analysis (MCDA) methods can provide a mechanism for bridging the gap between the general public and experts. Web-based GIS (WebGIS) can offer solutions that are accessible to non-experts; moreover, online tools, such as discussion forums, can provide an alternative to the traditional place-based planning (for example, public meetings/hearings and open houses) for they do not require in-person attendance (Boroushaki and Malczewski, 2010).*

The integration of MCDA methods in a WebGIS (WebGIS-MCDA) is able to provide an interactive tool that allows users to explore digital maps and voice their opinions on spatial decision problems. Pereira and Duckstein (1993) emphasize that the most important components of multi-criteria analysis are those that let you interact with decision makers and assigning weights to the decision criteria. These procedures generally take place outside the GIS environment because most of the software on the market do not provide for this possibility of interaction. Thanks to an integrated system instead, individuals who are uncomfortable to express their opinion and their preferences in public can do so in an independent environment; consequently, it can be reached a wider and more complete representation. Such accessibility means that WebGIS-MCDA systems have the potential to stimulate a "bottom-up" approach to the spatial decision-making process by providing public access to data and models. A WebGIS-MCDA system allows participants to enter their value judgments in different times and places than the space-time dimension of decision-making (Jankowski et al. 1997).

Most of the first WebGIS-MCDA application focused on the integration of GIS and MCDA in order to provide support in the decision process by facilitating access to information through map visualization. In recent years, such integration provided the inclusion of more comprehensive and sophisticated analytical modules (Rinner and Malczewski 2002). The main

issue which rises is the degree to which a GIS can play a role in a participatory system when it's based on commercial software, which is unavailable to most of stakeholders (Miller, 2006).
The launch of Google Maps service in 2005 gave free access to easy-to-use and browser-based Web mapping functionalities as well as high-quality geospatial data (Boroushaki and Malczewski, 2010). Applications developed by user-friendly and customizable Google Application Programming Interface (API) provide a free WebGIS that is widely available, familiar and accessible to the general public and non-GIS experts, which make Google Maps a good candidate to be.

At the current state of the art, many online GIS systems are tailored for specific tasks. Public participation in local decision-making is often relegated to a specific set of issues that requires a well-defined system to address the problems. There are several examples of studies that predict a MCDA Web-GIS focused on single issue.

In Carver (Carver et al., 2000) three scenarios of a case study are analyzed at a local, regional and national level. At the local scale, a small community in Colne Valley in Yorkshire, a Web GIS-MCDA to test public participation is used. The second case study covers a much larger area in Yorkshire. The Yorkshire Dales National Park presents a regional scenario, which involves not a single community of people who live in the park itself, but a wider set of actors and stakeholders, including tourists and visitors to the area. Here, online groups are being developed to encourage residents and visitors to participate in the decisions regarding the reforestation of parts of the national park. Finally, it analyzes a case of a national study in development, which addresses the role of the public in decisions concerning the location of disposal facilities for radioactive waste.

Still in Carver (Carver et al., 2004) the development and testing of a GIS-based e-learning resource on the Web that focuses on the application of GIS to the choice of a disposal facility site nuclear waste with the associated spatial decision making, using Boolean methods and weighted overlay. The results indicate that students, with little or no previous experience, find that GIS software are easy to use, they are useful to know the issues involved, and a good exercise of democracy based on the Internet.

Bugs (Bugs et al., 2010) deals with an approach to analyze the impact of Web 2.0 collaboration through PPGIS in relation to urban planning actions, developing an easy to use Web-PPGIS free tool, which consist of a web mapping service that users can comment. A database stores the contributions in a format supported by the GIS. A prototype in Canela (Brazil) has been set up, to test its usability. The results have shown that it is a valid approach, easy to configure and understandable by non-experts. The Web PPGIS can serve as a social tool to engage community members of any context at any spatial problem.

In Kyttä (Kyttä et al., 2013) a web survey for the Helsinki metropolitan area is conducted in order to define the main quality factors for the inhabitants. The method used is an example of public participation GIS that allows the study of the experiences of the inhabitants' localization. The over 10,000 experience gathered were examined in relation to the location of the houses of citizens and the number of urban structural features, such as urban density, percentage of green, and land use. The results revealed that, although the presence of green results very important, also the densely urbanized areas are significant for the inhabitants, in particular as regards the quality of social life.

Since 2013, the transnational NISTO project (keseru et al., 2016) funded by the European Regional Development Funding (ERDF), developed a toolkit to evaluate the smart mobility actions. This includes all initiatives that strengthen the flow of traffic, focusing on the integration of different transport modes and not giving priority to a single mode. In addition, it points to an improvement in travel time and environmental quality. The partnership wanted to focus on five key elements for successful projects: mobility, economy, environmental quality, safety and user satisfaction. The NISTO scoreboard provides methods for policy makers and transport planners to evaluate the small mobility projects in terms of sustainability, stakeholder preferences, social impact and the attainment of political objectives. The framework combines several evaluation techniques such as multi criteria analysis (MCA), a social simplified cost-benefit analysis (SCBA), multi-actors multi criteria analysis (MAMCA) and a monitoring target in a flexible framework. The evaluation process is supported by a set of basic and optional feedback criteria with a set of indicators that reflect the general meaning of the three pillars of sustainability as well as the local project characteristics. These criteria and the related indicators are used throughout the evaluation process for evaluating design options, monitor its implementation and evaluate the results. First the stakeholders are selected; then the evaluation criteria, the corresponding indicators and policy objectives to be achieved are identified on the basis of the characteristics of the project. After the first step, one or more assessment tools are chosen by the toolkit, basing on the attributes of the project (size, scope of the evaluation, modes of transport concerned, interested parties involved, project's lifespan). After you need to collect the data (or estimate them) for the base scenario, as well as the alternatives and enter them in the toolkit software for the evaluation. The assessment will provide a rating of sustainability for each project option, the cost-benefit ratio, the preference scores for stakeholders and an assessment of the potential achievement of objectives in the assessment tools used. This information will help the decision makers in making an informed decision that considers the sustainability, costs and social benefits and stakeholder preferences. The toolkit was developed through monitoring and evaluation of the five pilot projects across North-West Europe.

2.5. PUBLIC PARTICIPATORY GIS (PPGIS) IN DECISION MAKING PROCESS

Participation should be kept at the forefront: *Consider using spatial information technologies that can be mastered by local people (or local technology intermediaries) after being provided sufficient training - The use of GIS is not a must: it is an option. As technology complexity increases, community access to the technology decreases. (Fox, 2005)*

The term PPGIS originated at two meetings of the National Centre for Geographic Information and Analysis (NCGIA) as a new frame the next generation of GIS that would provide technical advancements in social and political contexts (Sieber, 2006) and should be more inclusive to nonofficial voices (Obermeyer 1998a). The resulting definition of PPGIS focused pragmatic approaches to engage the public in applications of GIS with the goals of improving the transparency of and influencing government policy (Schroeder 1996).

The main conceptual and theoretical foundations of PPGIS is that it’s a spatial process, which always involve a map; it is scale dependent, in terms of data, participants’ location and issues to be treated; it offers an opportunity for decision makers to propose a transparent decision making process (Kingston and Smith, 2007).

Many PPGIS focus too much on the technology, but it is important to remember that actually focus should be put also in the participation process, ensuring a socio-technical mix that would promote social shaping and social construction of technology.

There are several definitions and approaches to participatory mapping: PPGIS is defined as the application of GIS to tackle problems faced in 'geospatial deliberative participatory democracy', but also a mechanism to help communicate some location-based problems with nontechnical users. Some scholars argue about the difference among PPGIS and PGIS. We can say that PPGIS – tends to work within some kind of institutional framework; it's maybe a more 'top-down' than 'bottom-up' approach has a deeper technology focus; on the other side, PGIS data collection is not necessarily technology led and it's a more bottom up process.

PPGIS historically originates from spatial planning and spatial decision making with the GIS as tool to assist and enhance it; it does not require a unique model but there is some uniqueness to PPGIS in relation to scale. The "public" involved is anyone with an interest in a particular issue and it must be said that it's often very difficult to engage people in the process at the right time. The process in which people are involved can be top-down or bottom-up: anyway PPGIS/technology can enable a bottom-up approach from grassroots community groups (Seiber, 2000). One of the main issued is that the fast spreading of the importance of maps in our current society, leads to have a lot of PPGIS which actually are not about participation but provide just informing and consulting procedure, not ensuring involvement and "active participation.

The participatory map in PPGIS is a fundamental tool which gives an overview of issues and proposals reported by different users. It democratizes the teaching and use of GIS, which is made accessible and comprehensible by a wider range of communities and social groups; it makes citizens participate in space planning and decision-making; it allows the inclusion of public values in decision support systems; it describes the spatial perceptions of the public and the meanings that belong to these places.

Some European policies since 90’s support the development of PPGIS:

- Information/e-Society policies (e.g. from TENs to i2010)
- Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (1998, the Aarhus Convention)
- Water Framework Directive (2000/60/EC)
- Public Access to Environmental Information Directive (2003/4/EC)
- Re-use of Public Sector Information Directive (2003/98/EC)
- Infrastructure for Spatial Information in Europe (INSPIRE) Directive (2007/2/EC)

Advantages:

- It promotes the use of GIS technologies and the spatial thinking in citizens
- Data inaccuracy tends to be overcome by the increment of participants’ number
- Includes opinions and the involvement of a big number of stakeholders in the planning process;
- Help the reciprocal understanding and trust among parts involved in the project
- It allows to realize a public useful study with a minimum cost

Disadvantages

- Access to GIS technology might be limited; it depends on geographic and informatics alphabetization;
- Quality of data might be low (involvement of respondents, characterization of the survey sample);
- Lack of trust between survey's author and potential participant.

In summary: participation is important and should be kept at the forefront, should not be technology led; PPGIS should be a decision support tool, 'shaped' through practice; it is in principle is much more about how one approaches issues, whose interests are being served, and who is involved in it - or not, rather than its underlying technology.

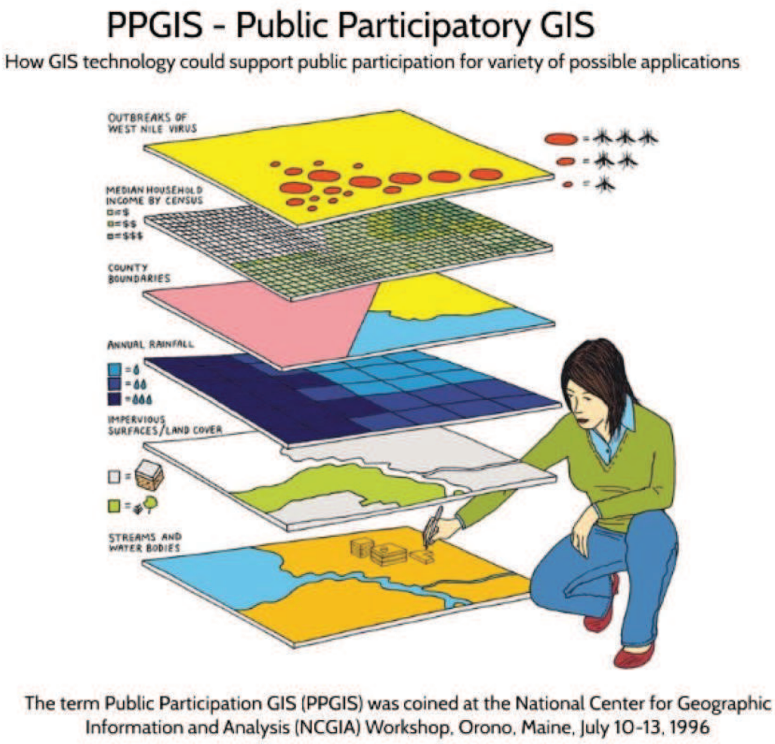


FIGURE 3 GIS AND DATA-ENRICHED DESIGN (HTTP://WWW.ARCHITECTMAGAZINE.COM/TECHNOLOGY/GIS-AND-DATA-ENRICHED-DESIGN_O)

3. METHODOLOGY

This research project focuses on the development of a methodology for the assessment of planning scenarios and planning transport that would allow to take into account also not quantifiable parameters and that it is easy to understand by decision makers and stakeholders. The study promises to evaluate the effective use of GIS as a tool to assist decision-makers and stakeholders in decision planning processes. The methodology used in the project involves the integration of a Public Web GIS and multi-criteria analysis techniques. In this chapter, divided in 3 sections, the adopted methodology will be presented: in first section MCDA techniques will be illustrated; in secondo section procedures of integration between GIS and MCDA will be investigated; in the last section a framework for a decision making through a PPGIS will be illustrated.

3.1. MCDA PROCEDURE

The main objective of a multi criteria decion making analysis is to assist the decision maker in selecting the best alternative among all the feasible options of choice, under certain decision criteria and different priorities. Each MCDM technique provides a common procedure that includes the following steps (Jankowski 1995, Figure 4):

- Definition of a set of alternatives
- Definition of a set of criteria
- Assigning scores to criteria

- Formulation of the decision table
- Assignment of the preferences of decision makers through weights
- Aggregation of data from the decision-making table for the ranking of the alternatives
- Analysis of susceptibility to test imprecision, uncertainty and inaccuracy of the results
- Final recommendations, best alternative or reduced number of "good alternative" or ranking of alternatives.

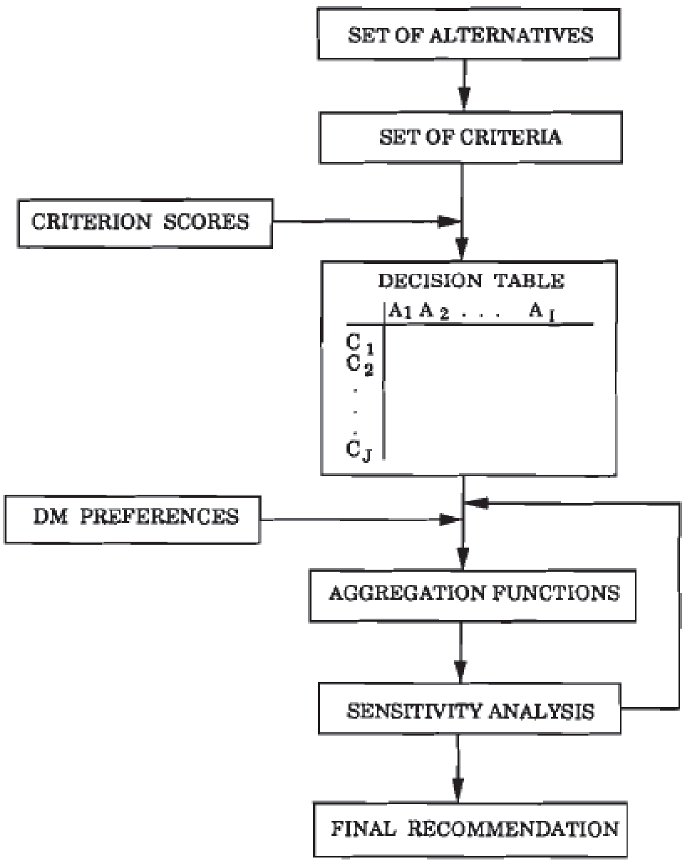


FIGURE 4 BASE SCHEME MCDA (JANKOWSKI 1995)

The multi-criteria analysis methods can be classified, according to their approach, in three different types (Ishizaka, 2013):

- Fully aggregated approach: a score is evaluated for each criterion and then they are synthesized into an overall score. This approach provides a compensation method, which means that a bad score on one criterion may be offset by a good one on another. Examples of this approach are the weighted summation techniques, correlation analysis and the Analytic Hierarchy Process.

- Outranking approach: a bad score cannot be compensated by a good one. The order of the alternatives may be partial, because there is the possibility of incompatibility. Two alternatives can have the same points, but their impact can be different and therefore not comparable; outranking techniques are for example the dominance techniques, conjunction, disjunction and lexicographical techniques.

- Goals reference level approach. This approach sets a goal for each criterion and then identifies the alternative that gets closest to the ideal level. Also these approaches are generally compensatory. Examples of this approach are the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Aspiration-level Interactive Method (AIM) and Multi-Dimensional Scaling (MDS).

All fully aggregated methods are based on the standardization of the criteria scores, which can then be compared and aggregated. The standardization allows the compensation of the weak performance of a criterion with those of another one. The total score of each alternative is obtained by multiplying the score of each criterion for the weight assigned by the decision maker, and adding all the weighted scores. The weighted sum allows the evaluation and sorting of all the alternatives on the basis of preferential policies for decision makers. However, there are techniques that allow assigning preferences to both criteria and scores.

3.2. GROUP MULTI CRITERIA DECISION MAKING

In transport decision making problems, there can be several individuals and social group which provide a social influence contribute to the outcome of the decision; so usually the situation faced is that individuals make collectively choices from the different alternatives, taking to the-so-called Group decision-making (or Collaborative decision-making).

The application of multi-criteria decision analysis (MCDA) in decision making processes promoted the idea of allowing more stakeholders to participate, choosing criteria, and evaluating the results also in transport field (Bana, 2001; Scannella and Beuthe. 2003; Keshkamat et al., 2009; Labbouz et al., 2008). The use of MCDM is able to foster group learning ability and it is particularly valuable in handling structured decision making problem (Srdjevic, B., 2006). Several MCDA techniques have been experimented in decision problems with different stakeholders (Group Multi-criteria decision analysis, GMCDA), also in transportation problems (Springael et al, 2000; Żak et al, 2014)

Recently, Macharis (Macharis, 2005; Macharis, 2007) proposed Multi-Actor Multi-Criteria Analysis (MAMCA) an extension of the traditional MCDA developed by Macharis (consisting of two main phases: an analytical one, trying to gather all the necessary information to perform the analysis; a synthetic or exploitation phase, which consists of the actual analysis. The two phases are then divided into seven steps (Figure 5): in the first step, the problem definition and formulation of alternatives is carried out; the 2nd step is the determination of all the relevant stakeholders as well as their objectives; in the 3rd step the objectives are translated into criteria; the 4th step links one or more measurable indicators to each criterion; in the 5th step the aggregation of the information of the previous steps into an evaluation matrix is performed; actual results are generated by using a Multi-Criteria Analysis (MCA) in step 6; finally, in the 7th step mitigation strategies and deployment strategies based on the new insights are defined.

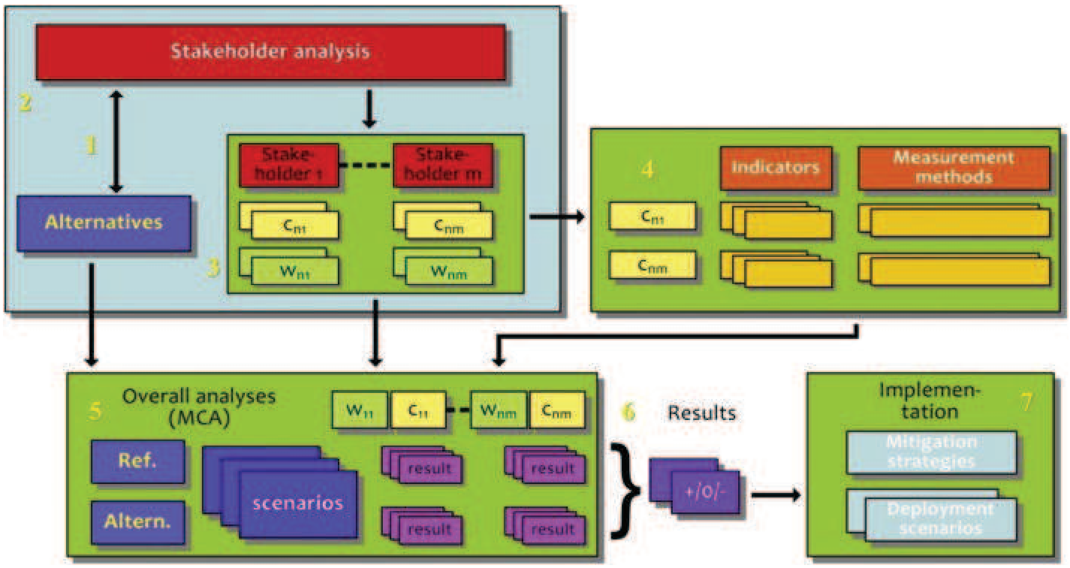


FIGURE 5 THE SEVEN STEPS OF MAMCA PROCEDURE (MACHARIS ET AL., 2009)

3.3. GIS BASED MCDA PROCEDURE

With the introduction of GIS systems, Malczewski (1999) proposes a more elaborate structuring of spatial decision problem (Figure 6). During the phase of definition of the problem raw data are obtained, processed and examined to assess opportunities and problems. In this phase the GIS ability to store, manage, manipulate and analyze the data it is of great advantage. The objectives describe the desired state of geographical space. Allow us to formulate the criteria that must be filled in order to make the best decision minimizing or maximizing some variables. The attributes instead contain measures used to assess the level of fulfillment of a criterion for each alternative. The evaluation criteria are represented on GIS through thematic maps or data layer. Each attribute must be clearly understood by all decision-makers. A set of attributes must be comprehensive, i.e. it must include all aspects of the decision problem; however, it must also be minimal, i.e. it should contain the least possible number of attributes to describe the problem, without redundancies. Moreover, the set of attributes must be decomposable: the evaluation of the attributes in the decision-making process must be able to be simplified into smaller decisions. Typically, the evaluation criteria have a hierarchical structure (Malczewski 1999).

The selection of an appropriate set of evaluation criteria can be made using literature studies or opinion polls. Government agencies sometimes distribute guidelines for the selection and evaluation criteria. Another method may be to recognize the goals by normative and government documents. Case studies can also be conducted with system modeling. Opinion polls should instead be directed to those affected by the decision-making process or to a group of experts (Malczewski 1999). The choice of objectives and attributes is still influenced by the availability of data, their cost and their acquisition time. Obviously, there should be a tradeoff between the accuracy of the result and the costs and time required.

The criteria maps form an output of the identification phase of the evaluation criteria. This is the stage that follows to the insertion of data into the GIS (acquisition, formatting, georeferencing, compilation and documentation of relevant data) stored in graphical and tabular, manipulated and analyzed in order to obtain the desired information.

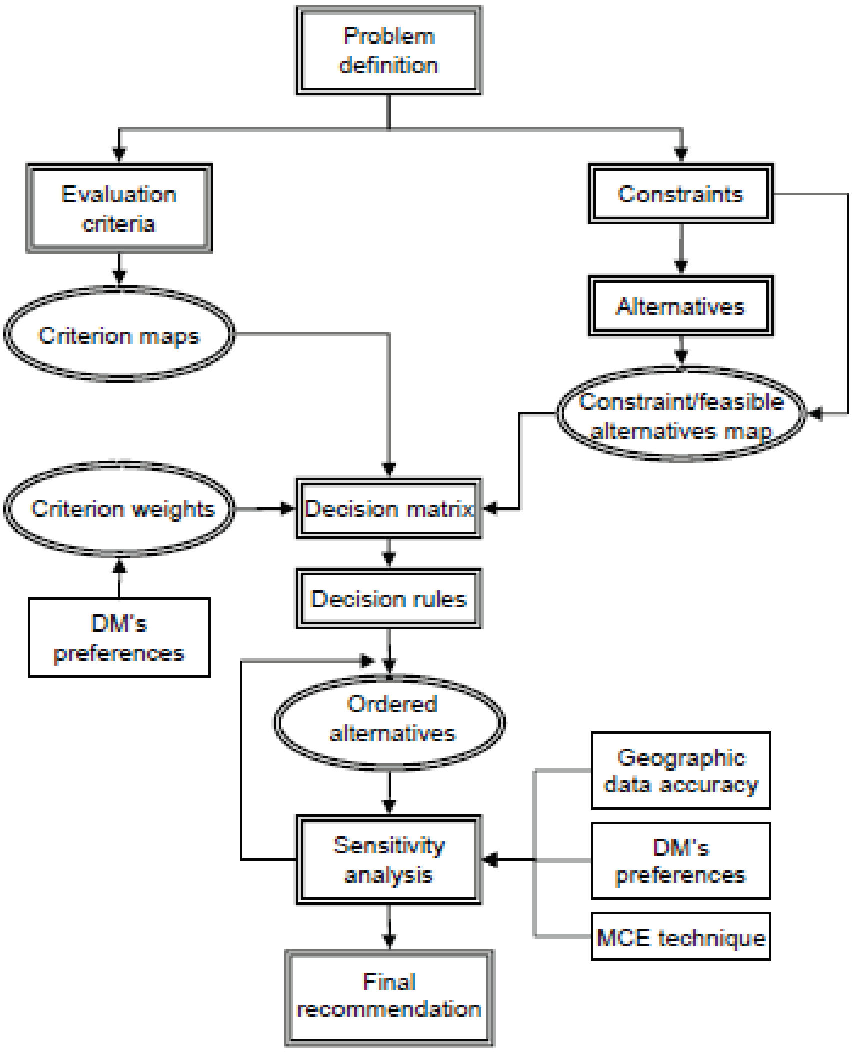


FIGURE 6 GIS BASED MCDA AFTER MALCZEWSKI (1999) (BELKA, 2005)

Typically, a base map is provided and it is used to reproduce the other criteria maps. Each criterion is displayed in a map through a layer which is defined thematic layer or data layer. The thematic layers represent the way in which the attributes are distributed in space and their degree of achievement of the objective. The attributes are measured with scales, which can be quantitative or qualitative. Scales can be natural or constructed: the natural ones are expressed with the units of the international system; the others are typically the result of personal judgments, ranked on a numerical or linguistic scale. The scales can also be direct or proxy. The direct scales directly measure the level of achievement of a target; the proxy scale is used when the attribute associated with an objective is not obvious and must be measured indirectly.

In order to allow comparisons between different criteria, attributes must be normalized. There are linear and nonlinear normalization procedures. In deterministic maps, that means maps in which each element is associated with a single value, linear transformation methods are the most used.

The Maximum score procedure is a linear transformation method that uses a formula in which each score is divided by the maximum value of each criterion (Malczewski 1999):

$$x'_{ij} = x_{ij} / x_{\max j}$$

where x'_{ij} is the normalized score for the i_{th} objective (alternative) and the j_{th} attribute, x_{ij} is the row score of the objective x_{maxj} is the maximum score of the attribute j_{th}.

The normalized scores range from 0 to 1. A benefit criterion is a criterion that must be maximized; to minimize criteria (cost criteria) the formula will be:

$$x'_{ij} = 1 - x_{ij} / x_{\max j}$$

The advantage of the linear transformation is that it is proportional and the relative order of magnitude remains constant. The downside is that when the scores are all greater than zero the minimum normalized score will not be zero. This could complicate the search of the alternative less attractive (Malczewski 1999). To The best alternative is, however, always given the value of 1.

The alternative method is the score range procedure that can be calculated with the formula:

$$x'_{ij} = x_{ij} - x_j^{\min} / x_j^{\max} - x_j^{\min}$$

for the benefit criteria and

$$x'_{ij} = x_j^{\max} x_{ij} / x_j^{\max} - x_j^{\min}$$

for cost criteria.

The factor x_{jmin} is the minimum score and x_{jmax} the maximum score of the attribute j_{th}, and $x_{jmax} - x_{jmin}$ is the range of values of a certain criterion. The range of scores goes from 0 to 1; the worst normalized score is always 0 and the best is always 1. Unlike the maximum score procedures, the procedures range score does not ensure proportional results; the linear scale transformation can be used for example to normalize proximity maps (Malczewski 1999). The scores of the criteria allow identifying the alternatives that do not meet the constraints imposed during the decision process.

Even the creation of alternatives can be fully carried out within the GIS. Each alternative can be represented by a single layer or by a record or a set of records; the decision criteria set is given by the map coverage of the attributes (Jankowski 1995). The choice of the alternative representation depends on the data. In the case of vector data, after a preliminary overlay, all feasible alternatives may be collected in a thematic layer. All decision-making criteria and ratings are placed in the attribute table. In case of raster data, each alternative is made up of one or more cells on the map which correspond to one or more records in the raster layer. Many raster layers can be a set of criteria and each of the records / cell value is a score. The decision matrix consists of a few raster layers connected in a geo-database. Actually, the geo-database is created along with the decision matrix and the data type decides its architecture. Examples of multicriteria made with raster evaluations are visible in a Carver (1991), and Snickars Rapaport (1998) and Grossardt et al. (2001).

The assignment of weights is generally carried out as a result of a consultation process with decision makers that turns into ratio values assigned to each map policy. The weights reflect the preferences of a criterion with respect to another. There are several assigning weights techniques: the most common are ranking methods, rating methods, and pairwise comparison methods. A characteristic they share is that all involve subjective judgments of the decision makers on the relative importance of decision-making factors.

The basic idea of the ranking methods is the positioning of the criteria according to their relative importance. In direct classification method criteria are sorted from most important to least important, in the inverse method the opposite happens. Once established the order, a series of procedures for the numerical calculation of the weights can be used. One of the easiest methods is the rank sum:

$$w_j = (n - r_j) / \sum_k (n - r_k + 1)$$

where w_j is the normalized weight for the j_{th} factor, n is the number of criteria taken into consideration and r_j is the ranking of the criterion.

Among the rating methods there are two quite popular: the points' allocation and the ratio estimation procedure. The common feature is that the decision-maker has a number of points, typically 100, and must distribute them among the criteria basing on their importance. The most important criteria get higher scores and the criteria considered unimportant are not awarded any points. These methods also provide an initial budget allocation. In the point allocation, points are then transformed into weighted summations with the final value of 1. In the ratio estimation to the most important criterion is assigned a value of 100 and to the rest reduced values attributes, in proportion to their importance. The smaller value is used as an anchor point for the calculation of the ratio. Each value is divided by the smallest, and then the weights are normalized by dividing them by the total. As the ranking methods, rating methods do not have a theoretical foundation, so the meaning of the numerical value of the weights is difficult to justify (Malczewski 1999). Another frequently used method is pairwise comparison. The pairwise comparison method was introduced by Saaty (1980) together with the Analytical Hierarchy Process (AHP) MCDA methodology. The method consists of three steps. First, a pairwise comparison is performed and the results are reported in a comparison matrix; the matrix is populated with values from 1 to 9 and fractions from 1/9 to 1/2 that represent the importance of a factor with respect to each other in pair. The consistency of the allocation of the scores achieved by the decision makers has to be verified. Comparison of an attribute with itself has assigned 1 as a score (which indicates equal importance). An explanation of the scores accompanies the table. For the calculation of the weights the values in each column of the table are added together and each element of the matrix is divided by the sum of the respective column. The new matrix is called normalized matrix of pairwise comparisons. In the end an average of the elements of each row of the normalized matrix is calculated. The weights that are obtained with this method can be considered as an average of all possible weights. This method is much more sophisticated than the others and it's often criticized because a bigger number of criteria corresponds to greater laboriousness. In any case the advantage is given by the fact that only two criteria need to be compared at a time (Malczewski 1999). The selection of a method must take into account the level of knowledge of the problem by decision-makers and their experience in the field. Malczewski (1999) argues that the pairwise comparison is more appropriate if you search accuracy and theoretical foundation. The other two methods are shown when you search simplicity, speed and cost savings in the weight generation. Moreover, it must be said that the more a technique is less sophisticated the more the decision-making appears transparent. Regarding the preferences of the decision makers, it is known that in some cases the decision makers are not able to provide accurate judgments because of limited or inadequate information or knowledge on the decision criterion. In assigning weights, it is important to understand how the alternatives and criteria are represented in the policy maps; the data must, therefore, be presented to the decision-maker in such a way that it can easily understand the information given by the criterion of maps (Malczewski 1999).

The method by which you later decide to aggregate scores of the alternatives is called the decision rule. The decision table consists of the evaluation criteria and their scores for each viable alternative; the matrix of weighted scores must then be aggregated with respect to each alternative. One of the most common techniques used to do this is the simple additive weighting sum (SAW), which is based on the concept of the weighted average of all decision criteria. The weighted alternatives are simply added together so as to provide an overall score for each alternative. The SAW orders the alternatives from the highest score to the lowest (i.e. the highest score will be 1).

The sensitivity analysis is a procedure that has the aim to identify possible errors in the maps, poor accuracy on the part of the decision-makers and uncertainty evaluation of each alternative. Some scholars also argue that the multi criteria technical choice could influence the final outcome (Carver, 1991). The sensitivity analysis allows to verify the robustness of the final result. If the input data and preferences of decision makers not overly affect the result, the final solution can be shown on screen. The sensitivity analysis can be performed in two ways, both considering two alternatives at a time and showing how the values of the weights of the criteria and the scores differ if the alternatives had the same position, or considering all alternatives simultaneously and controlling how their position changes coupled to the scores of the criteria and the weights. Errors can also result from poor accuracy and inaccuracy in the representation of spatial data. This is because the map is a simplified model of reality, obtained following a generalization and discretization process; mistakes can be either positional but also on the attributes; they can also be measurement errors or conceptual errors. Malczewski (1999) emphasizes in particular the problem of dependence on the location and scale of spatial criteria. A set of objectives can vary from one area to another and from a scale of another. Therefore, when data is prepared, the least possible aggregation should provide, because the final aggregation is no longer a problem nowadays thanks to advances in technology.

The choice of MCDM technique is often conditioned by the data available on the GIS platform. In the case of raster data, the study area is divided into regularly shaped spaces, usually square grid. Each cell is associated with data relative to each potential alternative and is a viable candidate for evaluation. In these cases, Jankowski (1995) recommends the technique of the weighted summation, motivating this choice for the huge number of alternatives which also makes difficult pairwise comparison. In the case of vector data generally there are a lower number of alternatives, and in this case other techniques can be used.

3.4. FROM GIS TO WEBGIS

INTRODUCTION

Maps can help decision makers to send a clear message: putting spatial data on an online map makes it accessible to a much wider audience and it can be considered a great medium to publish GIS data. Creating a high quality map on the web is a very different process than creating one in a GIS since, it's usually tightly related to programming, while GIS users typically are not web programmers. That is why recently several tools have been developed that easily translate GIS work into web maps.

QGIS2WEB

Qgis2web[1] is a plugin that turns QGIS layers into HTML, JavaScript, and CSS files. Qgis2web generates a web map from a QGIS project, including layers, styles (categorized and graduated), and extent without the need on any server-side software.

Examples of possible representation on web through the Qgisweb plugin are reported inFigure 7. In Figure 7 a transit accessibility map, bus stop location and bus routes of the city of Catania are shown in three different layers.

In Figure 9 and Figure 10 maps published through the Qgis2web plugin are integrated with other web elements, such as graphs and forms. In particular, Figure 9 shows pedestrian Level of Service according to Highway Capacity Manual (HCM, 2010) for two zones in the city of Catania.

[1] https://plugins.qgis.org/plugins/qgis2web/

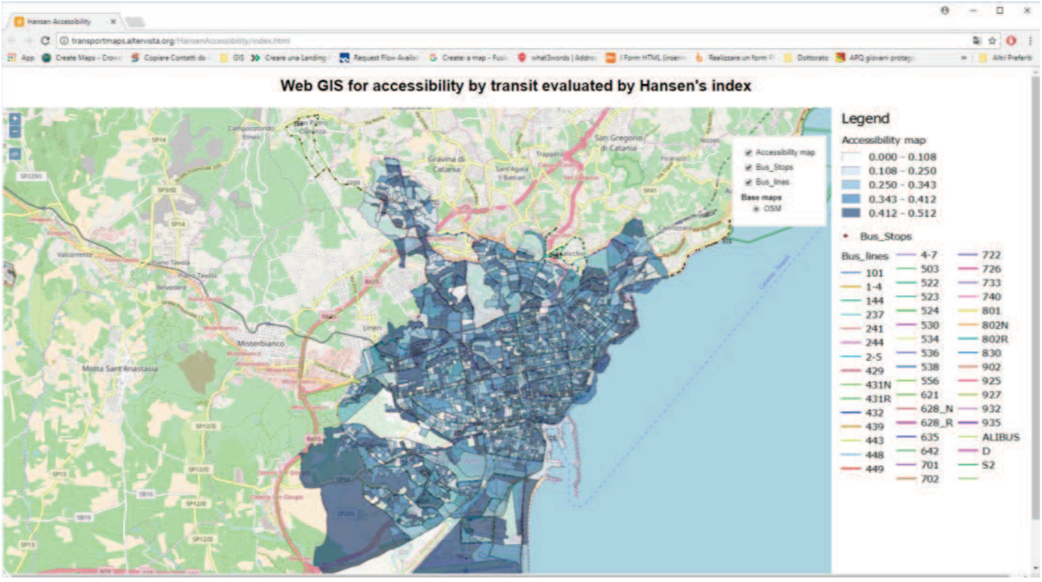
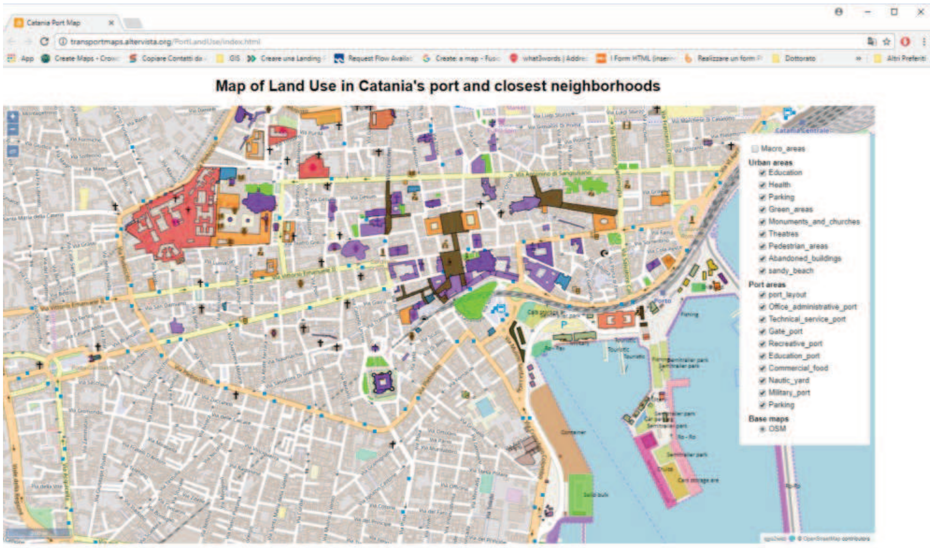


FIGURE 7 WEBGIS FOR HANSEN'S ACCESSIBILITY IN THE CITY OF CATANIA, ITALY (OWN ELABORATION [HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/HANSENACCESSIBILITY/INDEX.HTML](http://transportmaps.altervista.org/HansenAccessibility/index.html))

Figure 8 is a thematic map of the land use of the Port of Catania, showing different port



functions and point of interests in the surrounding urban area.

FIGURE 8 MAP OF LAND USE IN CATANIA PORT AND URBAN AREAS - ITALY (OWN ELABORATION [HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/PORTLANDUSE/INDEX.HTML](http://transportmaps.altervista.org/PortLandUse/index.html))

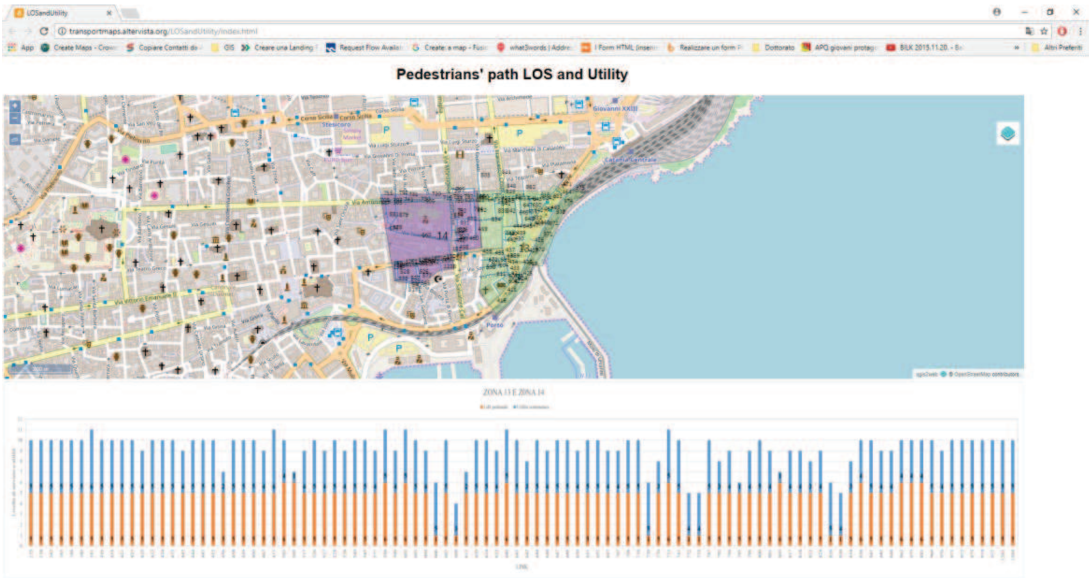


FIGURE 9 PEDESTRIAN LOS IN TWO ZONES IN THE CITY OF CATANIA, ITALY (OWN ELABORATION HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/LOSANDUTILITY/INDEX.HTML)

In Figure 10 the web map is integrated with a Google form which allows users to give their opinions about a transit service with reference to some spatial impacts of different alternatives.

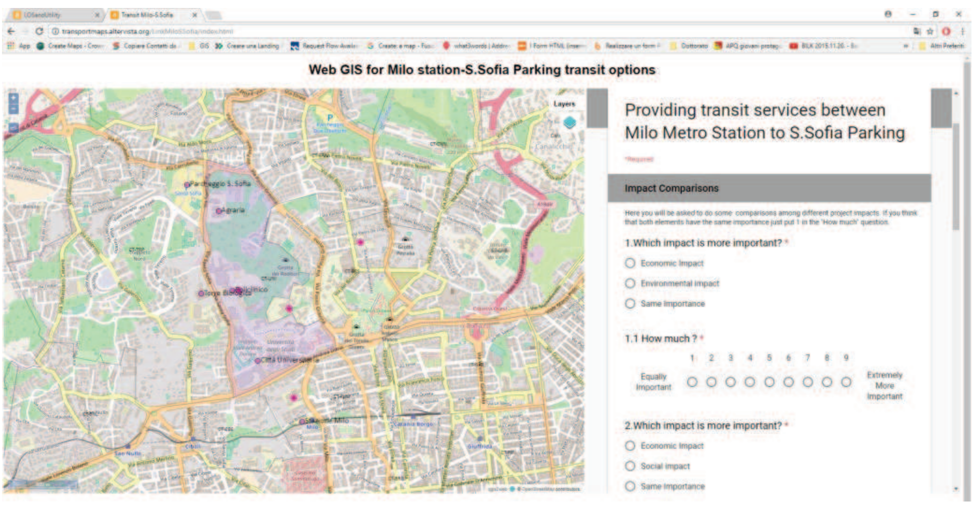


FIGURE 10 WEBGIS FOR PROPOSAL OF CONNECTION BETWEEN MILO SUBWAY STATION AND S.SOFIA PARK-AND-RIDE FACILITY (OWN ELABORATION HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/LINKMILOSSOFIA/INDEX.HTML)

Google Fusion Table

Google Fusion Tables is an experimental data visualization web application to gather, visualize, and share data tables developed by Google which allows a mash-up between spreadsheets and maps. This service will be deeply described in this work of thesis in section 4.6.

Google MyMaps

Google My Maps is a service launched by Google in 2007, which enables users to create customized maps than can be easily shared ed edited on the web. Users can add points, lines, and shapes on the map of Google Maps, using a WYSIWYG (What You See Is What You Get) editor. In the following updates, the possibility to insert layers with own data and to customize the items in each layer with uniform styles and having labels for the name or description has been added.

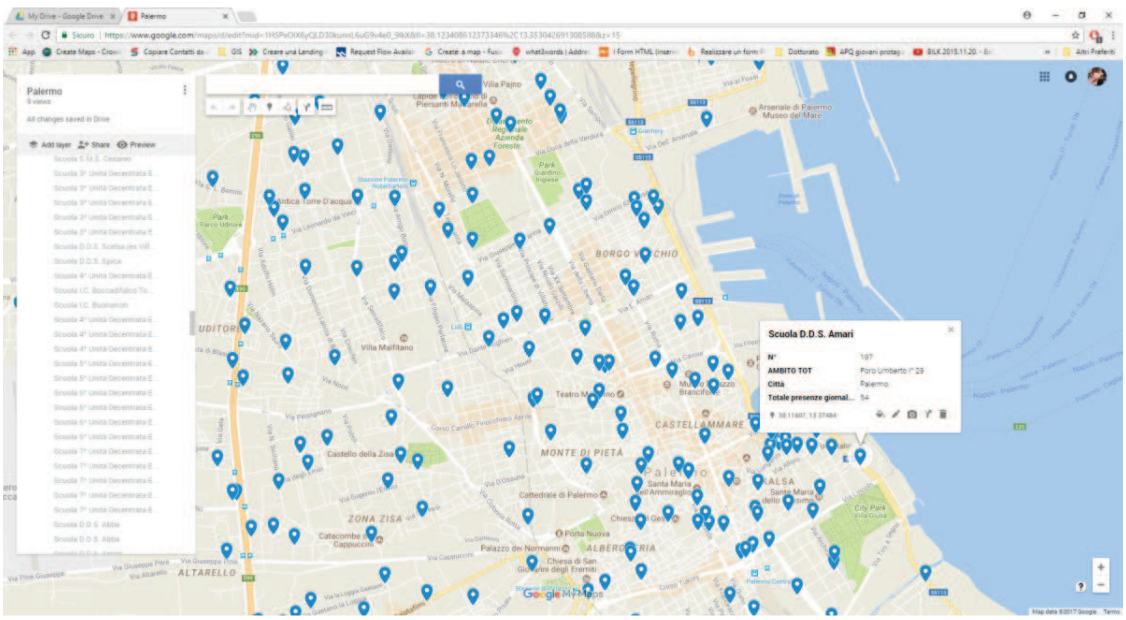


Figure 11 Example of MyMaps showing points of interest of the city of Palermo, Italy

Google Maps API JavaScript

The Google Maps API JavaScript allows for the embedding of Google Maps onto web pages of external developers, using a simple JavaScript interface. The API includes localization instructions for over 50 languages, region localization and geocoding, and has mechanisms for enterprise developers who want to utilize the Google Maps API within an intranet. The Google Maps API gives developers access to the abudance of data and features that Google makes available via their maps services (map data, street view, and places); Google provides many code examples and a JavaScript library for the web. Google Maps also provides web-based services such as returning the directions between different locations. The Google Maps API JavaScript opens the doors to the emulation of several complex functions: different icons per type, pop-up with figures on data, sidebar with personalized information (Figure 12), simulation of transit movement, elevation data on a path (Figure 13).

By using a styled map it is possible customize the presentation of the Google base map, changing the visual display of several elements as roads, parks, and built-up areas; in Figure 14 an example of styled map with university facilities in a neighborhood in Catania colored in yellow is shown.

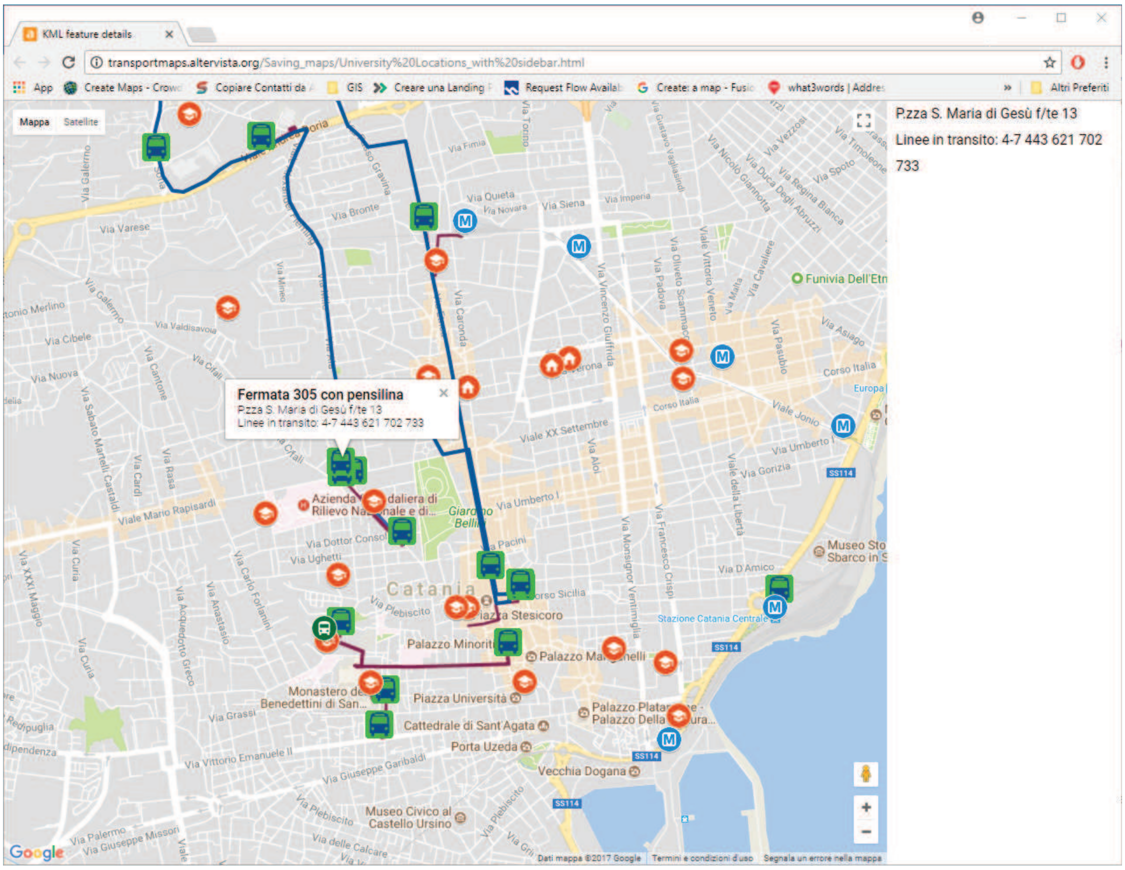


FIGURE 12 DATA FROM A KML WITH SEVERAL ATTRIBUTES, WHICH CAN BE SHOWED ON A SIDEBAR (OWN ELABORATION[HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/SAVING_MAPS/UNIVERSITY%20LOCATIONS_WITH%20SIDEBAR.HTML](http://transportmaps.altervista.org/Saving_maps/University%20Locations_with%20sidebar.html))

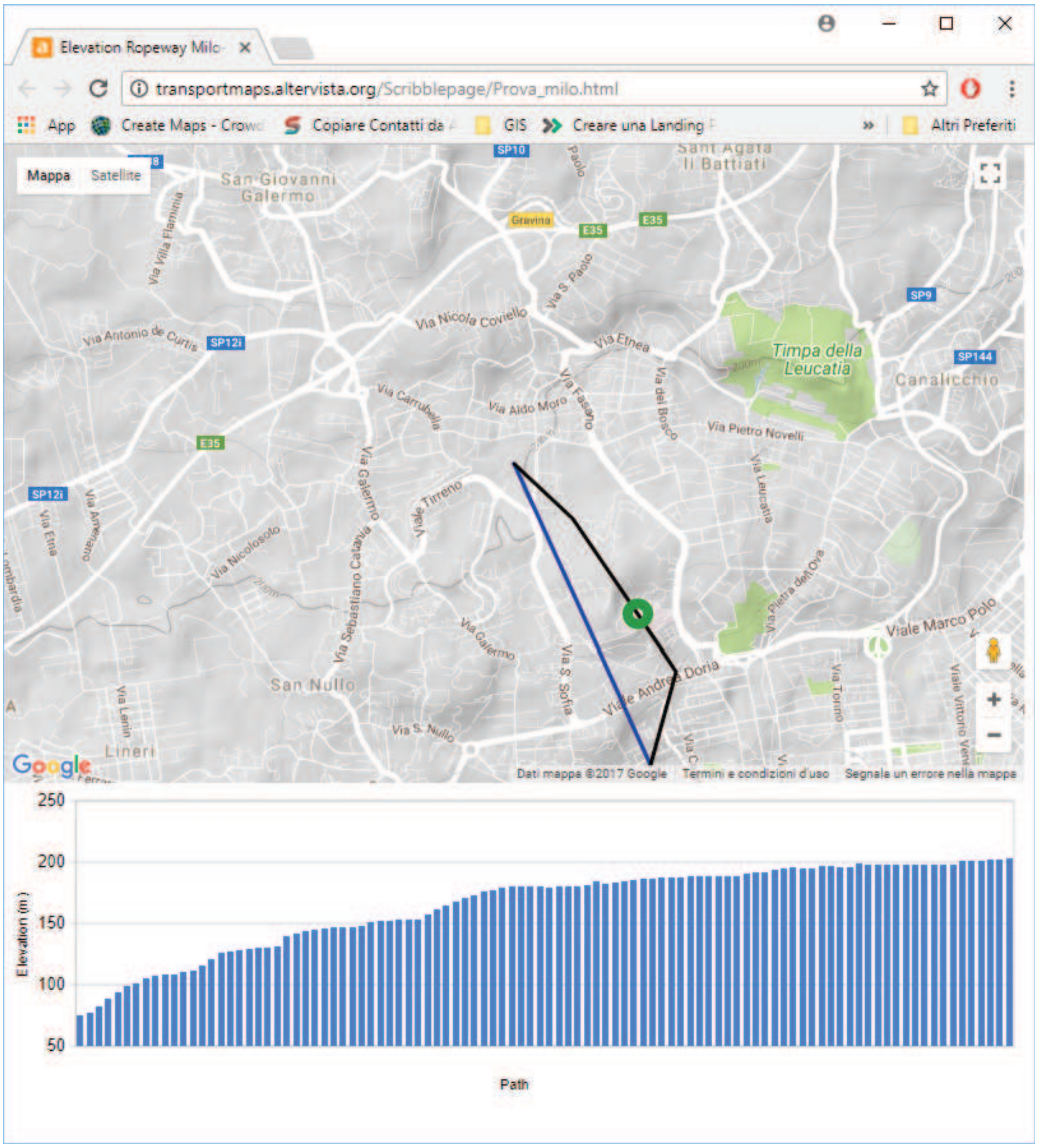


FIGURE 13 SIMULATION OF A TRANSIT LINE AND ELEVATION OF THE PATH (OWN ELABORATION HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/SCRIBBLEPAGE/PROVA_MILO.HTML)

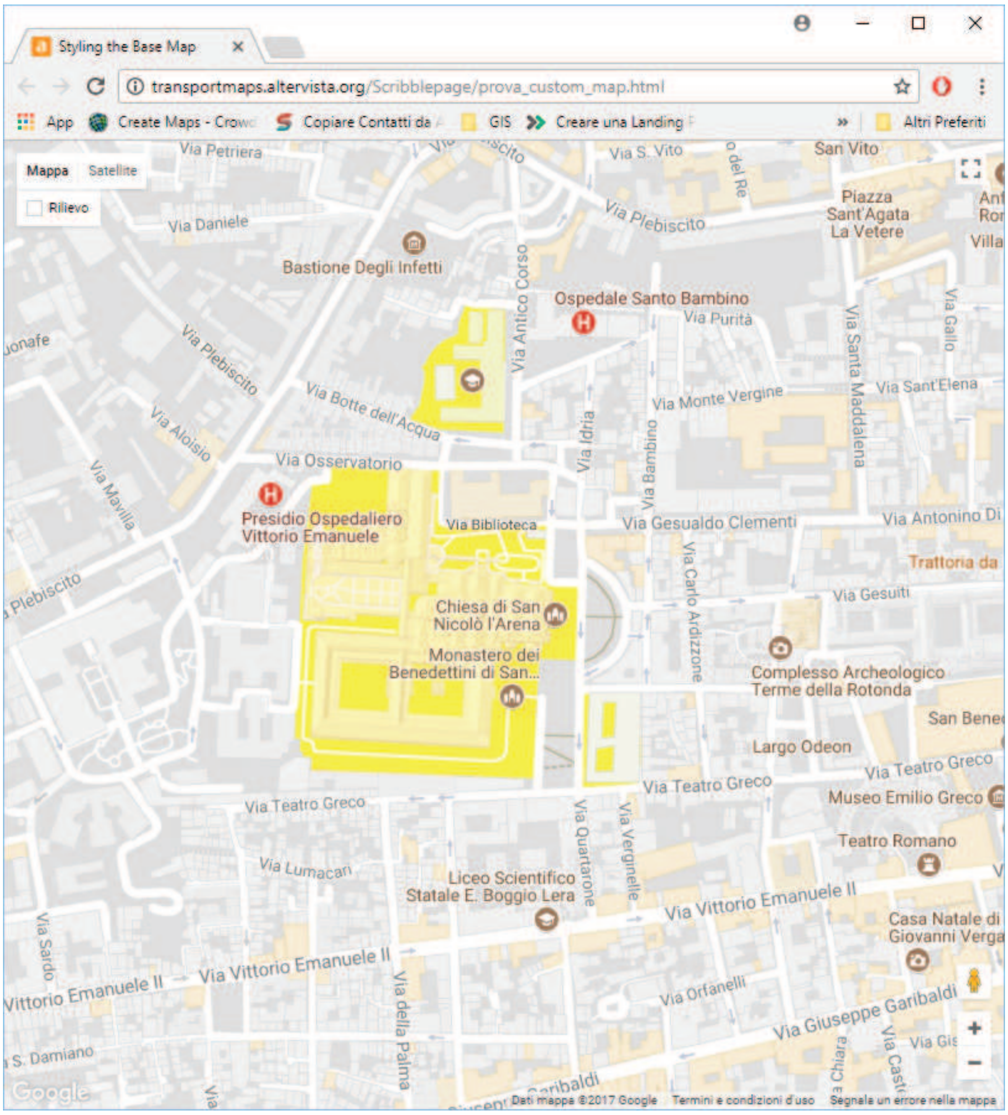


FIGURE 14 EXAMPLE OF STYLED MAP WITH UNIVERSITY FACILITIES IN YELLOW (OWN ELABORATION HTTP://TRANSPORTMAPS.ALTERVISTA.ORG/SCRIBBLEPAGE/PROVA_CUSTOM_MAP.HTML)

3.5. THREE INGREDIENTS FOR PERFORMANCE AND CONSENSUS BASED TRANSPORT DECISION MAKING

Transport decision problems and transport scenarios evaluations are spatial problems typically involving a set of feasible alternatives and multiple evaluation criteria; alternatives and criteria are often evaluated by a number of individuals (decision-makers, stakeholders, interest groups, citizens) with conflicting ideas, preferences and objectives. Finding the best trade-off between the solution based on consensus building and the one based on technical evaluations is considered a key issue in the evaluation of transport scenarios (Le Pira et al., 2018). A participatory transport planning framework (Figure 15) able to include (a) different levels of involvement, (b) different actors, i.e. experts, stakeholders and citizens that contribute with different degrees of competence and interest to the "bounded rationality" decision-making process (Le Pira et al., 2015a).

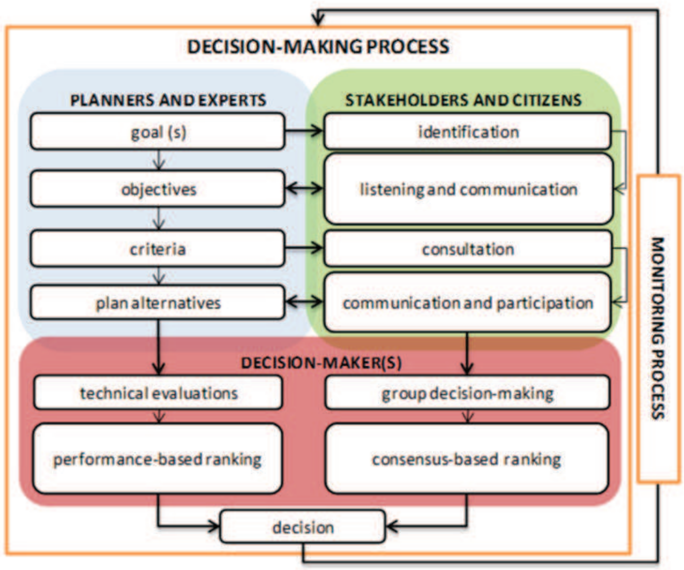


FIGURE 15 FRAMEWORK OF THE PARTICIPATORY DECISION-MAKING PROCESS IN TRANSPORT PLANNING (LE PIRA ET AL. 2015A)

The spatial dimension of transport decisions gives GIS an important role in analysing decision problems. The integration between GIS and MCDA can be thought of as a process that transforms and combines geographical data and value judgments to obtain information for decision making (Malczewski, 2006). By these premises, three main tools can be deducted as ingredients of the receipt to avoid the failure of transport policies, projects and plans: Public Participation, Use of GIS, and MCDA which, if fully integrated in a decision making process framework can take to a good social acceptability and robustness of decision (Figure 16).

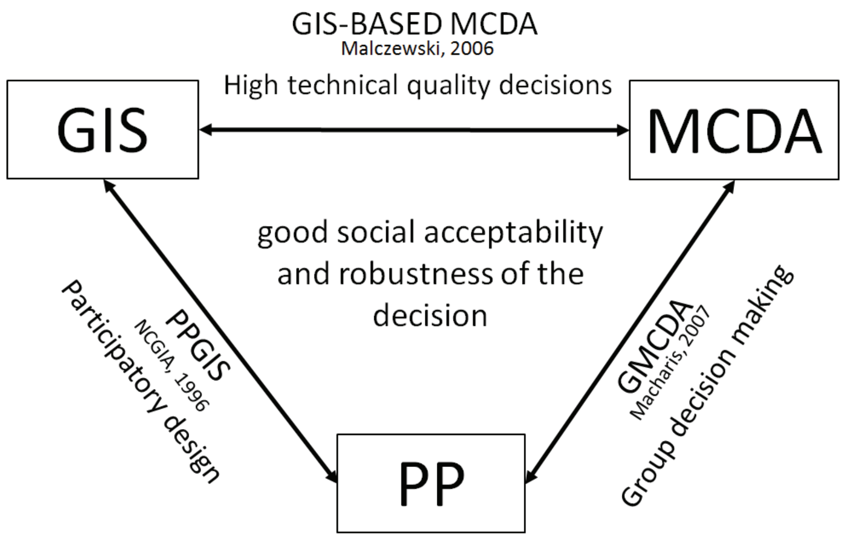


FIGURE 16 FRAMEWORK OF INTEGRATION OF GIS, PUBLIC PARTICIPATION AND MCDA

On the basis of the transport decision making problem and scenarios analysed, different level of implementation of the three ingredients can be adopted (Table 2):

Public participation:

- Poor: No citizen involvement, but inclusion of social issues
- Medium: Information giving

- High: Citizens' Active Participation (led by government or by the citizens)

Use of GIS to analyse decision criteria:

- Poor: GIS is used just to present the spatial problem and territorial framework
- Medium: GIS plays an important role in the analysis of scenarios, but some of the weights are decided with procedures that can take place out of the GIS
- High: GIS plays a predominant role in the analysis of the scenarios; weights in parameters of formulations are assigned according to indicators that are derived from GIS analysis.

MCDA: different levels

- Poor: No use of MCDA
- Medium: MCDA is used to evaluate alternatives
- High: MCDA is used to support consensus building

In terms of integration, different configurations can take place:

- Poor: No integration, the three components act as stand-alone.
- Medium: 2 out of 3. In this case we can have both:
    - GIS based MCDA
    - PPGIS
- High: 3 out of 3, which implies a PPGIS MCDA.

The highest the level of integration of the three components, the more the decision making process would take advantage of a tool supporting the evaluation of the alternatives for both technical performances and degree of consensus.

	Public participation	Use of GIS	MCDA	Integration
Poor	No citizen involvement, but social issues are included	GIS used to present the spatial problem and territorial framework	No use of MCDA	Poor or no integration
Medium	Information giving	Important role in the analysis of scenarios; weights are decided out of the GIS	MCDA to evaluate alternatives	Medium: 2 OUT OF 3
High	Citizens' Active Participation	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	MCDA to support consensus building	High: 3 OUT OF 3

TABLE 2 – DIFFERENT LEVELS OF IMPLEMENTATION OF PUBLIC PARTICIPATION, GIS AND MCDA AND THEIR INTEGRATION

In the next chapter a compendium of case studies on scenarios evaluation following the framework will be presented. Five papers, already published by the ahutor of the thesis in conference proceedings, will illustrate some case studies of implementation of Public Participation, GIS and MCDA and their level of integration.

4. CASE STUDIES

4.1. CASE STUDY 1: Comparison between Bus Rapid Transit and Light-Rail Transit Systems: a Multi-criteria Decision Analysis Approach[2]

4.1.1. INTRODUCTION

High Quality Level of Service (BHLS) systems, which can be defined as a system that "offers to the passenger a very good performance and comfort level, as a rail-based system, from terminus to terminus at station, into vehicle and during the trip" (COST, 2011).

Yet from this definition it is possible to understand why a great interest has been shown in the comparison between this type of system and the Light-Rail Transit (LRT) system; moreover, when comparing it to the Bus Rapid Transit (BRT) system, which, at its peak performance, can reach up to one million passengers per day (COST, 2011). Supporters of the BRT system highlight how rubber tires allow for operation flexibility, which is impossible for a tram system; while those decrying BRT say that such flexibility does not ensure a high quality of service. In the United States, the debate concerning BRT and LRT systems is very tight and supporters of LRT have accused the US Federal Transit Administration of excessively sponsoring systems like BRT only with the purpose to facilitate road transport and oil industry lobbying (Freemark, 2015).

The main differences between the two systems are essentially due to the following characteristics:

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2 This section is based on paper *Comparison between bus rapid Transit and light-rail transit systems: A multi-criteria decision analysis approach* (Annex A)

- BHLS systems allow for more track flexibility;
- LRT vehicles have a longer life than BHLS systems;
- Initial funding for the realization of BHLS systems is generally less than for LRT
- systems;

LRT systems can operate safely on rails, in tunnels and on overpasses;

- Access time to LRT stops is generally longer than to BHLS stops;
- LRT vehicles need less space both in stations and on tracks.

The characteristics of a BHLS system that make it more similar to a tramway are to be found in the improvements compared to a classic road for public transport:

- A reduced number of stops;
- Reserved lanes in which it is possible for the bus to achieve a higher speed, without excluding the possibility of operation in a mixed zone; reserved lanes introduction is not dependent "from means of transport riding but from political support which allows to deduct space for cars, offering alternative solutions to car drivers" (Lopez Lambas, 2013);
- Priority systems at intersections and turn prohibitions for motorized vehicles on the reserved lane;
- High frequency;
- Increased comfort due to the absence of continuous acceleration and braking;
- Information about the real-time position of the vehicle;

- Ticketing outside the vehicle;
- Road-level access through low-floor bus and stations equipped with facilities for passengers.

Marc Le Tourneur, a member of the Direction de l'Innovation et du Développement of Veolia/Transdev, argues that the choice between a BRT system and a tramway is mainly related to the number of passengers: a number of less than 3000 passengers/h should lead to opting for the BRT system; a larger number for the tram system (Le Tourneur, 2011). Actually, it is not possible to consider a system absolutely more suitable than the other; both the solutions could be ideal on the basis of a particular scenario. Choice criteria should include each system's available funds, its operation costs, environmental improvements and possible economic developments. Conventional cost-benefit analysis is not always able to take into account all of the wide range of impacts deriving from the competing projects, since it generally provides the decision maker with an economic assessment expressed in a monetary scale.

Multi-Criteria Decision Analysis (MCDA) techniques are indeed able to incorporate multiple parameters related to both economic and strategic aspects and they are a good aid for decision makers in identifying priorities.

In this study, MCDA will be used to evaluate the choice between the application of a BHLS system and a LRT one; a spatial analysis via a Geographical Information System (GIS) environment will be used for designing some parameters of the analysis.

4.1.2. Methodology

Literature review

Through an analysis of recent literature on the evaluation of transport projects, it can be seen that there are several articles reporting growing attention to the use of MCDA techniques; this is due to the fact that MCDA is able to cope with several criteria besides the economic aspects and can also deal with different, often contrasting, decision makers (Jankowski, 1995; Morisugi, 2000; Grant-Muller, 2001). In particular, the use of compensatory approaches (based on the assumption that a high performance achieved on a criterion can compensate bad performance of another one) is widespread in mobility management, infrastructure and public transport analysis; it is used in the comparison of different road or rail projects (Gercek ET AL., 2004; Tabucanon, M.T. & Lee, H, 2001) the construction of public transportation models (Seunglim, K. & Seongkwan, M.L, 2006), integrated planning for public transport and land use development (Sharifi et al, 2006), and in the creation of personalized route planning systems (Niaraki, A.S. & Kim, K., 2009).

Decision-making problems, as transport system evaluations, require taking into account some spatial parameters of each alternative; integration with GIS can be useful in this perspective. Jankowski (1995) distinguishes between two strategies for integrating GIS with MCDA: the first strategy suggests linking them by using a file exchange mechanism (loose coupling strategy); the second strategy suggests the full integration of multiple criteria evaluation functions into GIS with a shared database and a common user interface. In Gonçalves Gomes and Estellita Lins (Gonçalves Gomes, E. & Estellita Lins, M.P, 2002), a multi-objective linear programming technique integrated in a GIS environment is used to select the best municipal district of Rio de Janeiro State in Brazil, in relation to the quality of urban life. A good example of integration between MCDA and GIS in the transport field is the evaluation of alternatives in transportation planning made by Piantanakulchai and Saengkhao (Piantanakulchai, M. & Saengkhao, N, 2003) in which a case study of alternative motorway alignments in Thailand was conducted through the application of a compensatory approach.

In our study, a loose coupling strategy will be adopted and compensatory MCDA methods will be applied to evaluate the global score of both LRT and BRT systems.

Fundamental objectives and related criteria

MCDA techniques allow the evaluation of different project solutions on the basis of a limited number of criteria, through a unique global judgment, giving the decision makers the chance to tend to the most satisfactory opportunity.

In its basic application, any MCDA technique pursues the following steps:

- Identification of the alternatives, which may consist of different project solutions or different elements of a whole project;
- Identification of the objectives;
- Identification of criteria, which are performance indicators related to each objective; they can be both quantitative and qualitative.

In our study, the two different transport systems BRT and LRT will be compared through the application of a MCDA technique, illustrated in sections 2.3 and 2.4. Here we present the objectives to be satisfied, divided into three categories according to their corresponding impacts: transportation impact, economic impact, social and environmental impact.

The main objectives and their associated criteria in the transportation impact category are:

a) Improve safety: the number of interaction points with other road users such as road junctions, roundabouts, pedestrian crossings and right of way;

b) Improve security;

c) Improve accessibility: two different types of accessibility can be taken into account. A passive accessibility, i.e. the difficulty of access by communities to the transport system, which can be represented by:

$$A_i = \frac{1}{\sum_{i=1}^{n}(P_i \cdot d_i^{\,c})}$$

where Ai is the difficulty of access by community in the Traffic Analysis Zone (TAZ) of the transport system; Pi is the population in the TAZ i; di c is the distance of TAZ I to the nearest transport system station; c is a parameter reflecting the willingness to use the system; an active accessibility, measuring the easiness of reaching opportunities for people leaving the transport system, which can be measured by Hansen's accessibility index:

$$A_i = \sum_j \left(\frac{B_j}{d_{ij}^{\,\alpha}} \right)$$

where Ai is the difficulty of access by users getting off the transport system at the station i; B_j is the opportunities in the TAZ j; d_{ij} is the distance from i to j; a is a deterrence parameter. Nine different types of activities have been taken into consideration to evaluate active accessibility, according to the following categories: parking locations, health places, administrative offices, worship places, food shops and courts, entertainment, education, culture/tourism, tourists' accommodation. The results have been classified into 10 different levels of passive and active accessibility.

d) Minimize travel cost. Generally, the public transport systems, on rail or road, are represented with not-congested network models, which means that they neglect speed reductions due to the phases of boarding and alighting of the passengers at the stops, and also the cost perceived by users in relation to the degree of crowding on board. For systems on totally or partially mixed ways (e.g. tramways, buses, etc.), it is preferred to estimate the commercial speed of the line, which depends not only on the characteristics of the vehicles (maximum speed, acceleration, etc.), but also on road traffic on the mixed way.

e) Guarantee integration with other transport systems. The integration criterion is used to judge how well the structure is integrated with other transport systems and other city structures. Separate underground and aboveground systems are an example of disintegrated structures. Transfer nodes, shared stops, common information for passengers, common tariff, coordinated timetables, and shared road sections.

f) Guarantee flexibility. This criterion is related to the potential of renewing elements of the system, such as including other itineraries, displacing the track, moving the stops' locations.

g) Maximize capacity, in order to achieve a higher number of passengers carried at peak hour.

h) Optimize reliability. This criterion is used to guarantee the highest punctuality being in the interest of the operator, public transport management, and passengers.

The main objectives and their associated criteria in the economic impact category are:

- Minimize infrastructure cost;
- Minimize operating and maintenance costs;
- Minimize vehicle purchasing costs;
- Maximize urban public transport system profitability.

The main objectives and their associated criteria in the social and environmental impact category are:

- Avoid community severance: community severance, or the barrier effect, happens when the transport system limits people's mobility, instead of facilitating it. Railways, motorways, and roads with high traffic levels or speeds, create physical and psychological barriers that separate communities, with effects on walking and cycling mobility and possible negative effects on individual health and social cohesion.

- Minimize land use: the land use criterion should be considered in order to assess whether an element of the infrastructure is likely to require more or less space.
- Improve comfort. This takes into account the social requirements of urban public transport passengers by guaranteeing the optimum travel conditions. It determines the percentage share of the travel performed in good and very good conditions during an entire urban public transport journey. This criterion also takes into account the share of seated travel, i.e. the number of passengers able to occupy seats on the urban public transport vehicles.
- Minimize energy consumption, basing on kWh produced by both transport systems.
- Noise pollution. Roadway noise is the prevalent environmental noise in the cities; emissions from vehicles are influenced mainly by traction mechanisms, and by the contact between the wheel and the sliding surface. The noise level Ni to the TAZ i if a transport system would be constructed can be evaluated as:

$$N_i = N_0 - \alpha \log \frac{D_i}{D_0}$$

where N0 is the noise level at a standard distance from the center of the line; D0 is the standard distance from the centre of the line; Di is the shortest distance between the line and the TAZ centroid; α is a parameter reflecting type of ground and obstruction from roadside; total weighted noise impact N to neighboring communities could be represented by:

$$N = \sum_{i=1}^{n} \frac{\left(\frac{P_i}{P}\right)\left(\frac{N_i}{N_0}\right)}{L_{i,Noise}}$$

where Pi is the population within the community i; Pi is the mean population; Li, noise is the Land use factor related to the noise impact on the community i (equal to 1 in this study).

- Air pollution, expressed in kg/m3 using the Gaussian Air Dispersion Model (Colls, 1997)

TOPSIS

TOPSIS, which stands for 'Technique of Order Preference Similarity to the Ideal Solution', is a goal reference technique that requires a minimal number of subjective inputs (just the weights associated to the criteria; the fundamental idea is that the best solution is the one which has the shortest distance to the ideal solution and the furthest distance from the anti-ideal solution [5].

The TOPSIS method is based on five computation steps ([] Ishizaka, A. & Nemery, P, 2007):

- The first step is the gathering of the attribute values of each alternative on the different criteria.
- Attribute values need to be normalized in order to allow the comparison of different units. Normalization has been made through the application of two different methods. The distributive normalization, which requires that the performances are divided by the square root of the sum of each squared element in a column, according to the following equation:

$$r_{ia} = \frac{x_{ia}}{\sqrt{\square_{n=1}^{n} x_{ia}^2}}$$

for a=1,…,n and i=1,…,m

The ideal normalization, which requires dividing each performance by the highest value in each column if the criterion has to be maximized. If the criterion has to be minimized, each performance is divided by the lowest score in each column, according to the following equations:

$$ra_i = \frac{x_{ai}}{u_a^+}$$

$$ra_i = \frac{x_{ai}}{u_a^+}$$

For a=1,…,n and i=1,…,m where $u_a^+ = max(x_{ai})$ for all a=1,…,n;

- Normalized scores are then weighted. A weighted normalized decision matrix is constructed by multiplying the normalized scores r_{ai} by their corresponding weights w_i.
- The distances to an ideal and anti-ideal point are calculated. The decision has been made to assume an absolute ideal and anti-ideal point, defined without considering the actions of the decision problem, A+ = (1, ..., 1) and A− = (0, ..., 0). The distance for each action to the ideal action is calculated using the following equation:

$$da^+ = \sqrt{\square_i \left(v_i^+ - v_{ai}\right)^2}$$

With i=1,…,m

The distance for each action to the anti-ideal action is calculated using the following equation:

$$da^{-} = \sqrt{\square_i \left(v_i^{-} - v_{ai}\right)^2}$$

With i=1,…,m

- Finally, the closeness, whose value is always between 0 and 1, is given by the ratio of the calculated distances:

$$C_a = \frac{d_a^{-}}{d_a^{+} + d_a^{-}}$$

4.1.3. Context Framework

Cities Involved

For the application of the methodology, as a hypothetical exercise, the tramway of Santa Cruz de Tenerife in Spain and the BRT system of Prato in Italy have been chosen for comparison. These two cities were chosen because of their similar characteristics with regard to geographic and demographic data, and because of the similarities noticed between the two respective transport systems, as it can be seen from the data reported in Table 1. Data used for this study, as well as information regarding the transport system, refer to the year 2013 (see http://www.comune.prato.it/ and http://www.santacruzdetenerife.es/).

The public transport system in Prato includes a railway system and urban and sub-urban bus lines. This road network is based on different bus lines operating in the whole Prato area managed by CAP (Cooperativa Auto-trasporti Pratese). Five BHLS lines – LAM (Linee ad Alta Mobilità) – operate in the city: the Blue line (Figure 17, analyzed in this study), Red line, Orange line, Light blue line, and Purple line. The first three serve the urban area, whereas the Light blue line and Purple line link the city centre with the sub-urban area.

Table 1: Summary of the characteristics of the two cities included in the study.

Cities	Area (km^2)	Population (inhab.)	Density (inhab./km^2)	System	Line	Length (km)
Tenerife	150.56	214,477	1363.44	Tram	1	12.6
Prato	97.35	191,070	1962.01	BHLS	Blue	9.61

The main urban transport systems of Santa Cruz de Tenerife consist of collective guaguas (bus lines managed by the operator TITSA), and the tramway of Tenerife is managed by Metropolitano de Tenerife Sociedad Anónima (MTSA). The Tramway of Tenerife covers a total of 15.1 km and includes two lines, the Línea 1 and 2. The Línea 1, analysed in this study (Figure 18), opened in 2007, is the main line with 21 stops and a length of about 12.6 km, and links the Intercambiador de Transportes of Santa Cruz de Tenerife at the Trinidad station.

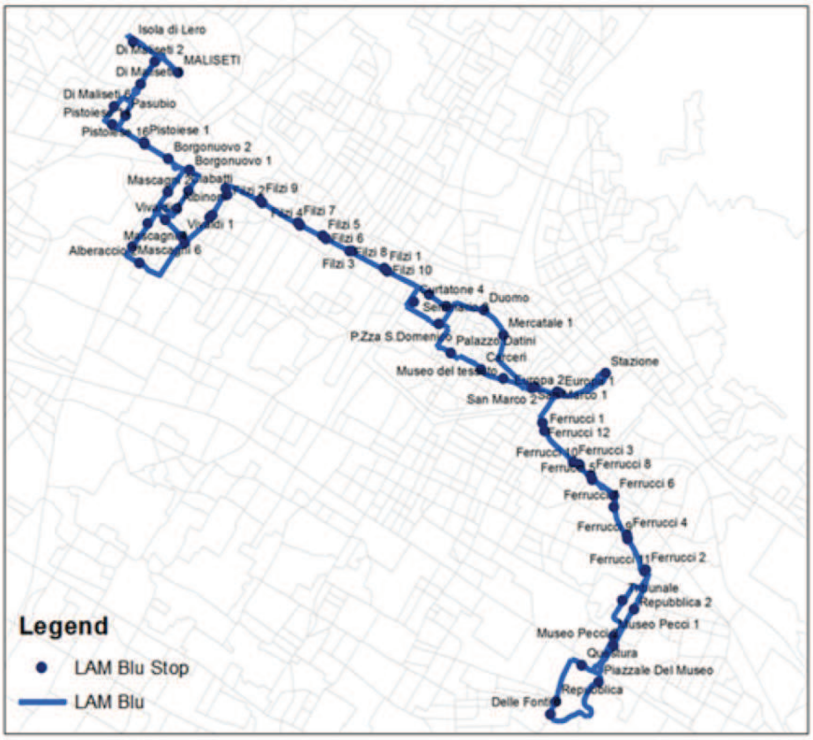


FIGURE 17: PRATO BRT STUDY AREA.

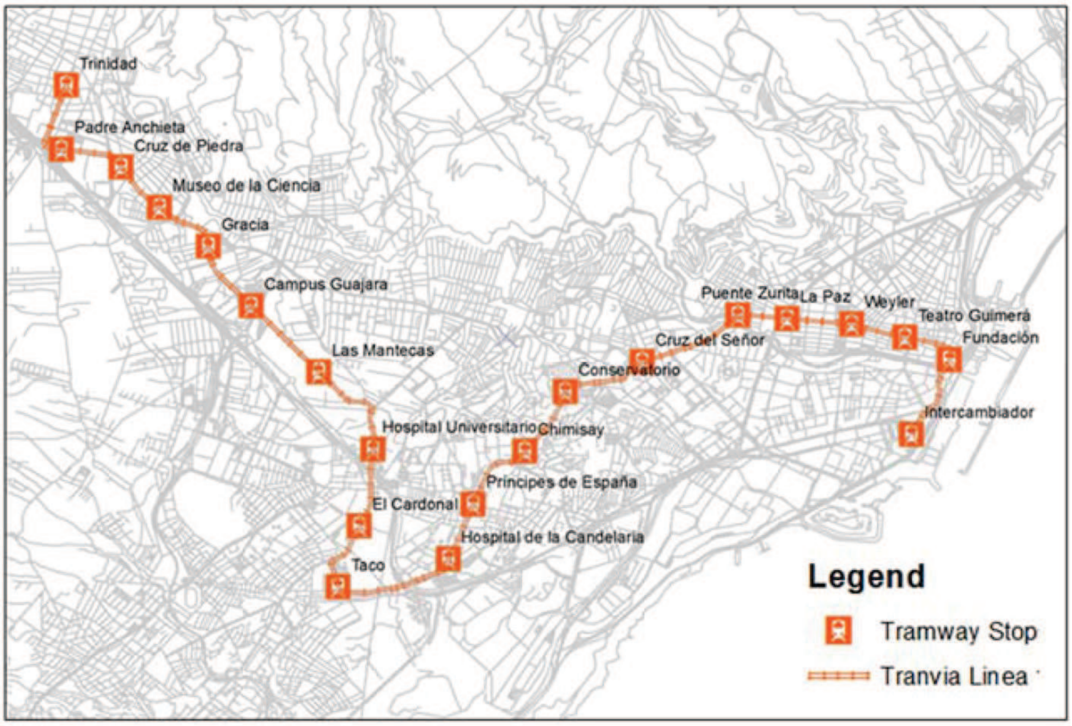


FIGURE 18: TENERIFE LRT STUDY AREA.

WEIGHT ASSIGNMENTS

Since it is not possible to involve, at this stage of the study, decision makers and stakeholders of the two communities, it has been decided to assign the same weight to all criteria, making sure that the total sum of the weights would be equivalent to 1.

EVALUATION OF INDICATORS

Data on vehicle purchasing costs, profitability and seated travel are not included in this case study; all the other indicators have been evaluated from COST Actions TU0603 and TU1103 (COST, 2011; COST, 2015), and from information given by the operation companies in their websites; the indicators used for analysis are shown in Table 2. The estimation of spatial indicators has been realized through the use of the software ArcMap10.1 in the ArcGIS environment. The final outputs of indicator evaluation are the criterion maps which, with regard to accessibility indicators, are shown in Figure 19 and Figure 20. In order to interpret what is represented in the maps, the values of accessibility indices have been normalized and grouped into 10 different levels (from 0 to 9, with 0 being the lowest accessibility level to 9 being the highest accessibility level). In both cities, it is possible to see how the zones surrounding the transit line always show high levels of accessibility.

TABLE 3 INDICATORS USED FOR TOPSIS METHOD

City		Tenerife	Prato
Transport system		Tram	BHLS
Criteria	*Unit*	*Attribute*	
Area	km^2	150.56	97.35
Population	Inhab.	205279	190777
Density	Inhab./km^2	1363.44	1959.70
Length	km	12.62	15.10
Interaction points	Number/length	38.00	283.00
RoW	length mixed/length	0.00	0.30
Accidents	Acc./km	1.73	4.37
Criminality	Number/year/inhab.	0.00	
Passive accessibility	INDEX (medium)	0.58	110.50
Active accessibility	INDEX (medium)	1288.59	856.95
Cost	h	0.59	0.80
Speed	Km/h	21.30	18.90
integration nodes	percentage	1.00	4.00
shared stops	percentage	0.44	0.46
information for passengers	yes/no	0.00	1.00
common fare	yes/no	1.00	1.00
coordinated timetables	yes/no	0.00	1.00
shared intermodal sections	Length/tot length	0.00	0.00
Flexibility	yes/no	0.00	1.00
Capacity provided	Pass/h	5400.00	282.86
punctuality	percentage	0.995	0.74
Infrastructure cost	€/km	€ 22,821,638.06	€ 589,400.00
Operating and maintenance costs	€/km	€ 812,500.00	€ 1,300,000.00
Community severance	m/km	0.18	0.00
Energy	kWh/km	6.53	7.72
Noise level	INDEX	42.91	215.40
Air pollution N_{ox}	kg/m^2	0.000001	0.000033
Air pollution PM_{10}	kg/m^2	0.000000	0.000000
Air pollution CO_2	kg/m^2	0.000086	0.000002
Air pollution CO	kg/m^2	0.000000	0.000003

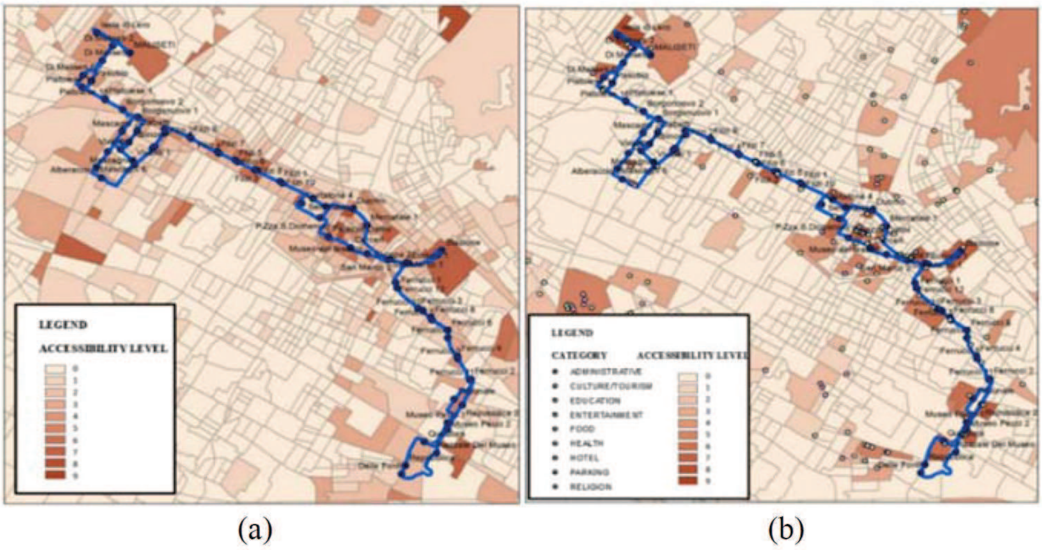


FIGURE 19: (A) PASSIVE AND (B) ACTIVE ACCESSIBILITY LEVELS IN PRATO.

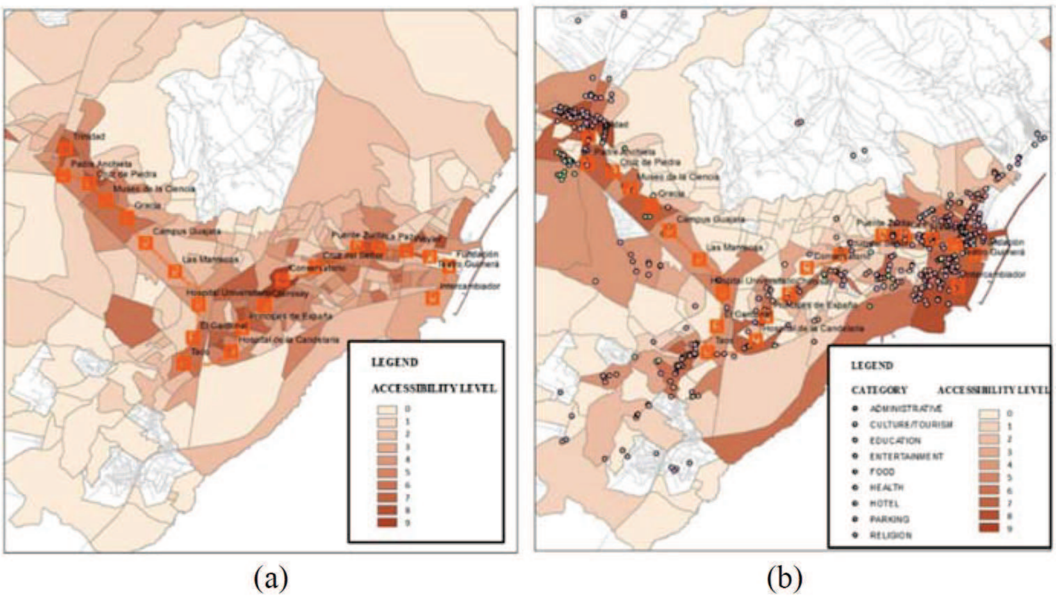
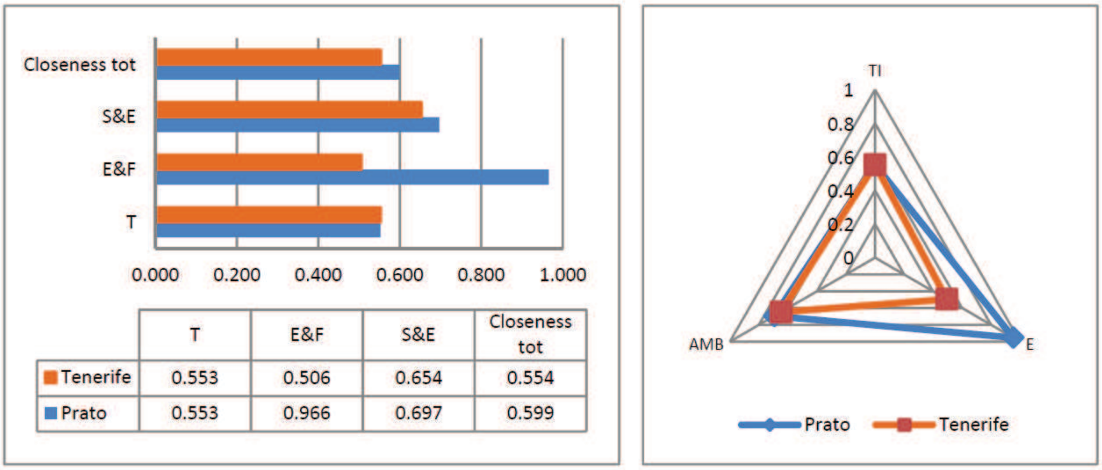


FIGURE 20: (A) PASSIVE AND (B) ACTIVE ACCESSIBILITY LEVELS IN TENERIFE.

MCDA THROUGH TOPSIS APPROACH

The ideal normalization approach has been applied; the technique ranked the two alternatives assigning a better global score to the BRT solution, indicated through the total closeness in

Figure 21 (a). Analyzing partial scores, BRT obtained a better score for Social and Environmental impact score (S&E; Fig. 5), a high partial score for the Economic and Financial impact score (E&F; Figure 21), while in the Transportation impact score, LRT just overpasses BRT. In the radar chart of Figure 21 (b), it is possible to appreciate the closeness of each partial indicator to the ideal solution, with the Economic impact score of BRT standing out among the others, almost reaching the value of 1.



(a) (b)

FIGURE 21: IDEAL NORMALIZATION TOPSIS (A) RESULTS AND (B) RADAR CHART.

SENSITIVITY ANALYSIS

A sensitivity analysis has been conducted in order to identify whether the outputs coming from the method are influenced by the weights assigned to the input factors. Most of the time, in fact, data in multi-criteria decision-making problems are changeable and unstable, and a sensitivity analysis after problem solving can effectively contribute to the choice of the appropriate method to obtain more accurate decisions.

Three more possible weight scenarios of analysis have been assumed: a scenario in which all the impacts have the same weight; a hierarchical scenario in which social impact criteria have the biggest weights and economic impact criteria the smallest ones; a scenario with random weights assigned. Partial scores, global score and their variances (Tables 3 and 4) within the four analysis scenarios have been calculated. Sensitive analysis shows that the solution is robust.

TABLE 4: PARTIAL AND GLOBAL SCORE COMPARISON WITHIN THE FOUR DIFFERENT WEIGHT SCENARIOS.

Method	Scenario	City	T	E&F	S&E	TOT
TOPSIS ideal	Base	Prato	0.552	0.952	0.694	0.599
		Tenerife	0.553	0.495	0.648	0.554
	Impacts	Prato	0.553	0.927	0.691	0.599
		Tenerife	0.554	0.414	0.641	0.519
	Hierarchy	Prato	0.552	0.9524	0.694	0.600
		Tenerife	0.553	0.4956	0.648	0.554
	Random	Prato	0.552	0.940	0.678	0.598
		Tenerife	0.553	0.489	0.598	0.545

TABLE 5: VARIANCES OF THE FOUR ANALYSIS SCENARIOS.

	Transportation impact	Economic impact	Social and environmental impact	Total score
Prato	3.72E-06	1.39E-06	6.54E-08	3.16E-06
Tenerife	2.37E-05	1.58E-05	9.29E-08	1.88E-05

4.1.4. CONCLUSIONS

After some years of the disposal of tramway lines, we are currently witnessing their great renaissance and a consequent modernization of vehicles and operations that are leading to the increased use of LRT systems. At the same time, a new bus system concept providing high quality service is developing and the competition between the two types of systems is becoming more frequent. In this study, a comparison between LRT and BRT systems has been conducted with the use of the TOPSIS technique. A case study involving the cities of Prato and Santa Cruz the Tenerife has been presented. The results of the application to a medium-sized city with similar characteristics gave comparable results concerning partial and global scores, indicating that the BRT system is the best solution.

4.1.5. SUMMARY AND AND DEGREE OF IMPLEMENTATION

In this study, MCDA has been used to evaluate the choice between the application of a Bus with High Level of Service and a Light Rail Transit; a spatial analysis via a Geographical Information System environment has been used to design the parameters of the analysis. The study provided an ideal solution for a medium sized city; this kind of approach, being a hypothetical exercise, does not allow the inclusion of public participation in the procedure. Levels of application of GIS, PP and MCDA are summarized in TABLE 6.

	Public participation	Use of GIS	MCDA	Integration
Level	No citizen involvement, but social issues are included	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	MCDA to evaluate alternatives	Medium

TABLE 6 LEVELS OF APPLICATION OF GIS, PP AND MCDA IN CASE STUDY 1

4.2. CASE STUDY 2: Public Transport Accessibility and Social Exclusion: making the Connections[3]

4.2.1. Introduction

In the last few years, cities have been developing fast in more complex and fragmented systems: the reorganization of residential areas, activities and metropolitan services, as well as and the increasing mobility, have distorted rhythms and social dynamics. Vehicular traffic flows and land occupation by parked cars create a barrier effect and a consequent decrease of the possibilities of socialization.

An early form of social exclusion is manifested when individuals possess a poor "mobility capital" (Borlini and Memo, 2011), i.e. their ability to move is reduced, so they are ousted from all those resources located outside of its space range. People too young, too old, unable to drive, or too poor to afford a car or a plane ticket become "second class" citizens, leaning on a public transportation is often unreliable.

Van Wee and Geurs (2011) define social exclusion as the tendency of some people or groups of people to be excluded from a certain minimum level of participation in regional activities in which they wish to participate. The complexity of the phenomenon is evident: it is very difficult to recognize and quantify a minimum level of participation; moreover, the barriers that prevent the ability to participate in civil society are many and not only related to the economic factor. With regard to the field of transport, there is a close relationship between accessibility and

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[3] This section is based on paper*Public Transport Accessibility and Social Exclusion: making the Connections* (Annex B)

social exclusion. The latter is not so much due to lack of services and social opportunities, as to a lack of access to such opportunities.

Preston and Rajé (2007) suggest that social inclusion can be achieved through both the proximity to the activities and services you want (which does not require to support travel costs) and the ability to reach distant destinations within reasonable time, even if with high transportation costs, or both by an intermediate state between those presented.

Lucas (2012) says that inadequate access to transportation and social disadvantage interact more or less directly resulting in what can be defined as "transport poverty". This in turn causes the goods and essential services and opportunities for social interaction to become inaccessible and at the same time cut off citizens from decision-making processes. The social exclusion that results risks triggering a degrading vicious cycle that causes an increase in social inequalities and centralized transport.

One of the policies for the urban mobility of large cities should be to discourage the use of private car when it is not necessary in order to promote new travel behavior and incentives to carry out an extensive and efficient public transport network. While all this is feasible, it must also be assured that the activities and main services are easily accessible by every transport mode. Therefore, a close interaction between the location of urban opportunities and the planning of public transport and of the urban transport system as well is strictly required.

Many people experiment different obstacles to reach opportunities and services: from physical barriers (availability and accessibility of transport) to economic (cost of transport) or urban structure mobility constraints (services located in places which are difficult to access). Until these barriers will not be removed, a significant portion of the population will remain unable to move as they would and, therefore, their opportunities to participate in the life of the communities will remain poor.

Public transport may be able to reduce this mobility gap and therefore to favor social inclusion. In fact, when it’s not accessible by the weakest population groups and it’s unable to break down the barriers that do not allow the participation to social activities, public transport fails its primary goal: to give access to employment or educational opportunities, medical care services and entertainment venues. In summary, public transport should offer everyone the ability to move and therefore it’s a critical issue for social inclusion policies.

The city of Catania, a medium-sized city (300,000 inhabitants) located in the eastern part of Sicily in Italy, has been for years on the top position of the Italian city for the highest car ownership rate. It appears totally necessary to convert this car possession trend by improving the efficiency of the whole transport system that presents some critical issues as traffic congestion, limited public transport utilization, little diffusion of cycling and walking for systematic trips, inefficiency of the parking management, absence of city logistics measures.

In this paper the relation between transport accessibility and social exclusion will be investigated by means of an approach using Lorenz Curve and Gini coefficient that will evaluate the relative accessibility of census regions in Catania city; methodology will be applied to public transport network and will verify the effectiveness in social inclusion improvements of different transport scenarios.

4.2.2. Methodology

Measuring social exclusion

The equity policies in the field of transport must be supported by a large amount of socio-economic indicators, in order to meet the high level of disaggregation required by social exclusion data.

One of the methodological approaches in the literature is presented by Currie (2010), which makes use of GIS technology by combining the offer of public transport measures with social needs indexes and transport poverty.

The extent of the public transport for each zone is a function of frequency of service and access to stops distance estimated by GIS, while for deeper analysis of the demand for public transport, Currie proposes an aggregate indicator called Transport Need Index. The measure is composed of a summation of social disadvantage indices associated with different weighting, as showed in Table 1. Weights are estimated through a survey of users' travel behavior in the city of Adelaide (Australia), but may not be the same in the case of an Italian city, whose inhabitants have a different travel behavior. Anyway similar indicators can be used to test the correlation among social exclusion and accessibility to public transport.

TABLE 7 SOCIAL DISADVANTAGE INDICATORS SOURCE: (CURRIE, 2010)

Need indicator	Weight
Adults over 18 without cars (Census, 2010)	0.25
Persons aged over 65 (Census, 2010)	0.13
Persons with disabilities (Census, 2008)	0.13
Low income households (lower quintile) (Census, 2008)	0.13
Persons over 15 without a job (Census, 2010)	0.13
Students (Census, 2010)	0.13
Persons 10-18 (Census, 2010)	0.13

Other indicators of social exclusion, showed in Table 2, are suggested by the Italian Statistic Institute ISTAT (2015):

TABLE 8 DEPRIVATION INDEX PARAMETERS SOURCE: (ISTAT, 2015A)

Parameter
Young people abandoning education and training pathways
Regional poverty index
Population living in rural areas
People at risk of poverty or social exclusion
People in severe material deprivation condition
Overcrowding
Businesses and non-profit institutions that carry out activities with social content
Rate of juvenile crime

MEASURING ACCESSIBILITY

The concept of accessibility plays an increasingly important role in in transport planning as useful tool to measure the combined effect of locations' proximity and transport connectivity. At the same time, accessibility indicators can incorporate social issues when they measure the level of difficulty experimented by different categories of individuals to reach the economic opportunities or social interaction throughout the area.

However, drawing up a strict and unambiguous definition of accessibility is a complex task. One of the first scholars which considered its importance in the context of spatial planning was Hansen, who defined accessibility as "the potential of interaction opportunities" (Hansen, 1959).

A recent definition that highlights the mutual interaction between land use and transport systems has been provided by Geurs and van Wee (2004). According to the authors, the accessibility can be considered as the measure with respect to which the use of the territory and of transport systems allow groups of individuals to reach activities or locations by a combination of modes of transport.

From these and other definitions in the literature, four major accessibility components can be identified: land use, the transport system, the time factor and the individual dimension (Geurs and van Wee, 2004).

A classification of accessibility measures depending on land use can be done considering the place in question as the origin or destination of the travel. We can therefore distinguish the active accessibility (or origin accessibility), and the passive accessibility (or destination accessibility) (Cascetta, 2009):

- Active accessibility refers to the need to carry out the activities located throughout the area by a user that is in a particular place (generally the resident) and it measures the ease with which he can reach various destinations from an origin. It is useful in locating settlement decisions.

- Passive accessibility refers to the need for the various opportunities that are located in a certain area of the territory, to be achieved by the various users scattered throughout the study area. In other words, it measures the ease with which individuals, business and the services of a target area of the displacements can be reached by the users concerned. It is useful in the location decisions of public services and economic activities.

Most of the formulations in the literature refer to an urban accessibility of active type, whose indicator, in analytical terms, is generally a function of the number of spatial opportunities and the generalized transport cost. In particular, the accessibility indices based on gravitational models provide a measure of the continuous type which weighs the value of the opportunities with respect to a spatial impedance function. The impedance function reflects the effect of decreasing accessibility due to the increase of distance, travel time, or in general of the generalized cost of shipping.

The first application of the gravity model to accessibility measures is attributed to Hansen (1959), which suggested that accessibility across regions was directly proportional to the attractiveness factors (jobs, shops, sports centers, etc.) and inversely proportional to the travel time between the zones, which represents the cost of moving. The Hansen's index has the following form:

$$A_i = \sum_{j}^{n} O_j \cdot f(C_{ij})$$

Where O_j is the number of opportunities in the zone j and $f(C_{ij})$ the impedance function among zones i and j. A negative exponential impedance is often used, such as:

$$f(C_{ij}) = e^{-\beta \cdot f(C_{ij})}$$

With Cij generalized cost of travel among i and j zone and β is a parameter related to the cost, estimated by choosing a destination model. The generic measure of cumulative opportunities can be considered a special case where $f(C_{ij})$ is equal to 1 if C_{ij} is less than the predetermined threshold; it is equal to 0 otherwise.

This type of indicators offers the advantage of requiring a relatively small amount of data (ease of processing and calculation), allowing to differentiate the areas of study and to derive the accessibility indices for each of them. They are particularly useful for assessing the potential of suburban residential areas in allowing access to activities such as shops, schools, workplaces, health care and other services.

LORENZ CURVE AND GINI INDEX

If we assume the existence of a correlation between accessibility and social exclusion, accessibility indicators can be linked to an economic index, such as the Gini coefficient (which can be calculated as a result of the Lorenz curve tracing) in order to verify the social equity of its improvements.

The Lorenz curve is a simple and effective graphical representation of horizontal inequality, since it was created as an aggregate measure of the distribution of wealth within the population. It lends itself to many applications, from education to biodiversity, quantities that can be combined through the population.

The horizontal axis (Fig. 1) shows the cumulative percentage of the population under examination (from 0 to 100%), sorted according to the increasing value of the indicator, while the vertical axis shows the cumulative percentage same indicator. In the economic field, it is mainly used as a graphical tool for the analysis of inequality of income distribution.

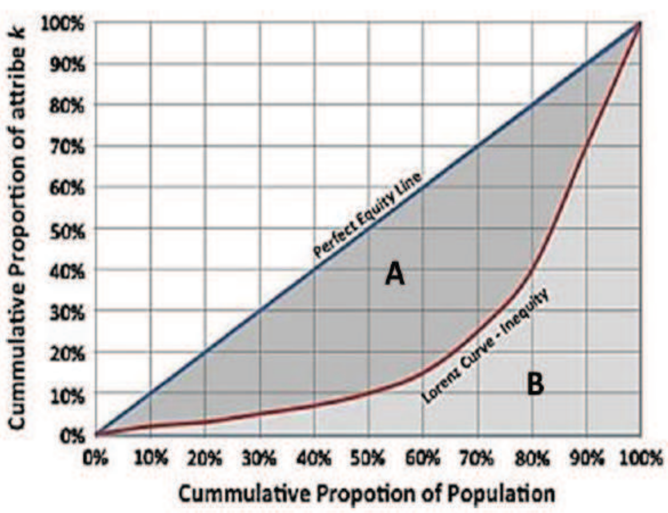

FIGURE 22 LORENZ CURVE FOR A GENERIC ATTRIBUTE K. SOURCE: (ROFÉ ET AL., 2015)

In the transport field, social equity considerations are complicated by the fact that not only income plays a role, but also factors such as age, occupation, physical condition and the level of accessibility to services.

In this regard, the use of the Lorenz curve represents an original approach to provide a measure of overall accessibility compared to the entire population (Delbosc and Currie, 2011).

Basing on Fig. 2, Lorenz curve (in red) describes the actual accessibility distribution: each point of the curve indicates the percentage of accessibility owned by a given percentage of population. The blue line at 45° represents the line of equal distribution, i.e. the one corresponding to a perfect distribution of the same attribute. The more the Lorenz curve deviates from the straight line of equal distribution, the higher is the inequality of the distribution of accessibility in the population.

The Gini coefficient, introduced in 1912 by the Italian statistician Corrado Gini, is a mathematical measure of the degree of inequality, related to the area between the Lorenz curve and the straight line of equal distribution (indicated with the letter A in Figure 2). The relationship between this area and the area below the line of perfect equality (A + B in Fig. 2) is the Gini coefficient, which can be mathematically calculated using the following approximate formula:

$$G = 1 - \sum_{k=1}^{n} (X_k - X_{k-1}) \cdot (Y_k + Y_{k-1})$$

where X_k is the generic interval of the cumulative percentage of the population variable and Y_k is the corresponding interval of accessibility cumulative percentage, for k = 1, ..., n and $Y_0 = 0$, $Y_n = 1$.

Gini coefficient can take any value between 0 and 1. A value of 0 implies a situation of complete equality, while a value of 1 corresponds to complete inequality. The lower the coefficient, the lower the inequality of the distribution concerned.

The method described above is useful to analyze the changes over time of the distribution of accessibility in a given region, making it possible to see if inequality is increasing or decreasing. In addition, the Gini coefficient can be compared between different urban realities, obviously using the same methodology for the calculation of accessibility.

However, like any index of its type, it has the limit to remain unchanged if the accessibility of all individuals increases in the same proportion. In fact, being calculated from the relationship between two quantities, it cannot take into account the difference between the absolute values.

4.2.3. Case study

Territorial framework and transport supply

Catania is a city of about 300.000 inhabitants, located in the eastern part of Sicily (Southern Italy); it has an area of about 183 km2 and a population density of 1.754,54 inhabitants / km2 (Istat, 2015b). It's part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania. The main city contains most of the working activities, mixed with residential areas. With reference to the urban area, the transport service is provided by 51 bus lines, a Shuttle line (ALIBUS) connecting the city center with the airport and a second fast bus (called BRT1) connecting a park-and-ride facility on the northern periphery (Due Obelischi) to the city centre (Stesicoro Square). BRT1 is the first of three lines provided by the City of Catania with equipped lanes protected by curbs on the majority of their path and was promoted commercially as Bus Rapid Transit. In Catania it is also operated an urban subway line that currently connects the station "Porto" with the station "Borgo" from which continues as a surface long-distance railway line. By 2016 it is expected the undergrounding of the line until the station “Nesima” and it’s also planned the opening of a branch linking the station “Galatea” to Piazza Stesicoro.

TRANSPORT MODEL AND SCENARIOS

A mathematical representation of the transport system has been built by the TransCAD modelling tool, a software which combines a Geographic Information System and a set of transport models in one integrated environment.

The zonation used for the city is the one given by ISTAT, which divides the study area in 2480 CENSUS sections. Three different scenarios have been analyzed. The first one, called Scenario 0 (Fig.2), includes 51 bus lines with a speed of 15 km/h; this will be considered as the current scenario and will be taken as base for the comparison with the other two transport solutions. The second one, called Scenario 1, provides for the introduction of three BRT lines and the subway line with the new extension from Borgo Station to Nesima station. The last one called Scenario 2, provides for an improvement of all bus lines speed from 15 km/h to 18 km/h.

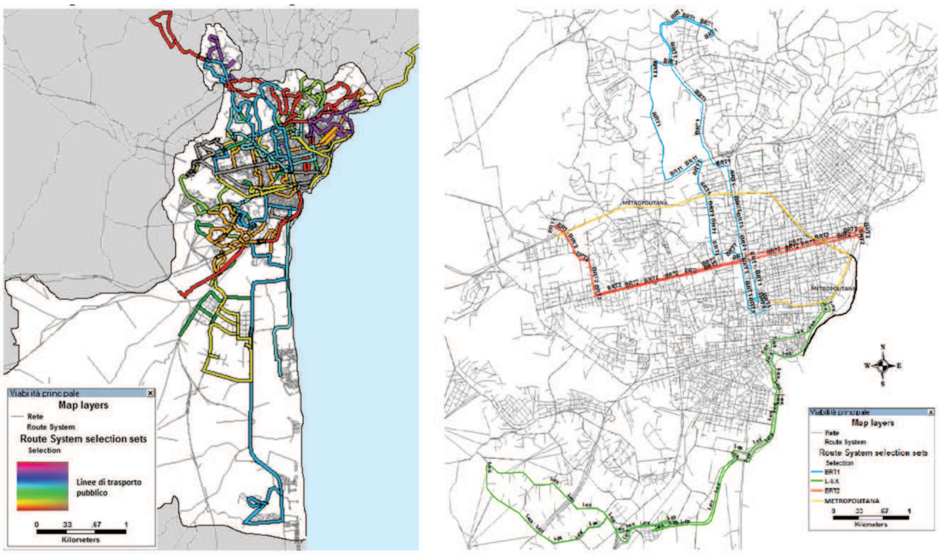

FIGURE 23 SCENARIO 0 ON THE LEFT AND IMPROVEMENTS IN THE TRANSPORT SYSTEM OF SCENARIO 1 ON THE RIGHT

ACCESSIBILITY MEASURES

Through the use of TransCAD software, Hansen accessibility measures have been evaluated for the three different scenarios.

The opportunities considered in the analysis include the accessibility of goods and services classified into: Health (hospitals, pharmacies); Education (University, schools, libraries); Places of worship (churches); Entertainment (theaters, cinemas, museums); Restaurants (Restaurants, bars, fast food); Transport services (metro, train station, bus stops). The Hansen Index has been evaluated considering as impedance a function based on the generalized cost of transport and taking into account parameters such as travel time, the cost of travel time, the number of transfers and considering a flat travel fare. The software provides standard values for deterrence index β, based on the selected transport mode and type of opportunities at destination. Values for our study are indicated in Table 3.

TABLE 9 DETERRENCE PARAMETER FOR HANSEN ACCESSIBILITY INDEX CALCULATION

Scenario	Mode	Destination	β Value
Scenario 0	Bus	Local Centers (No car)	0.082
Scenario 1 and 2		Local Centers (No car)	0.079

The active accessibility of the 2480 zones of the case study has been calculated for the 3 scenarios. Results show that the introduction of the improvements both in Scenario 1 and Scenario 2 provide an increase of accessibility; the amount of improvement for each zone can be deducted by the comparison of maps in Fig. 3, Fig. 4 and Fig. 5. The caption of the maps shows in brackets the number of zones that benefit from increased accessibility.

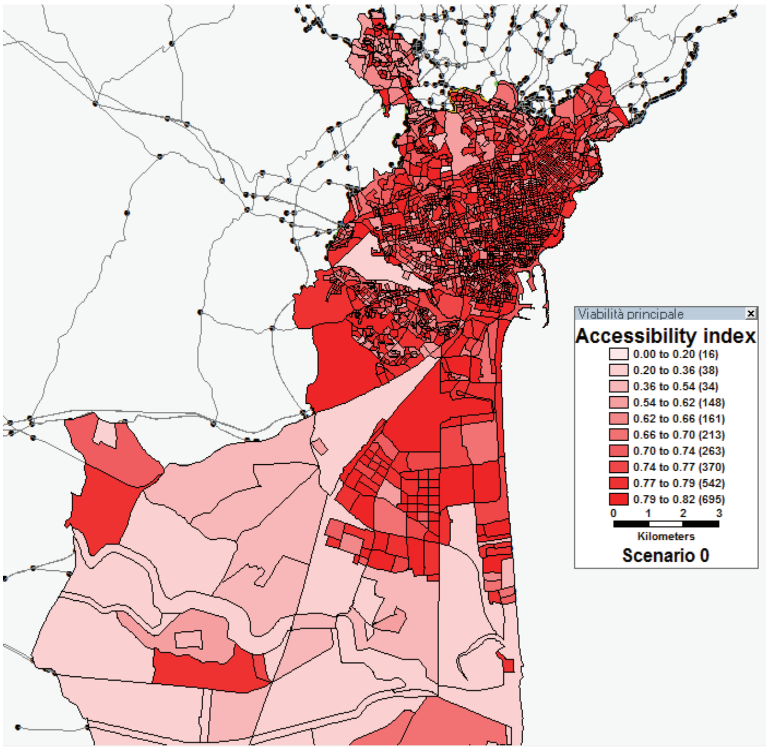

FIGURE 24 ACCESSIBILITY MAP FOR SCENARIO 0

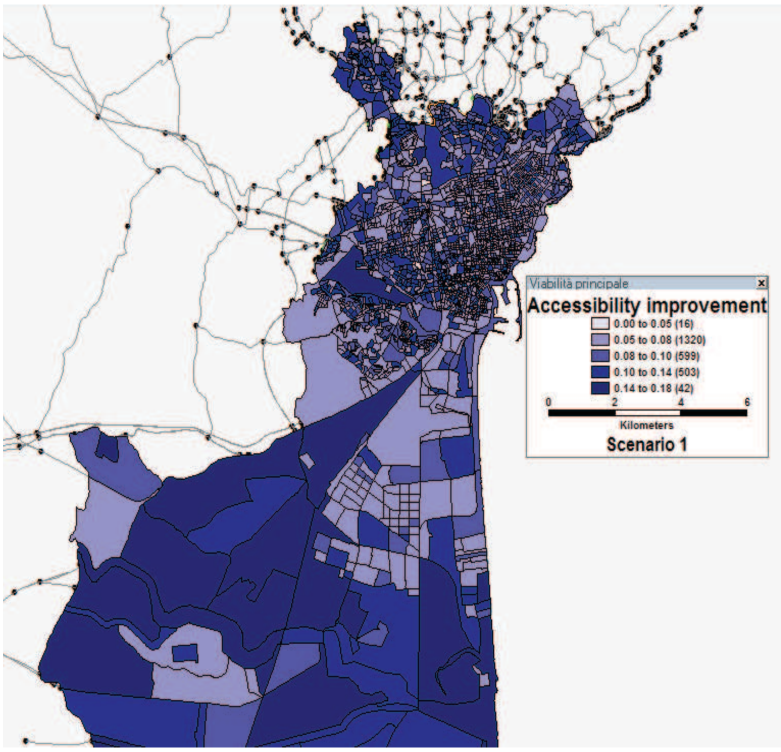

FIGURE 25 ACCESSIBILITY IMPROVEMENT MAP FOR SCENARIO 1

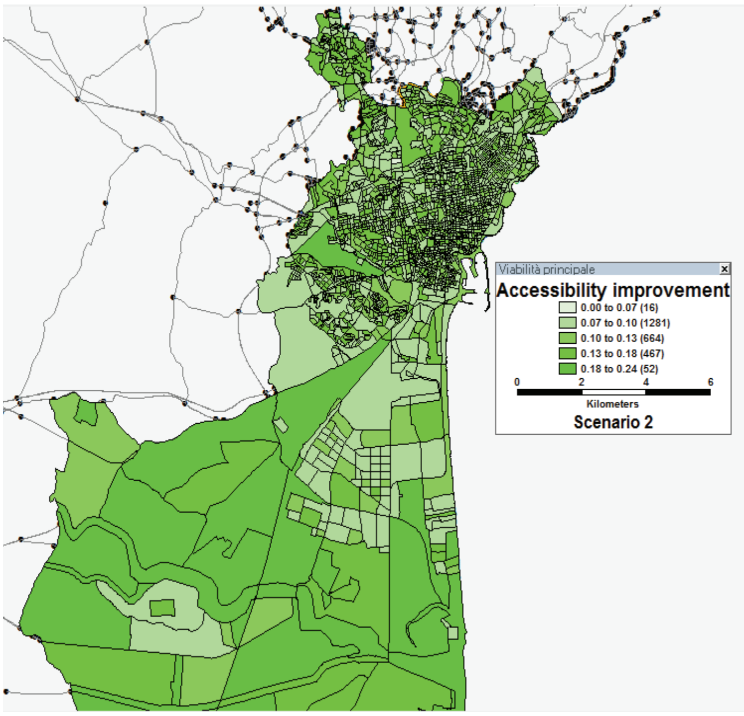

FIGURE 26 ACCESSIBILITY IMPROVEMENT MAP FOR SCENARIO 2

LORENZ CURVE AND GINI INDEX

Lorenz Curve and Gini Index based on Hansen Accessibility measures have been calculated under the 3 scenarios. A graphical representation of Lorenz curves is shown in Fig. 6.

The Lorenz curves for all scenarios are close the perfect equality line (bisector). This does not imply a high level of service public transport, but a low inequality due to a quite uniform service coverage of the whole urban area. Both scenario 1 and 2 produce a significant improvement of equality as it is visible from the increased proximity of each Scenario's curve to the perfect equity line. The distribution of accessibility is quite the same for scenarios 1 and 2, so the relevant curves overlay each other.

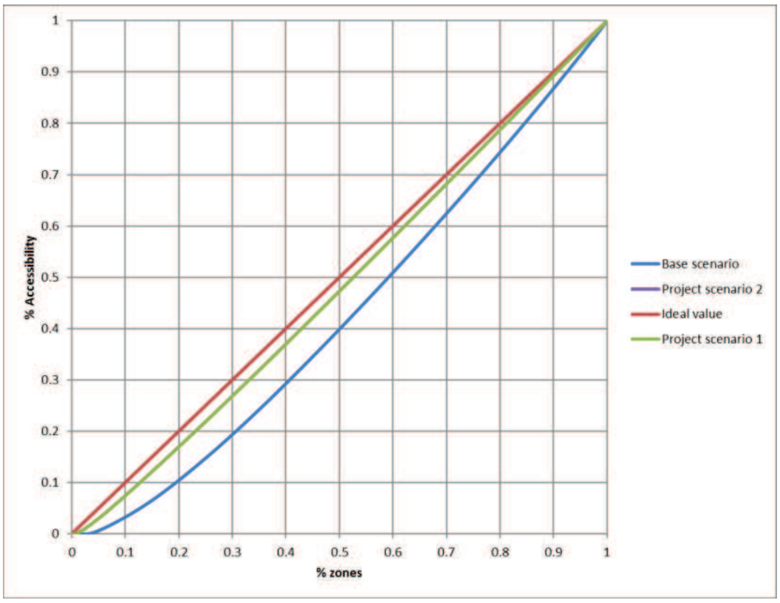

FIGURE 27 COMPARISON AMONG LORENZ CURVE FOR SCENARIO 0 AND 2

Evaluation of Gini indices, which results are showed in Table 4, confirms the previous results and moreover underlines how Scenario 2 shows slightly better improvements than Scenario 1.

TABLE 10 GINI INDEX FOR THE THREE DIFFERENT SCENARIOS

Scenarios	Gini Index
Scenario 0	0.148485562
Scenario 1	0.046431085
Scenario 2	0.041428445

4.2.4. CONCLUSION

The ability to move and reach places even at great distances, has become an indispensable condition to live well and to integrate into today's society. Mobility is no longer just an option but has become a necessity. However, there are still many citizens who have limited resources or fewer resources than others, and the aim of social inclusion policies is to improve the quality of life of such the weakest sections of the population, in order to reduce exclusion.

Social inclusion is linked to the level of accessibility perceived by the individual, assessed according to the ease of reach of different places, with different availability of transport system. Accessibility awareness by citizens is a key element to coordinate the intervention measures in the field of transport and public services, but also to foster social receptiveness of such measures.

In this paper three different transport accessibility scenarios have been evaluated for the city of Catania. The application of an approach based on Lorenz Curve and Gini Index has showed that the proposed changes in the public transport network design corresponds both to an accessibility improvement and to a major equity of accessibility distribution as well. The methodology described seems to suit well to take decision in transport planning when both accessibility improvement and equity magnitude is crucial to address land use and transport decisions.

4.2.5. Summary and and degree of implementation

In this study different scenarios of transit solutions have been evaluated through Hansen accessibility index; starting from these results, a social issues analysis has been performed through the evaluation of an index of inequality. The scenarios evaluation only considered accessibility as parameter; a MCDA could allow the evaluation of other criteria and include stakeholders' opinions and public participation. Levels of application of GIS, PP and MCDA are summarized in TABLE 11.

	Public participation	Use of GIS	MCDA	Integration
Level	No citizen involvement, but social issues are included	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	No use of MCDA	Poor or No integration

TABLE 11 Levels of application of GIS, PP and MCDA in Case study 2

4.3. CASE STUDY 3: The Queensway of New York City: a Proposal for Sustainable Mobility in Queens[4]

4.3.1. INTRODUCTION

The gradual increase in private mobility, dating back to the second half of the last century in western countries, has caused the shutdown of several secondary railway lines which are rarely used and therefore little profitable to any institution, either owner or manager (Guerrieri and Ticali, 2012). In addition to the decrease of rail passenger transport demand due to the improvement of the road system, the other two causes, that have contributed over the last 50 years to this phenomenon, can be sought in the construction of new high performance railway track parallel to the pre-existing one and in the decrease of rail freight transport demand due to the disposal of industrial areas.

Therefore, it is urgent to consider the issues related to inactive railway lines as there are hundreds of thousands of kilometres of inactive railways (Bertolini and Spit, 1998). One estimate is that it costs substantially less to redevelop an abandoned urban rail line into a linear park than to demolish it. Consequently, the disused railways are potential new pathways and the abandoned stations provide available spaces for new activities, supporting sustainable local development and regeneration processes.

According to this, disused railway sites are becoming a focus of redevelopment projects in many European countries and, recently, some former railway lines have been converted into cycling and pedestrian paths. In the USA, where road transport and private cars have a considerable

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[4] This section is based on paper *The Queensway of New York City: a Proposal for Sustainable Mobility in Queens* (Annex C)

role in transport system, areas of disused railways are often replaced by road layouts. Only recently it is possible to notice a few cases of conversion of railway tracks in non-motorized mobility spaces, especially in urbanized areas. This is due to the fact that issues such as ecology and sustainability have come to the forefront only in recent years, raising awareness and urging cities to promote environmental protection programs, including the convertion of disused railways within the concept of "soft mobility". Some of the norms and initiatives aimed at maintenance or recovery of the disused railway in the USA are the voluntary agreement Rail Banking (1983), the no profit organisation Rail to Rail Conservancy (1986), the transport legislation Intermodal Surface Transportation Efficiency Act (1991) and the policy statement of Federal Highway Administration "Design Guidance on Accommodating Bicycle and Pedestrian Travel" (2000). Currently, a movement is being developed thanks to a "bottom-up" push, which sees the population aggregated in spontaneous organizations that stimulate, provide ideas, collaborate in the creation and management of greenways.

Although the actuality of greenways' concept is nowadays increasing more and more, thinking the greenway as part of a network infrastructure should be one of the main concept to be taken into account in its planning and designing. The planning process should try to provide sustainable landscapes against disintegrating, space decreasing, urban development and uncontrollable change of area use (Ahern, 1995).

In this view the topic of this paper is a project of conversion of Rockaway Beach Branch Line (RBBL) in Queens into a greenway. This study proposes a methodology characterized by a GIS approach to evaluate the need of different kind of interventions for the realization of the greenway and the requalification of its surroundings.

4.3.2. THE BIRTH OF GREENWAYS AND RELEVANT BEST PRACTICES

The greenway literature of the past decade consistently names Frederick Law Olmsted as the father of the greenway movement in America (Little, 1990). He developed the idea of parkway system which leads to taking shape of current greenways (Kent and Elliott, 1995).

The influence of the environmental decades on landscape architecture was most prevalent in the academic environments during the 1960s and the 1970s. Lewis' environmental corridor concept was used to plan first a major state wide greenway system with a focus on protecting environmentally sensitive areas, or river corridors (Lewis, 1964).

After 1985, greenways were integrated with space and resource management concepts (Mugavin, 2004). They started to have more comprehensive duties: beyond meet people needs and satisfy aesthetical and recreational requirements of city dwellers, they took on a lot of goals such as preserving habitat, reducing flood harms, increasing water quality, protecting historical sites and education.

Nowadays greenways brought together 2 functions: to form open spaces for public and for recreational uses and to ensure the protection and development of natural resources: many countries around the World have tackled these issues in creative and successful ways(TABLE 12).

Country	Project	Length (km)
France (Paris)	Promenade Plantée	4,9
Belgium	RAVeL Réseau Autonome de Voies Lentes	900
Australia	East Gippsland Rail Trail	96
Australia (Sydney)	Goods Line	0.5
United Kingdom	Bristol and Bath Railway Path	24
USA (Missouri)	Katy Trail	390
USA (Chicago)	Bloomingdale trail	4.3
USA (New York)	High Line	2.33

TABLE 12 BEST PRACTICES FOR THE REQUALIFICATION OF ABANDONED RAILWAY LINES WORLDWIDE

In recent years an outstanding example of greenway promoted by a bottom-up process is the High Line, a linear park built in Manhattan on an elevated section of a disused New York Central Railroad. In 1999, the nonprofit organization Friends of the High Line was formed by 2 residents of the neighborhood that the line ran through, advocating for the line's preservation and reuse as public open space. The High Line is inherently a green structure: it winds between buildings and constitutes a green elevated walk-path with spaces to stay and to relax in a no-green fully urbanized area. Furthermore, there is a good relationship with some requalified adjacent buildings having a new modified destination of use (Figure 28a and b).

As great number of studies recommends new approaches to urban and transport planning as solutions to climate change mitigation (Caprì et al., 2016), the High Line landscape functions essentially like a green roof designed to allow the plants to retain as much water as possible. This can be considered a soft approach seeking to raise awareness on how green infrastructures can play a vital role in create climate-resilient development - a role which is currently not sufficient recognised nor integrated into mainstream planning (Inturri, 2011).

FIGURE 28 PARK'S ATTRACTIONS AND VIEWS OF THE CITY FROM THE HIGH LINE

4.3.3. CONTEXT FRAMEWORK: THE QUEENSWAY

The QueensWay is a project of conversion of a former rail line, LIRR Rockaway Beach Branch (RBB), a 3.5 miles stretch which lies abandoned since 1962. During this time, vegetation have sprouted along the former right of wayand illegal dumping has become an increasing problem, with trash and remnants of drug and alcohol use litter the ground (Figure 29). In 2011, a group of residents living along the former RBB, teamed up to advocate for its conversion into a new linear park, joining in a movement called The Friends of the QueensWay (FQW) with the goal of converting the long-abandoned property into a public park. FQW entered into a partnership with The Trust for Public Land, the nation's leading nonprofit organization working to create parks and protect land for people. abban

Thanks to the fundings obtained by the State of New York, in 2013 The Trust for Public Land has commissioned the QueensWay Plan to WXY and dlandstudio, in order to lead an interdisciplinary team to analyze the economic, social, environmental, engineering and transportation dynamics of the site and surrounding area. ata

FIGURE 29 VEGETATION SPROUTING IN THE ABANDONED RBB LINE

The planning approach was based on community involvement, with five large public meetings, 30 workshops and meetings with community groups, and hundreds of stakeholder discussions. The ideas arising from these sessions, as well as the analysis of the site, helped establish the six themes explaining the vision for the QueensWay:

- Connections + Neighborhoods: The QueensWay is seen as a connector to parks, commercial avenues and facilities; it's also a gateway to neighboring communities;
- Ecology +Education: there are 12 schools within a 5-minute walk of the QueensWay; morevoer visitors can encounter a variety of environments and learn aboutplants, geology, stormwater management, and natural habitats for urban wildlife;
- Safety + Comfort: The QueensWay will provide for the needs of all ages and abilities; it will be carefully designed to avoid conflicts between walkers and cyclists. Particular attention will be given to the preservation of privacy for neighbors;

- Play + Health: sport and recreational programs will be developed in partnership with local associations;
- Culture + Economic Development: visitors to the QueensWay will bring new business to commercial activities located in the surrounding neighborhoods; provision of platforms for performances and public art and the opportunity for adaptive reuse of underutilized buildings will give life to a new cultural offer;
- Care + Stewardship: The community will be engaged through a continued public input process to ensure the park and design meet local needs.

The QueensWay plan divides the park into 6 areas (Figure 30): 4 integrate activities; 2, called *the passages*, are closer to homes and will be paths for walkers and cyclists.

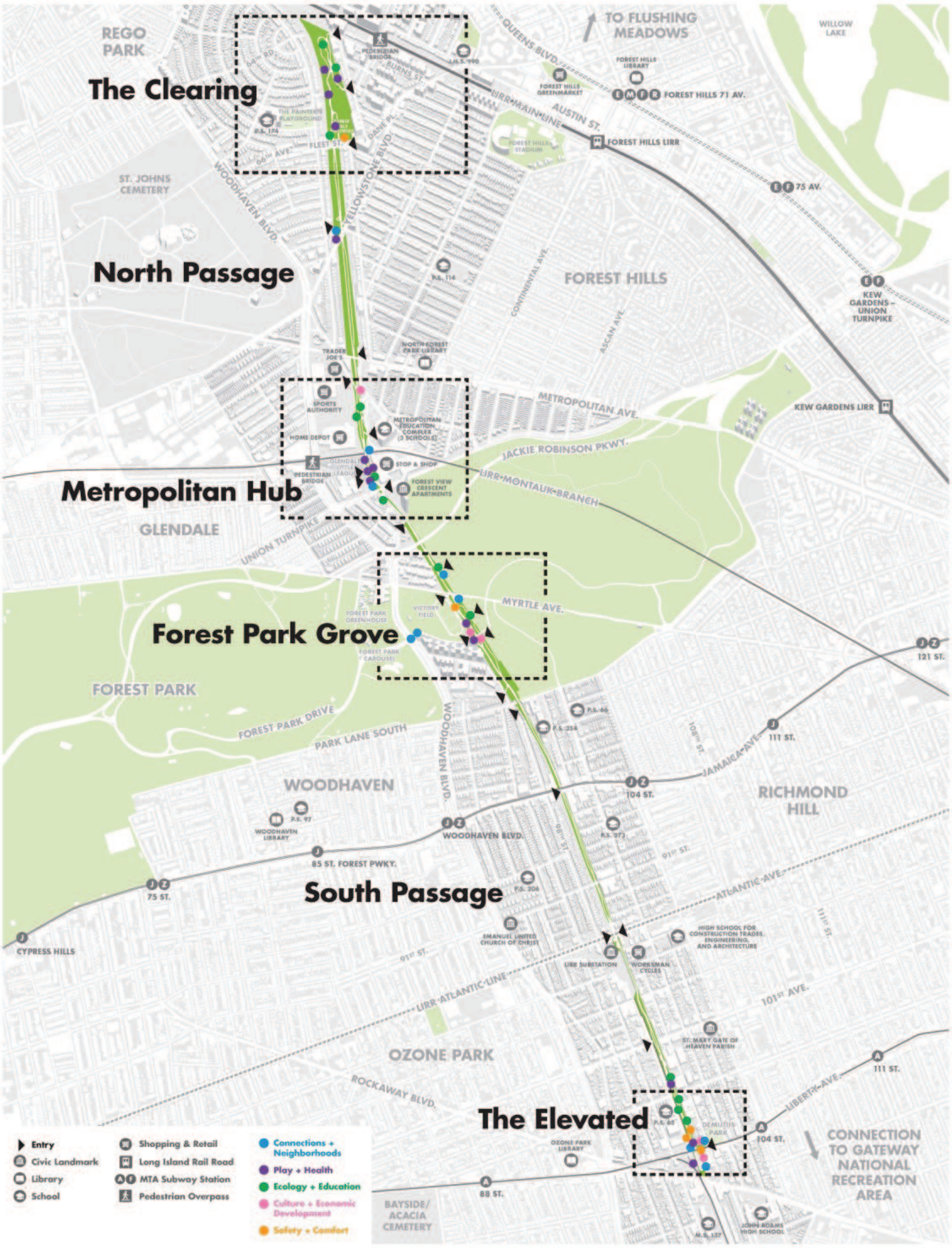

FIGURE 30 THE QUEENSWAY PLAN MAP (SOURCE: THEQUEENSWAY.ORG)

A particular attention is put by WXY and *dlandstudio* proposal in a design which try to maximize safety and privacy for neighbors (whose houses are close to the track, Figure 31) while still giving a good permeability and visibility for park users. A proposed solution for pathways that run by private homes is a design with vegetated buffers at the top of the embankment; secure fencing with planting to provide additional screening are put at the property line to physically and visually separate backyards and homes from park users. Moreover, in order to decrease any visual connection between the QueensWay users and adjacent homes, the pathway can be lowered by excavating the embankment. Finally, all the main activity spaces will be located close

to non-residential amenities, while the two lenghts that run by homes (North Passage and South Passage), will be used as a walking and cycle path.

FIGURE 31 CLOSENESS OF TRACK TO PRIVATE HOUSES

4.3.4. METHODOLOGICAL APPROACH

The QueensWay project realized by FQW is a bottom up process involving stakeholder. This paper proposes a GIS approach, based on suitability analysis, useful to evaluate the necessity of the different kind of intervention according to the 6 focus areas defined during the decision process. Suitability analysis describes the search for locations or areas that are characterized by a combination of certain properties.

GIS allows to obtain suitability scores that can be used to determine hot spots regarding each focus area through the intersection of multiple levels of information. In our case, the approach consists of the superposition of 5 different score layers (one for each focus area) constructed through critera which are depending from spatial characteristics evaluated through the use of a GIS software (Figure 32):

$$S_{fa} = c_1 + c_2 + ... + c_i + ... + c_n$$

Where S_{fa} is the score for the specific focus area and *i* are the *n* related criteria cocurring to the its construction. The selected crieria for each focus are showed in

FOCUS AREA	CRITERIA
Connections + Neighboroods	Number of road crossings Subway stations within 1 km Bus stop within 1 km Number of parks Gateways to adiacent avenues Number of parkings within 1 km Population age
Ecology + Education	Number of schools within 1 km Number of libraries within 1 km
Safety + Comfort	Buffer from neighboring residents' houses Viewshed analysis Number of accessible ramps needed Lighting
Play + Health	Number of sport facilities Emissions from road traffic
Culture + Economic Development	Number of workers Turistic points within 1 km Commercial buildings Number of abandoned facilities within 1 km State of the buildings

A buffer of 1 km from the rail line is taken into account as threshold for the analysis of the surrounding land use. The method assumes that each criterion's values are normalized between 0 and 1 according to the following equation:

$$SN_{fa} = \frac{S_{fa-j} - S_{fa-\min}}{S_{fa-\max} - S_{fa-\min}}$$

Where, for each focus area, SN_{fa} is the normalized score, S_{fa-j} is the generic score and S_{fa-min} and S_{fa-max} are respectively its minimun and maximun value. Since the score is a need score a value close to 1 corresponds to an area with more need.

After the evaluation of each score into a layer, the six layers would be combined/overlaid using raster calculation function to get a composite map showing priority hot spots and areas where intervention is not necessary: the final result of our suitability analysis will be a thematic map showing which locations or areas are more in need for a specific focus area.

FOCUS AREA	CRITERIA
Connections + Neighboroods	Number of road crossings Subway stations within 1 km Bus stop within 1 km Number of parks Gateways to adiacent avenues Number of parkings within 1 km Population age
Ecology + Education	Number of schools within 1 km Number of libraries within 1 km
Safety + Comfort	Buffer from neighboring residents' houses Viewshed analysis Number of accessible ramps needed Lighting
Play + Health	Number of sport facilities Emissions from road traffic
Culture + Economic Development	Number of workers Turistic points within 1 km Commercial buildings Number of abandoned facilities within 1 km State of the buildings

FIGURE 32 CRITERIA FOR EACH FOCUS AREA

4.3.5. FIRST RESULTS

This viewshed analysis (Figure 33) shows which areas are visible from a specific location. Viewshed analysis was performed putting some points on the railroad as observation points. The raster is a DSM (DEM + building eights). The result shows that the future project would guarantee the privacy of people who live nearby the QueensWay infrastructure (especially in the Southern part) and, in the same moment, the QueensWay would offer great views of the Forest Park (Figure 33). Figure 34 shows that QueensWay would be a great link between the built area of Southern Queens and the Forest Park which is not easily accessible nowadays. In addiction a lot of students could use the QueensWay as daily path to reach their schools or other public facilities. In this way there will be also a decrease of traffic congestion, because a lot of commercial buildings are located nearby the former railroad. Last but not least QueensWay could connect two areas of Queens with different Medium Age. The park would be easily reached by Metro thanks to 5 stops (1 in the Northern part, 2 in the middle, 2 in the Southern part) located within a distance of 300 m from the former railroad (Figure 35). QueensWay would be the only N-S link between the metro stops which are on 3 different lines.

A proposal of intervention is shown in Figure 36, which highlights the importance of accessibility to Forest Park. Connection to parks and commercial areas is one of the main project aims; the reconversion would expect 1 million annual visitors to the QueensWay, based on similar projects and on the annual number of visits to Forest Park (approx. 900,000), assuming that 250,000 of the visitors will be from outside of Queens bringing new business to local shops and restaurants.

FIGURE 33 VIEWSHED ANALYSIS

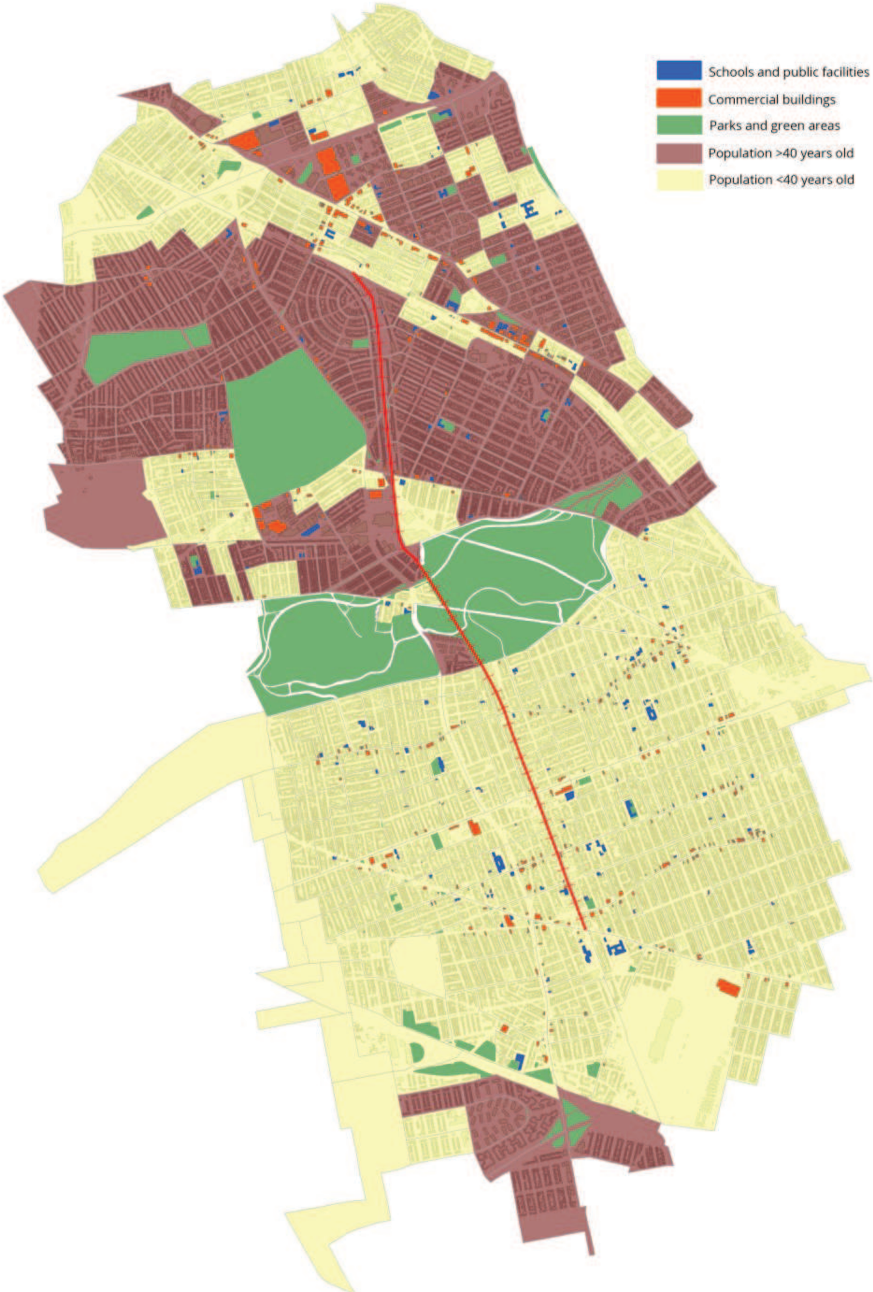

FIGURE 34 ACTIVITIES ANALYSIS

FIGURE 35 INFRASTRUCTURE ANALYSIS

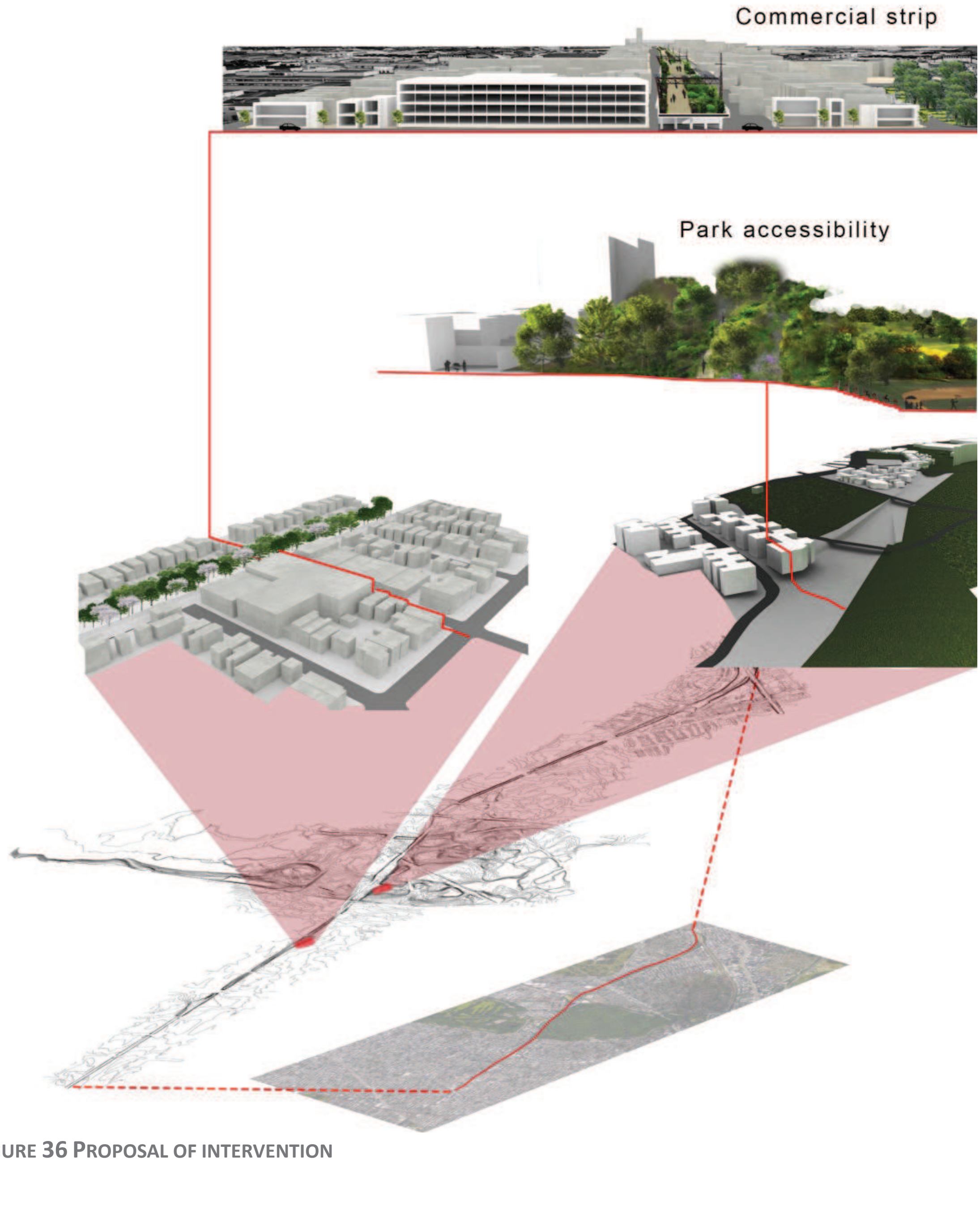

FIGURE 36 PROPOSAL OF INTERVENTION

4.3.6. Conclusions

In USA, where road transport and private cars have a considerable role in transport system, the disused railway areas are often remained unused, or replaced by road layouts. Only recently, due to the fact that issues such as ecology and sustainability have come to the forefront, it is possible to notice a few cases of conversion of railway tracks in non-motorized mobility spaces, especially in urbanized areas.

In this theme, the topic of this paper is a method to improve a project idea of conversion of an abandoned rail line in Queens into a green cycling – pedestrian path and make it operational. This study proposes a GIS approach, based on suitability analysis, to evaluate the necessity of different kind of intervention according to different focus areas. Since community involvement is one of the basis of the proposal project of FQW, in future researches the GIS approach could be integrated with a Multi Criteria Decision Analysis process which would give the possibility to the community to assign different weights to focus areas' criteria and allow the decision maker to obtain priorities of interventions.

4.3.7. Summary and degree of implementation

The aim of this study was to provide a method to improve a project idea of conversion of an abandoned rail line in Queens into a green cycling – pedestrian path through a GIS approach. GIS has been used to provide Public information to citizens about this requalification which is, however, a bottom up initiative. A Public Participatory GIS would allow citizen to add proposals and take part to the design of interventions. Levels of application of GIS, PP and MCDA are summarized in TABLE 13.

	Public participation	Use of GIS	MCDA	Integration
Level	Information giving	Important role in the analysis of scenarios; weights are decided out of the GIS	No use of MCDA	Medium

TABLE 13 LEVELS OF APPLICATION OF GIS, PP AND MCDA IN CASE STUDY 3

4.4. CASE STUDY 4: GIS-based criteria for the design of a cycling network

4.4.1. INTRODUCTION

Cycle mobility is a widespread mode of travel around Europe, in particular in countries with a high level of well-being, such as the Netherlands and Denmark. Italy takes realistic distances from these standards: the cities of the peninsula do not support the comparison with European models; in particular, the city of Catania is ranked 63st in the ranking of Italian cities that evaluate the equivalent meters of cycle paths every 100 inhabitants (Figure 37).

CITTÀ	M/A	CITTÀ	M/A	CITTÀ	M/A
REGGIO EMILIA	41,06	BOLOGNA	10,76	CATANZARO	2,23
MANTOVA	26,66	BENEVENTO	10,29	LECCO	2,08
LODI	26,61	PAVIA	10,10	SAVONA	2,07
CREMONA	26,31	BERGAMO	9,78	TRIESTE	1,66
VERBANIA	24,02	ROVIGO	9,34	TERAMO	1,66
SONDRIO	20,16	ASTI	9,05	BARI	1,48
FERRARA	19,97	PRATO	7,54	CATANIA	1,36
ORISTANO	18,78	FIRENZE	7,43	MACERATA	1,28
PADOVA	18,76	BELLUNO	7,20	RAGUSA	1,28
PESARO	18,38	MASSA	5,99	PALERMO	1,24
RAVENNA	17,67	AOSTA	5,85	TRAPANI	1,16
MODENA	17,03	LUCCA	5,80	AGRIGENTO	1,01
BOLZANO	16,80	TRENTO	5,55	ANCONA	0,76
ALESSANDRIA	16,40	GROSSETO	5,13	MESSINA	0,74
PIACENZA	15,82	GORIZIA	5,11	SIRACUSA	0,62
VERCELLI	15,45	TORINO	4,88	SASSARI	0,45
FORLÌ	14,93	PESCARA	4,85	NUORO	0,37
RIMINI	14,61	NOVARA	4,82	NAPOLI	0,33
PORDENONE	14,43	BIELLA	4,73	AVELLINO	0,29
TREVISO	13,77	TERNI	4,05	SALERNO	0,24
BRESCIA	13,14	MILANO	3,66	REGGIO CALABRIA	0,06
VENEZIA	12,82	SIENA	3,18	L'AQUILA	0,00
VICENZA	12,79	PERUGIA	3,16	CALTANISSETTA	0,00
VERONA	12,05	MONZA	2,83	POTENZA	0,00
PARMA	11,72	LA SPEZIA	2,61	CHIETI	0,00
PISA	11,67	VARESE	2,36	VIBO VALENTIA	0,00
RIETI	11,44	CAGLIARI	2,35	CASERTA	0,00
UDINE	11,12	LATINA	2,25	ENNA	0,00

FIGURE 37 REPORT ON BIKE ECONOMY IN ITALY AND CYCLING IN CITIES (HTTPS://WWW.LEGAMBIENTE.IT/SITES/DEFAULT/FILES/DOCS/RAPPORTO_LA_BI_CI.PDF)

Even if literature on cycling in the transportation and its planning is spreading, there is still poor research on decision processes and dynamics to prioritize and choose locations for investing in cycling infrastructure (Larsen et al., 2013).

The purpose of this study is to provide design criteria for a cycling network, based on the use of GIS, relatively to the city of Catania. The main objectives are the introduction of a methodology that allows to design a bicycle network through the support of a GIS software; the characterization, through this methodology, of a road network based on a set of evaluation criteria that will determine the degree of cycling compatibility of each road segment; the assessment of the adequacy of the road paths for the realization of a cycle track. The GIS-based vector-model includes readily-available data sources in an easily interpretable graphical format suitable for decisionmakers and the public and it aims at supporting bicycle facility prioritization and location.

4.4.2. Current cycle path in Catania

Catania is a city of about 300.000 inhabitants, located in the eastern part of Sicily (Southern Italy); it has an area of about 183 km2 and a population density of 1.754,54 inhabitants / km2 (Istat, 2015b). It’s part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania. The main city contains most of the working activities, mixed with residential areas. Currently there are 7 cycling routes in Catania; two of them stretch across the Ionian coast, the others are located in the center of the city. These paths are extremely disjointed, and most of them are promiscuous with vehicular paths (Figure 38):

FIGURE 38 – CURRENT CYCLE PATHS IN CATANIA

4.4.3. METHODOLOGY

In the design of a bicycle network it is good to know what are the requirements that allow to define a suitable and safe bicycle ride. In the main cycling network, in order to promote the physical continuity of the cycling route and the right of way for cyclists at road intersections, the design of the track must ensure compliance with the following conditions:

- Continuity of cycle paths;
- Absence of promiscuous paths
- Realization of crossings paths at intersections.

In secondary network where, for several reasons, physical continuity and priority for cyclists cannot be guaranteed, the design must meet the following conditions:

- To inform the cyclists of promiscuous routes with appropriate signs and markings;
- To provide connection elements at cycle paths' breaks

According to art. 4. of the Italian Decree of 30 November 1999, no. 557 (DM 557/1999), which contains the rules on the definition of the technical characteristics of the bicycle lanes, cycling routes located within the inhabited area or connected with neighboring dwellings can include the following typologies (Figure 39):

a) Bicycle paths on private lane: uni or bi-directional, if the track is physically separated from cars and pedestrians' lane by means of longitudinal invalicable spartitraffics;

b) Cycle routes on segregated lane, normally located to the right with respect to the latter lane, with a separation element essentially made of a longitudinal strip or delimiter;

c) Promiscuous pedestrian and cycle routes on the sidewalk, with a single or dual direction of travel, if the width permits it to be carried out without prejudice to pedestrian traffic and it is located on the side adjacent to the roadway;

d) Promiscuous cycling and vehicular routes;

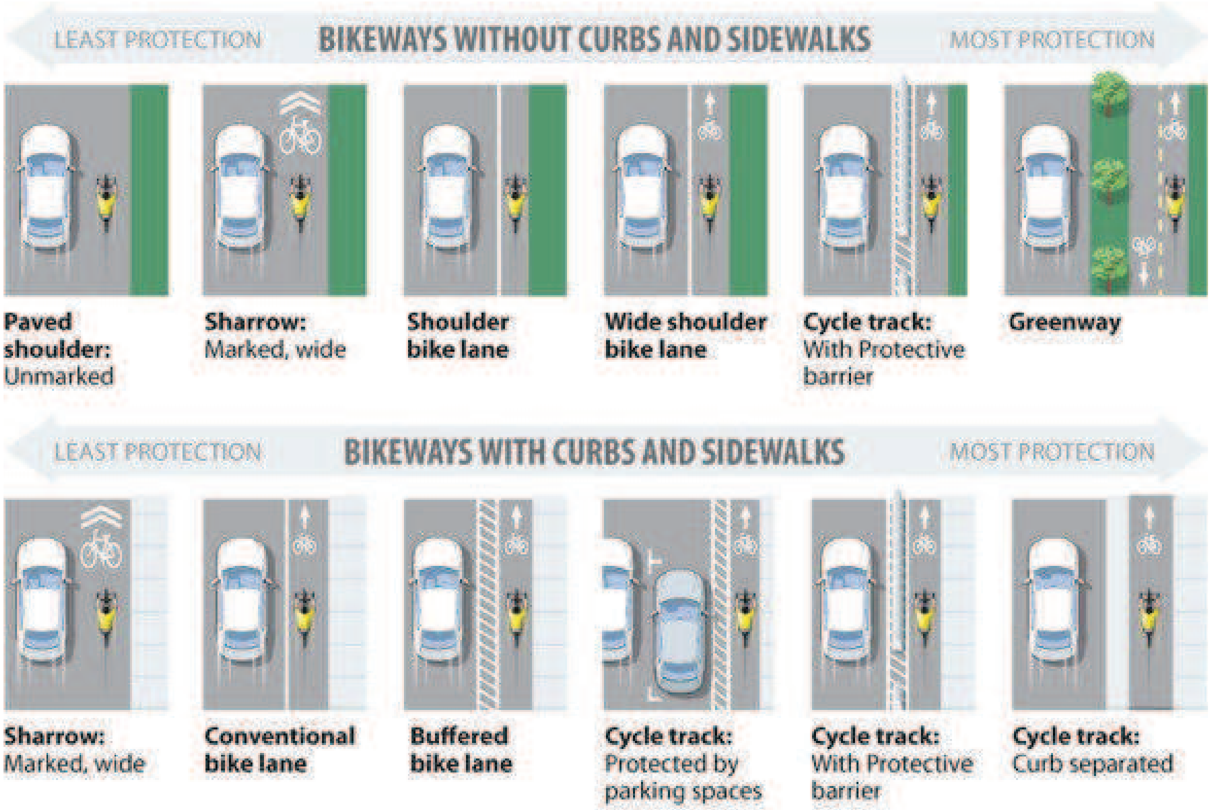

FIGURE 39 TYPE OF BYCICLE FACILITIES (SOURCE: JEFFERSON PARISH BYCICLE MASTER PLAN)

Article. 7 of the law contains information about the width of the lanes and the median:

- A minimum width of the bicycle lane and a suitable side barrier free from obstacles: the minimum width of the bicycle lane, including margin strips, shall be 1,50 m; such a width shall be reduced to 1.25 m in the case of two contiguous lanes, of the same or opposite direction of travel, for a minimum total of 2.50 m;
- For bicycle lanes on private and segregated lanes, the width of the bicycle lane can exceptionally be reclaimed up to 1.00 m.

Finally, Art. 8 shows which are the project speeds and the plane-altimetric characteristics. The project speed must be defined for each trunk of the cycle tracks, given that cyclists generally ride at a speed of 20-25 km/h, and that downhill with a slope of 5% can reach speeds even higher than 40 km/h. In the case of the realization of private cycle paths, the longitudinal slope of the individual levels may not exceed 5%. For singular short points and for staggered cross-sectional ramps, a maximum slope up to 10% can be used. The average longitudinal slope of the track section must not exceed 2% with the exception of for particular allowances justified by the designer. In the insertion of new bicycle paths on existing road infrastructures the longitudinal slope of the level of the road infrastructure should be less than 7%.

4.4.4. Case study application

In order to accomplish with the design standards, some useful criteria for assessing the suitability of routes for a cycle track have been ervaluated for Catania road network, with the aim of revealing which streets are more suitable for the construction of a cycle track. The roads will be analyzed with the aid of QGIS software, which is an Open-Source GIS for managing, visualizing, modifying, and analyzing geographic data. The data provided represent streets network, points of interest and geo-referenced census areas in the WGS 84 reference system (Figure 40):

- The census areas are those published by the Italian Statistic Institute ISTAT;

- The used network refers to the General Urban Traffic Plan (PGTU) data of the Municipality of Catania;

- Points of interest were exported through the *Openstreetmap* service;

In the following sections thematic maps of the evaluated criteria are presented. Some of the criteria used have been derived from similar studies in the cities of Athens and Seattle (Malakis D., Athanasopoulos K, 2012; Malakis D., Athanasopoulos K, 2014; Rhodes J, 2014), others have been elaborated starting from considerations about what a cyclist might require from the path.

Numerical results for each index have been normalized between 0 and 1.

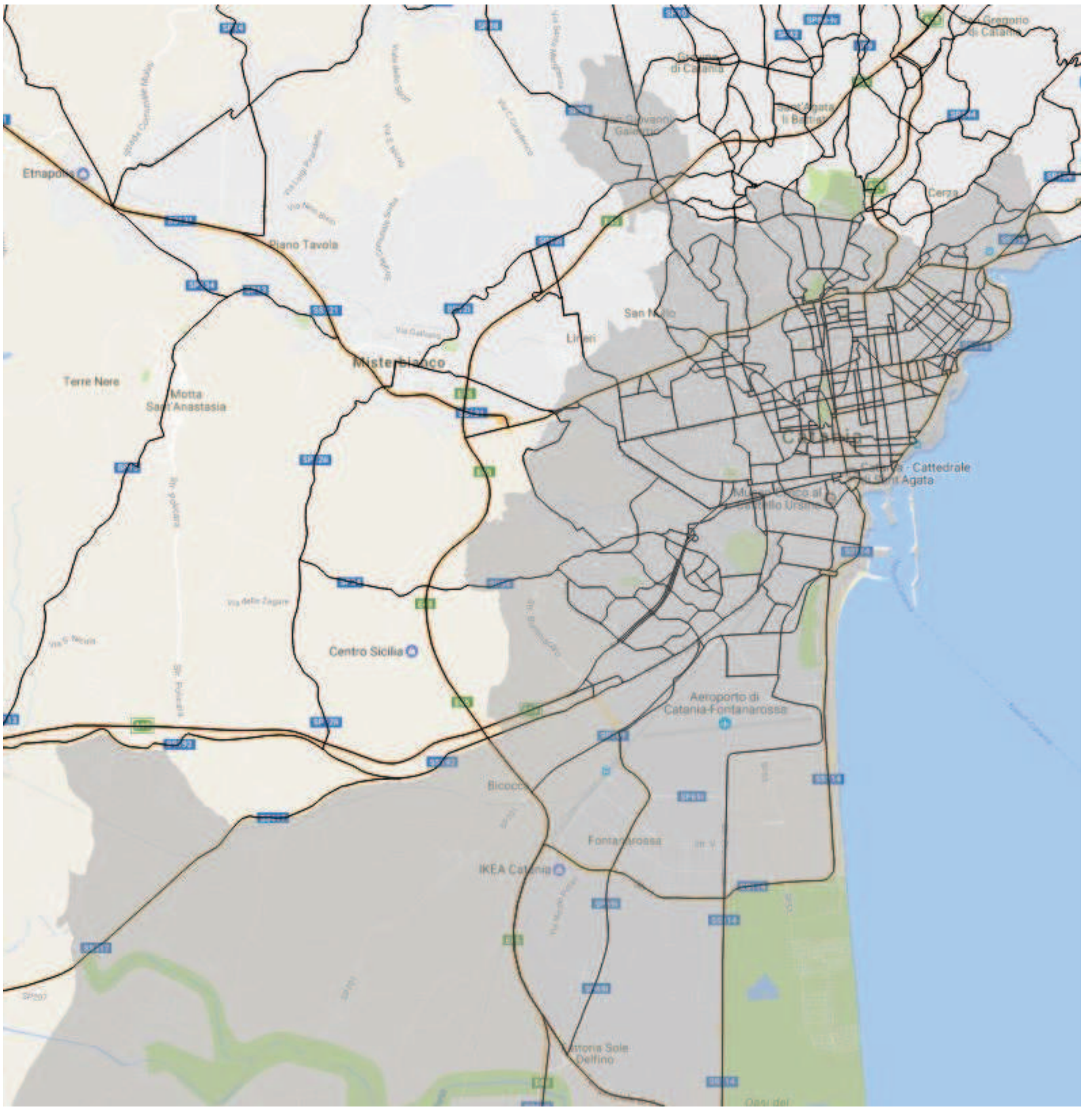

FIGURE 40 STUDY AREA AND NETWORK MODEL USED FOR ANALYSIS

TRAFFIC VOLUME (V)

Traffic volume index is equal to the number of vehicles per hour (Figure 41).

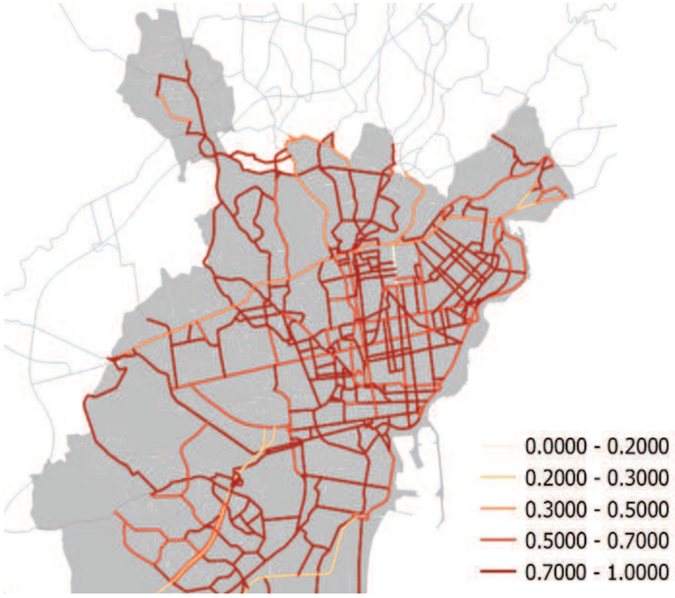

FIGURE 41 TRAFFIC VOLUME

TRAFFIC SPEED (S)

This index is measured as average vehicle speed (Figure 42).

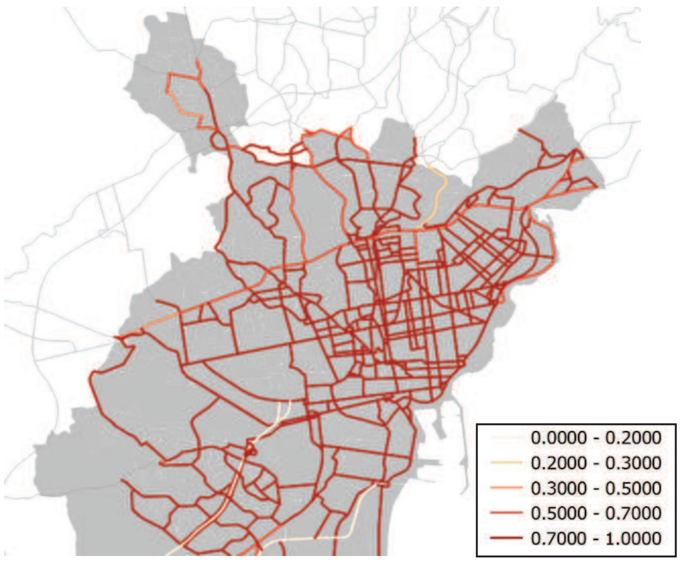

FIGURE 42 TRAFFIC SPEED

State of the buildings (SoB)

This index evaluates the quality of the urban architectural environment of the route. ISTAT informs about the number of buildings in good, well, mediocre and bad conditions in each census area. it is therefore possible, given the areas crossed by cycling routes, to make a weighted average of the values:

$$SoB = \frac{4NO_i + 3NB_i + 2NM_i + NP_i}{NE_i}$$

Noi= Number of buildings in perfect conditions

NBi= Number of buildings in good conditions

NMi= Number of buildings in mediocre conditions

NPi= Number of buildings in bad conditions

Nei= Total Number of buildings

The information given by ISTAT, related to census tracts, is showed in Figure 43, where green corresponds to the best condition, the red to the worst.

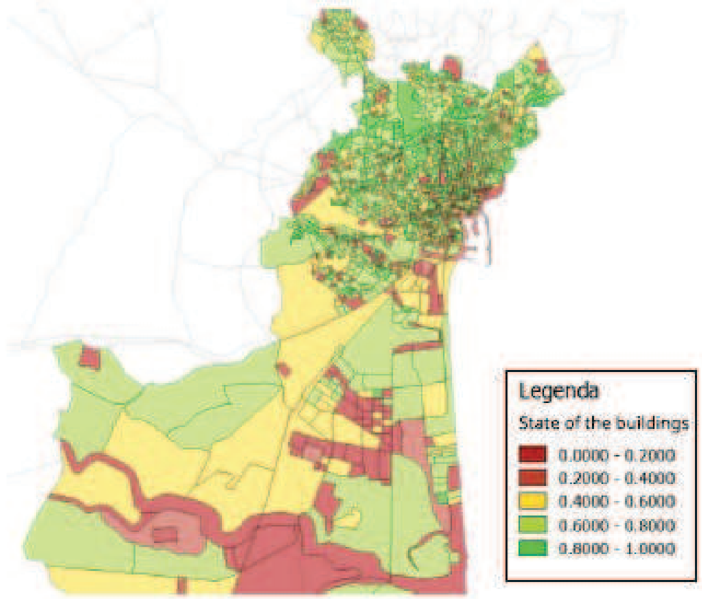

Figure 43 State of the buildings for census tract

Then, the Intersect tools, which allows to exclude the area that is not overlapping, was used to transfer the data to the arches (Figure 44).

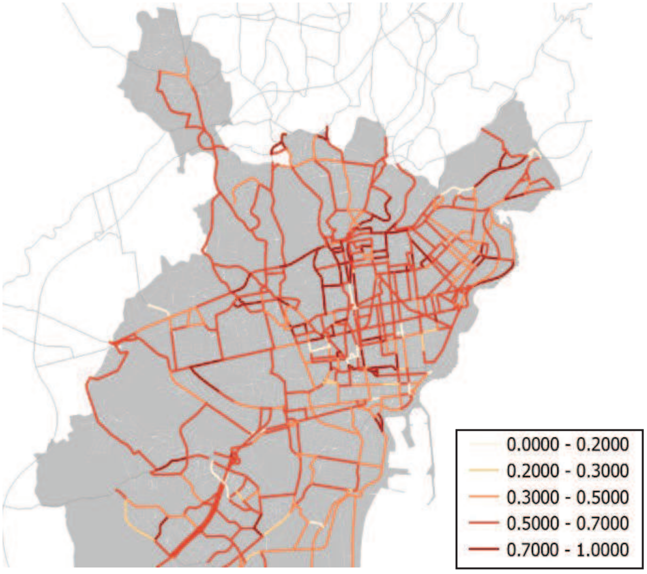

FIGURE 44 MAP INTERSECTION WITH ROAD NETWORK

POINTS OF INTEREST (POI)

This criterion describes the number of points of interest that fall within a radius of 200 meters from the road. The points of interest considered belong to various categories: entertainment venues (bars, restaurants, cinemas, theaters), education (university and schools), places and public offices (car parks, post offices, police, places of worship, social centers). To evaluate the index for points of interest, we collected all the points for the municipality of Catania (Figure 45), then we created a buffer of the street arcs of 200 meters, and counted points within each area through a QGIS analysis tool. Then intersect tool was used to transfer the information to the arcs (Figure 46).

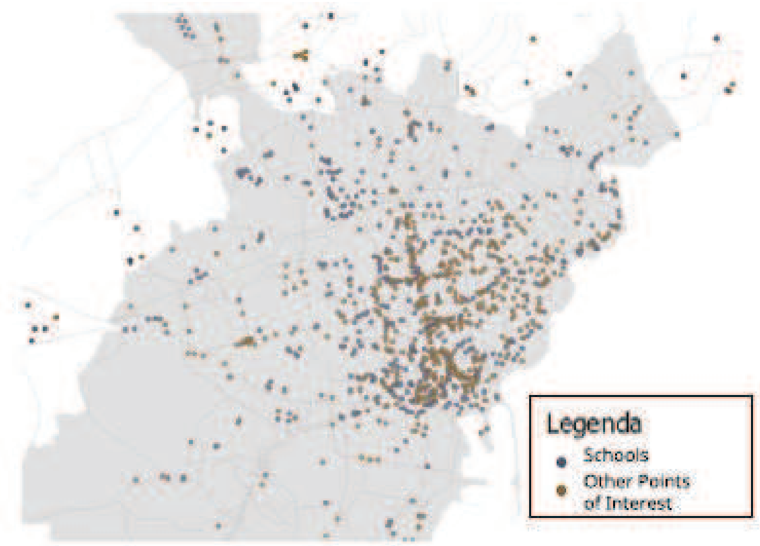

FIGURE 45 POINTS OF INTEREST

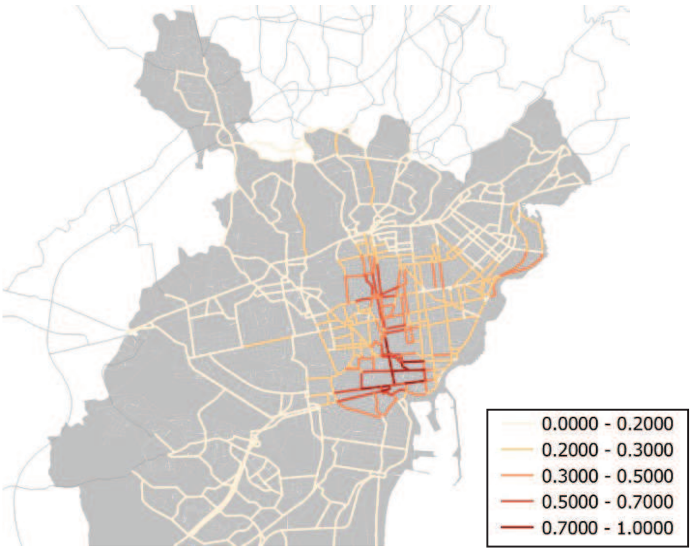

FIGURE 46 MAP INTERSECT WITH ROAD NETWORK

NUMBER OF EMPLOYEES (E)

For the criterion on the number of employees we have processed the data provided by the ISTAT. This information, as in the state of the buildings, refers to censorship areas. An intersect was performed to transfer the spatial information to the arc (Figure 47).

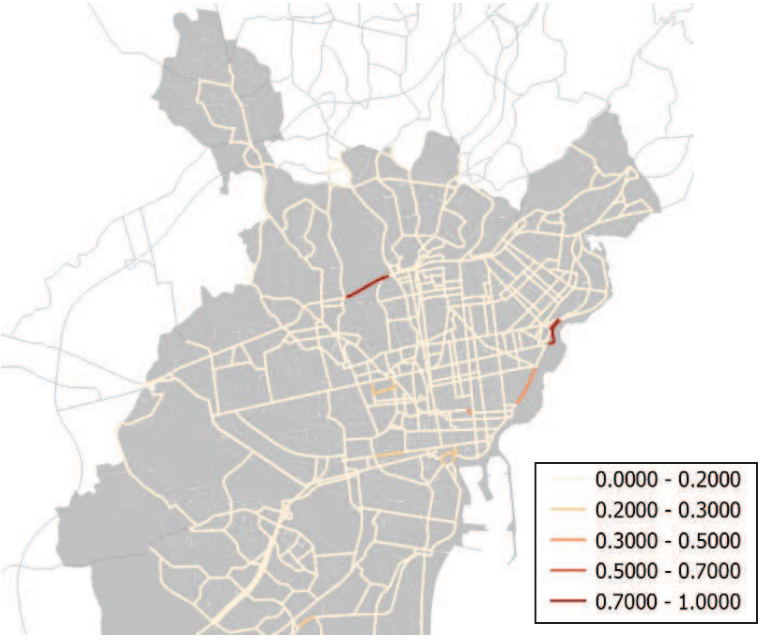

FIGURE 47 NUMBER OF EMPLOYEES

EVALUATION OF COMPATIBLE ARCS

After the analysis of each criterion a Global Compatibility Index (GCI) for each arc *i* has been defined as the sum of the contribution brought by each normalized criterion:

$$GCI_i = V_i + S_i + SoB_i + PoI_i + E_i$$

Where

V_i= Traffic Volume criterion for arc *i*

S_i= Traffic Speed criterion for arc *i*

SoB_i= State of Building criterion for arc *i*

PoI_i= Points of Interest criterion for arc *i*

E_i= Number of employees criterion for arc *i*

Based on the result coming from the evaluation of Global Compatibility Index, a classification of the arcs in three levels of compatibility has been performed (TABLE 14) and thematic maps of arcs' compatibility have been elaborated (Figure 48).

TABLE 14 – CLASSIFICATION OF ARCS ACCORDING TO COMPATIBILITY

GLOBAL INDEX OF COMPATIBILITY OF α	COMPATIBILITY
0,7≤α<1,6	Poor compatibility
1,6≤α<2,5	Medium compatibility
2,5≤α<3,4	High compatibility

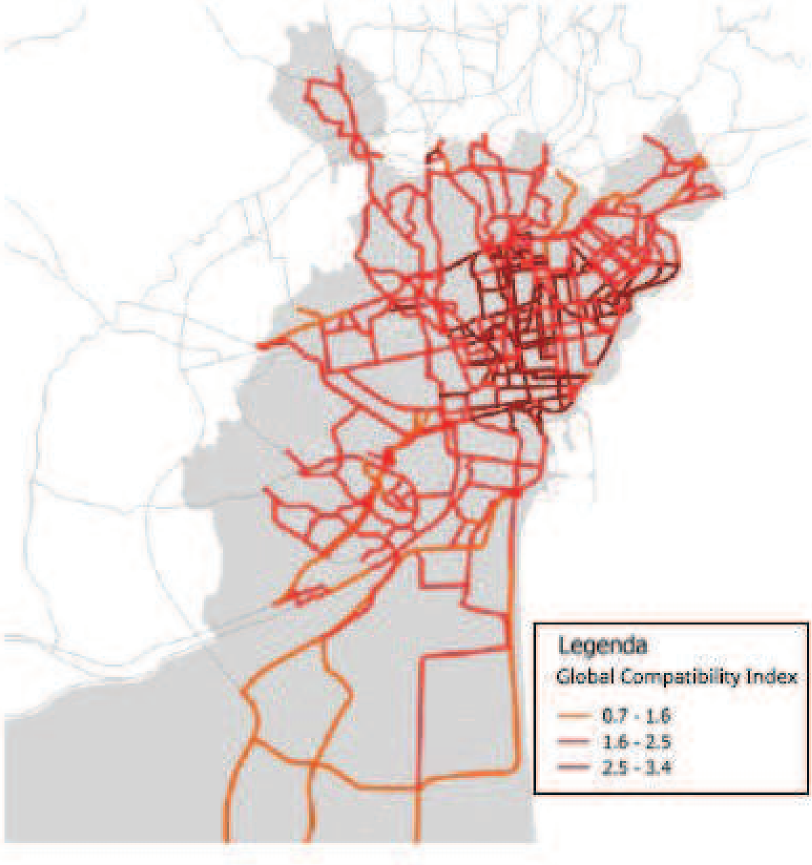

FIGURE 48 MAP OF THE GLOBAL INDEX OF COMPATIBILITY

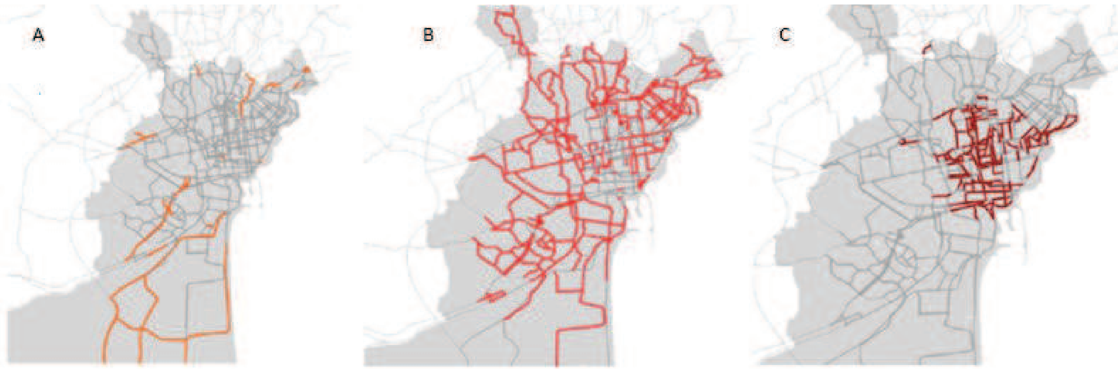

FIGURE 49 MAP OF ARCS WITH LOW COMPATIBILITY (A), MEDIUM COMPATIBILITY (B,)HIGH COMPATIBILITY (C)

As we can see form the maps inFigure 49, the most compatible arcs are located in the urban center and as we move away from it they become less and less compatible. The chart in Figure 50 shows the seven classes of compatibility and the total arc's length in kilometers relative to each class.

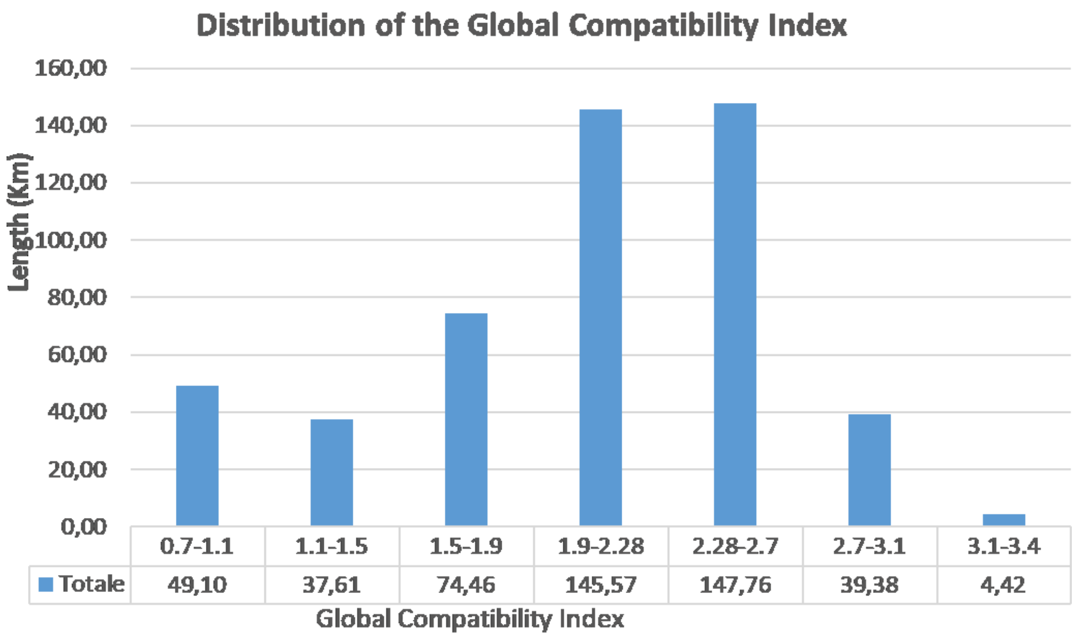

FIGURE 50 DISTRIBUTION OF THE GLOBAL COMPATIBILITY INDEX

SLOPES CHECK

Once the arcs have been classified according to the global compatibility index, it is good to check the slope and the width of the road. Both basic elements for the realization of a cycle track. Walking on a bicycle, besides being an alternative mode to car mobility, must be enjoyable. For this reason, an extremely important aspect to consider when designing a cycle track is definitely the relationship between the length of the path and its slope. It is easy to guess that it is preferable to have slow slopes for long journeys; however, for short journeys it is tolerable, in the minimum imposed by law, to have higher slopes. The maximum slope values should then be inversely proportional to the length of the section. According to this statement we can establish three ranges of length of a path and the corresponding maximum allowed gradient (Figure 51). If one of these relations occurs for each arc, then it means that the bike path realized is really viable and doesn't need excessive effort for the cyclist:

- For ramps of <100 m length, gradients< 5% are allowed;
- For ramps of <200 m length, gradients <3.5% are allowed;
- For ramps of length> 200 m, gradients <2% are allowed.

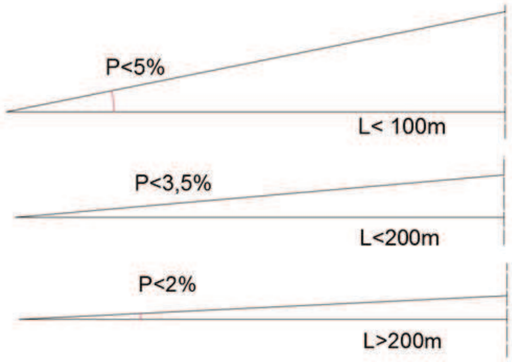

FIGURE 51 - RANGES OF LENGTH OF A PATH AND THE CORRESPONDING MAXIMUM ALLOWED GRADIENT

Based on this analysis, a thematic map of arcs gradient check has been elaborated (Figure 52).

FIGURE 52 ARCS GRADIENT CHECK VERIFICATION

Then a verification of gradients on arcs in relation to the three different levels of compatibility have been performed and a thematic map have been realized (Figure 53).

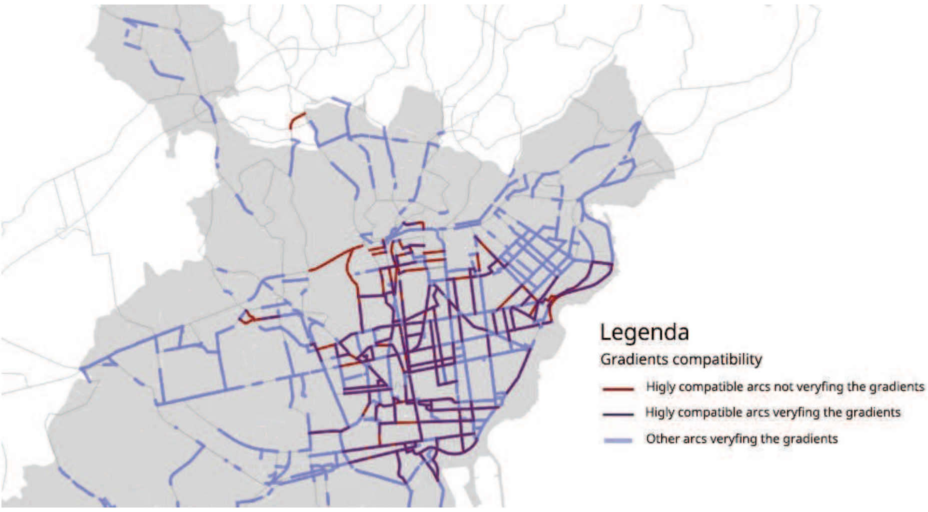

FIGURE 53 ARCS VERIFYING GRADIENTS ACCORDING TO THEIR COMPATIBILITY

ROAD WIDTH CHECK

Another essential factor for the design of a bicycle network is certainly the width of the road. As we have seen the realization of a cycle track follows very precise rules: it is therefore necessary to know whether the arcs satisfy or not these requests. Figure 54 shows a classification of the arcs according to their width.

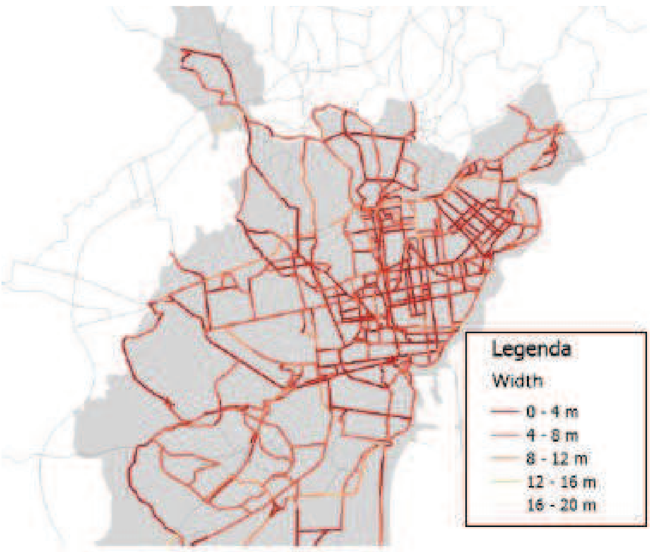

FIGURE 54 MAP OF WIDTH OF ROAD NETWORK

4.4.5. CONCLUSIONS

The analysis of arch through the Global Compatibility Index and the verification of gradients and road widths, allows the proposal of a new cycling network framework woven into the territory of Catania, emerging from the methodology outlined in this study (Figure 55).

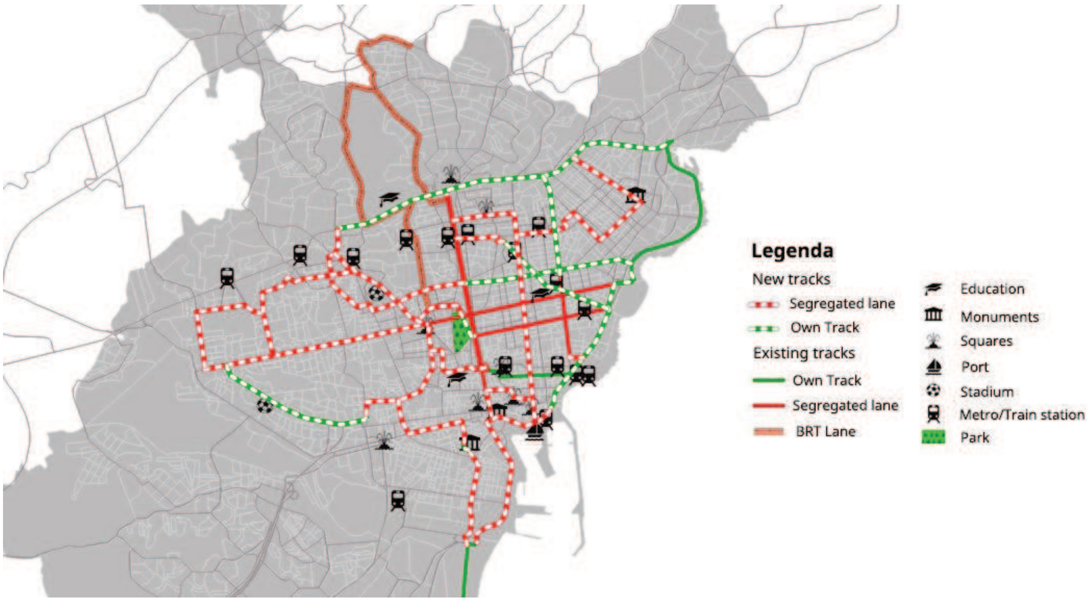

FIGURE 55 DESIGN OF NEW TRACKS ACCORDING TO GIS ANALYSIS RESULTS

The methodology used in this study allowed the combination of several attributes into a single compatibility index through a GIS-based bike planning analysis. Results show how GIS can be used to aid the planning of additions to an existing bicycle network. The methodology described can be improved in order to increase accuracy bu including all fixed-route transit stations, stops, and terminals. In addition, a bike demand analysis taking into account demographic information of residents and workers could be also included in future researches.

4.4.6. SUMMARY AND AND DEGREE OF IMPLEMENTATION

This study presented the use of a vector multilayer GIS as a decision support tool to design cycle paths. Results could be reinforced by the application of a MCDM to evaluate inicators provided by the GIS. The methodology could be improved by including public participation of citizens and stakeholders. Levels of application of GIS, PP and MCDA are summarized in TABLE 15.

	Public participation	Use of GIS	MCDA	Integration
Level	No citizen involvement, but social issues are included	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	No use of MCDA	Poor or No integration

TABLE 15 LEVEL OF APPLICATION OF GIS, PP AND MCDA IN CASE STUDY 4

4.5. CASE STUDY 5: Providing a Transit Service between Milo Metro Station and Città Universitaria[5]

4.5.1. Introduction

This case study regards a procedure for structuring a transport decision-making problem through a hierarchy by involving key stakeholders representing a first step towards a participatory decision-making process. The decision analyzed in the case study is about a new hectometric (i.e. short-range) transit system in the city of Catania (Italy), which should connect a new metro station with a University district. The method presented in this paper has been applied to the case study of Catania metro accessibility, specifically regarding the realization of a dedicated transit service linking two transport nodes, a metro station and a park-and-ride facility. Four alternatives have been proposed: bus, minimetro, monorail and ropeway. The decision is based on different criteria, including non-monetary ones, and it should be able both to solve the mobility needs of the district and to improve the quality of life of the whole city. The method consists on a creation of a stratified system organized in hierarchy in order to focus on understanding a single component of the whole, temporarily disregarding the other components at this and all other levels. In this view, the key stakeholders belonging to the metro company, the public transport company, the University and the municipality of Catania were identified and involved via in-depth interviews. A questionnaire, a GIS map and a SWOT-

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[5] This section is based on paper *Structuring transport decision-making problems through stakeholder engagement: the case of Catania metro accessibility* (Annex D) and paper *Combining Analytic Hierarchy Process (AHP) with role-playing games for stakeholder engagement in complex transport decisions* (Annex D)

like graph have been used to present them the decision problem and capture their preferences and opinions.

The overall participatory procedure consists of three steps and it is summarized in Figure 56 .

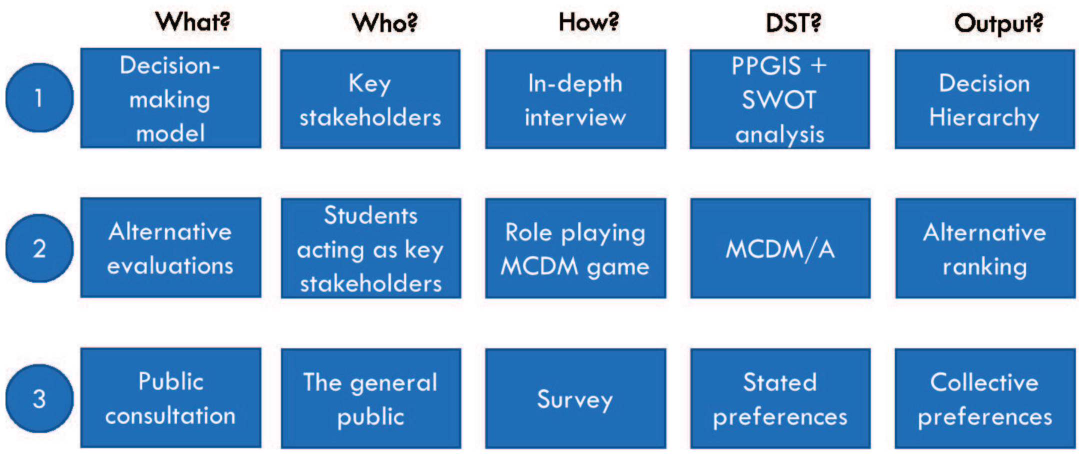


FIGURE 56. THE OVERALL PARTICIPATORY PROCEDURE.

In the first step, key stakeholders are identified and involved via in-depth interviews. A questionnaire, a GIS map and a SWOT-like graph are used to present them the decision problem and capture their preferences and opinions. From the results of the interviews, a first hierarchy of the problem is built. In the second step a role-playing game is used to reproduce a participatory process where University students are asked to act as key stakeholders and to obtain a ranking of transport alternatives. In the third step, a public consultation will be performed via a stated preference survey, to collect their preferences for transport system alternative configurations.

4.5.2. CONTEXT FRAMEWORK

Catania is a city of about 300.000 inhabitants, located in the eastern part of Sicily (Italy); it has an area of about 183 km2 and a population density of 1.754,54 inhabitants/km2. It is part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania.

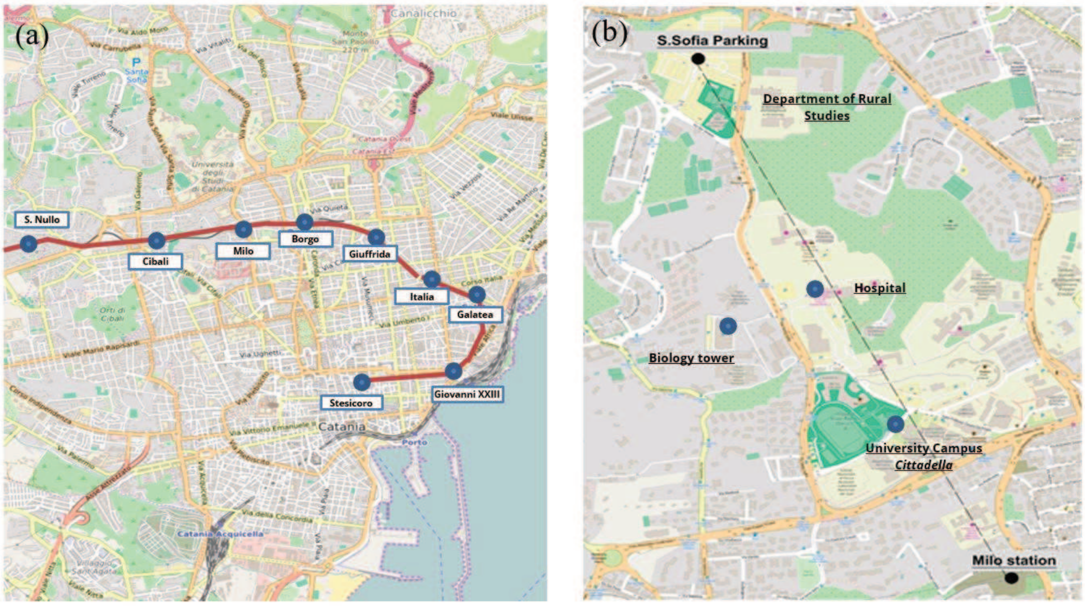


FIGURE 57(A) TERRITORIAL FRAMEWORK WITH THE METRO LINE; (B) AREA OF INTERVENTION (FROM MILO STATION TO S.SOFIA PARKING)

The main city (Figure 57a) contains most of the working activities, mixed with residential areas. With reference to the urban area, the transport service is provided by 51 bus lines, a Shuttle line (called ALIBUS) connecting the city center with the airport and a second rapid bus (called BRT1) connecting a parking located in the northern part of the urban area with one of the main squares in the historical center. An urban metro line currently links the port of the city (which is very close to the historical center) with the area immediately out of the historical center, from which it continues as a surface long-distance line. The line is expected in the next years to grow from 7 km to 11 km, connecting the city center with the peripheral areas. A new subway station, named “Milo”, has been recently opened. Its position will make it the closest station to an area where important University sites, health services and a park-and-ride facility (S. Sofia parking) are located (Figure 57b). Due to slope and distance between the station and the University sites, a new dedicated hectometric transit service linking the two transport nodes is under evaluation.

4.5.3. TRANSIT ALTERNATIVES

After a first analysis of feasibility of the possible solutions on the basis of best practices review and of future expected transport systems projects for the city of Catania, four different transit alternatives have been proposed: a urban bus, a minimetro, a monorail and a ropeway. A description of the main characteristics of these system can be found in Table 16.

Transit system alternatives	Bus	Minimetro	Monorail	Ropeway
Slope (MAX)	**12 - 20**	**12**	**4 - 8**	**15**
Radius (MIN)	12 - 20	20 - 30	50 - 60	0
Station distance (m)	200 - 500	100 - 2.400	700 – 2.500	620 - 3.500
Capacity (pass/h)	**200 - 2.500**	**200 - 3.000**	**2.500 - 9.400**	**100 - 4.700**
Headway (min)	5 - 10	3 - 5	3 - 5	0,14 - 5
Frequency (UT/h)	6 - 12	12 - 20	12 - 20	12 - 430
Commercial speed (km/h)	10 - 25	5 - 30	25 - 50	5 - 30
Acoustic pollution (dB*)	**70-80**	**60-70**	**70-75**	**60-70**
Environmental pollution	Yes	No	No	No
Investment cost (M€/km)	**0,3 - 2**	**15 - 33**	**35 - 94**	**2 - 16**
Maintenance costs (€/VKM)	2,2 - 2,9	2,0 - 5,5	6,0 - 8,5	1,0 – 5,0

TABLE 16 – TRANSIT SYSTEM ALTERNATIVES MAIN FEATURES (ELABORATION OF RUSSO ET AL., 2008)

MINIMETRO

People mover are modern automatic transport systems on rails, operation is automatic and vehicles are usually equipped with rubber tires circulating on metallic or concrete guides. Main characteristic of this kind of system are a segregated right of way, integral automation, a capacity that can go from very low values up to 3000-4.000 pass/h, a frequency of less than 1 minute and the possibility to overcome slopes of 15%. Between the various typologies of people mover, we are taking into account a particular one, called Minimetro, constructed by the Leitner Rope-ways S.p.A (Figure 58).

FIGURE 58 MINIMETRO PROJECT FOR CATANIA BY LEITNER ROPE-WAYS S.P.A

BUS

Urban buses are the most popular means of collective public transport in our cities and their technology is now firmly established. Taking into account existing arteries and various boundary conditions along the route Milo – Città Universitaria - S. Sofia, the bus line has been designed (Figure 59): a "tangential" line, which does not enter the heart of the university campus, but rather touches it and has its stops close to the main entrances. Given the fairly linear path (with forward and return lines side by side) and the large spacing between the stops, the system gets close in characteristics to a modern Bus Rapid Transit.

FIGURE 59 BUS ROUTE FOR CONNECTION BETWEEN MILO STATION AND SANTA SOFIA PARKING

MONORAIL

Etna Rail is the name of a project of monorail de-signed for the metropolitan area of Catania, including 3 different lines, with the green one tangential to our study area (Figure 60). It is a modular system, designed for the prefabrication of all major components; it can overcome a maximum slope of 12%; the guide can be manual or with a fully automatic system "driver-less" from a remote control room; the speed can reach up to 160 km/h.

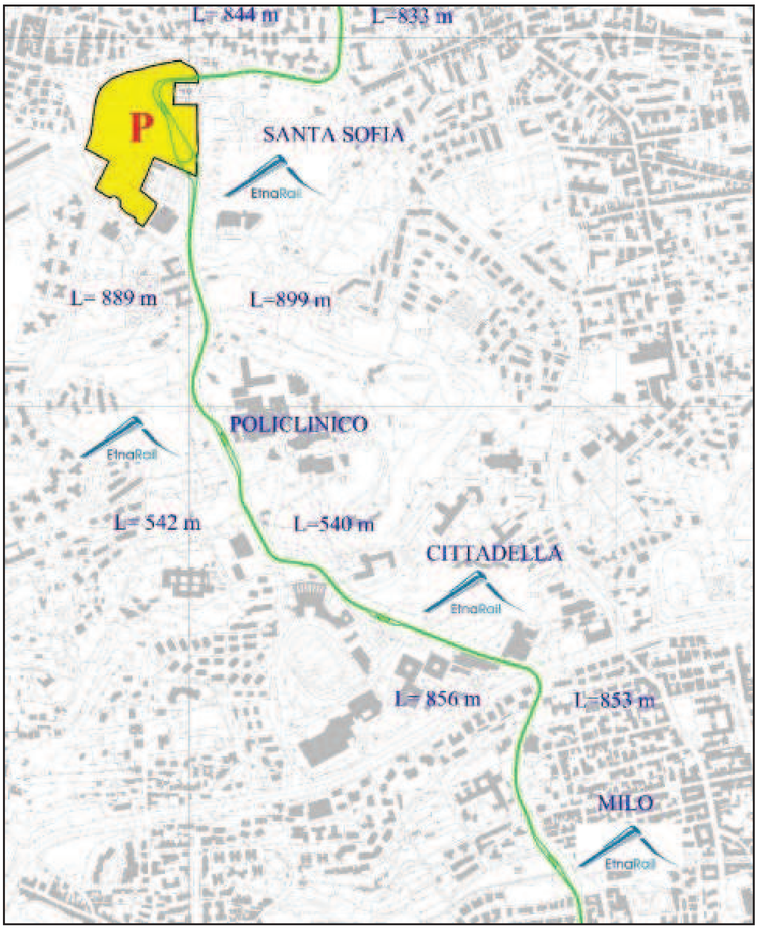


FIGURE 60 ETNARAIL PROJECT FOR CATANIA

ROPEWAY

Ropeway, which falls into the category of cable transport, is the most common technology used for public transport services on lines with very high slope (from 10% up). It is a shuttle which consists of a pair of cars (or possibly groups of cars joined together), an ascending and a descending unit, permanently attached to the two ends of the same cable (a steel cable). Vehicles are built according to the transportation needs and characteristics; for the transport of people highly variable capacity cars are employed (from a few people to over one hundred), on the base of suitability to the service (citizens' movements, summer or winter tourism, etc.). For out study we took into account Ropeway proposal by the Leitner Rope-ways S.p.A (Figure 61).

FIGURE 61 MINIMETRO PROJECT FOR CATANIA BY LEITNER ROPE-WAYS S.P.A

A summary of main characteristics of the four alternatives can be found in Table 17.

Transit system alternatives projects	Bus	Minimetro	Monorail	Ropeway
Total length (km)	6,6	2,4	2,4	2,1
Number of stops	9	6	4	4
Building accessibility	indirect	direct	direct	direct

TABLE 17 TRANSIT SYSTEM ALTERNATIVE PROJECTS MAIN CHARACTERISTICS

4.5.4. STAKEHOLDER SURVEY

Five stakeholders, representing the main interest groups affected by the intervention, have been involved:

- University of Catania, in the person of Rector's delegate for mobility management;
- Urban bus transit company (Azienda Metropolitana Trasporti – AMT Catania), represented by one of its transport planners;
- University Students' Council, in the person of a representative student of the students' council; Municipality of Catania, represented by an administration consultant;
- Metro rail company (FCE – Ferrovia Circumetnea), in the person of its general manager.

Before the beginning of the questionnaire, a Web GIS map of the main impacts of the four different alternatives has been shown to the stakeholders (Figure 62). The map has been composed with the aid of the Open Source software QGIS (2016) by using the free plugin *qgis2web*. The base map references the live tiled map service from the OpenStreetMap (OSM) project. It’s made available under the Open Data Commons Open Database License (ODbL). The base map already shows the future subway line track with a dotted line. Four different layers have been added to the map, showing for each alternative:

- The design track;
- Value of hypothetical capacity (pass/h);
- A noise map
- The location of stops and stations.

Moreover, two more layers show the main interest point of the zone and the Traffic Analysis Zones from Urban Traffic Plan of Catania (PGTU, 2013).

Each stakeholder has been asked with some general information about his company/body: his company position; company’s objective and specific abilities; company’s main interests in relation to the project; collaboration with other bodies in relation to the project. The stakeholder has then been asked if he would consider the intervention necessary and the reasons of his opinion. Always in relation to the project and to the company’s objectives, he has been asked to assign an importance level to four different impacts:

- Transportation impact, related to the ability to meet the demand, considering characteristics related to system performance, such as frequency, speed, etc.;
- Economic impact, related to construction, operation and maintenance costs;
- Social impact, relating to system security, ease of access, acceptability;
- Environmental impact, in terms of air pollution, noise, visual intrusion, etc.

The importance level has been evaluated by the stakeholder with a numeric scale going from 1 (*not important*) to 5 (*very important*).

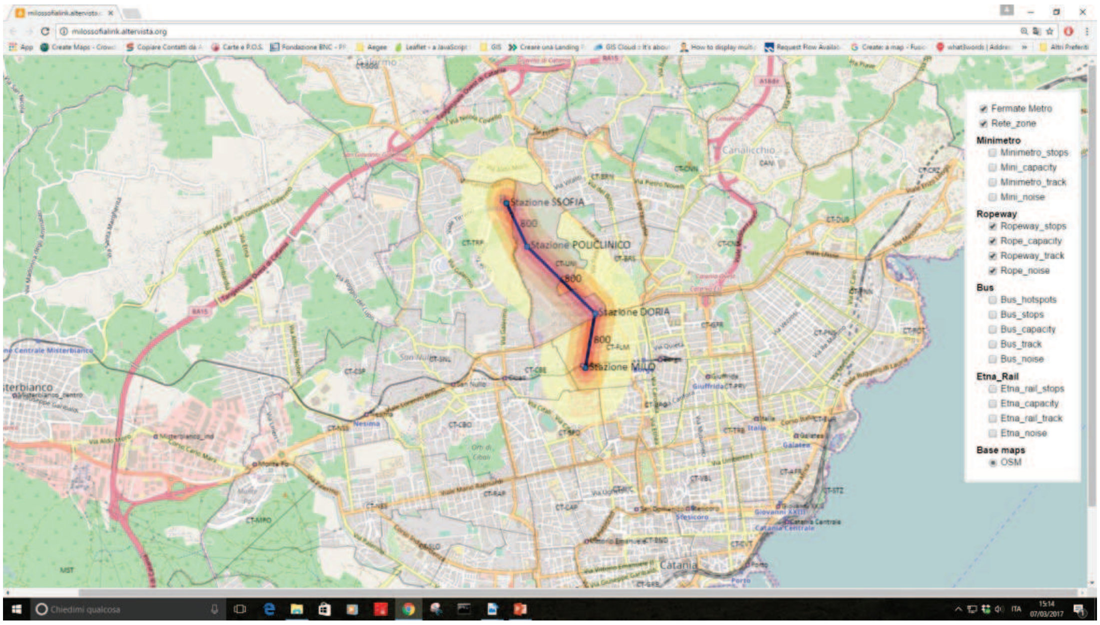


FIGURE 62 WEB-GIS MAP HTTP://MILOSSOFIALINK.ALTERVISTA.ORG

In the final part of the interview the stakeholder has been asked to conduct a SWOT analysis for each alternative, in order to consider for all the transit option:

- its strengths, i.e. the characteristics of the project providing an advantage over others; those should be internal features of the project;
- its weaknesses, i.e. the inherent characteristics that place the project at a disadvantage relative to others;
- its opportunities, meaning the external issues that the project could benefit of;
- its threats, the external elements in the environment that could cause failures of the project.

4.5.5. Survey's results and hierarchy construction

In this section there are described survey's results and the hierarchy model construction associated to the case study, to be (eventually) used for analysis via appropriate multicriteria decision-making methods.

From the surveys, the fundamental aspects taking into consideration to build the hierarchy have emerged. For the first interviewed stakeholder (University of Catania), the transportation impact results the most uppermost one in terms of accessibility. Furthermore, the environmental and economic impacts were considered important, respectively in terms of pollution and visual intrusion, economic risks and costs distinguishing in implementation and operation costs for each system.

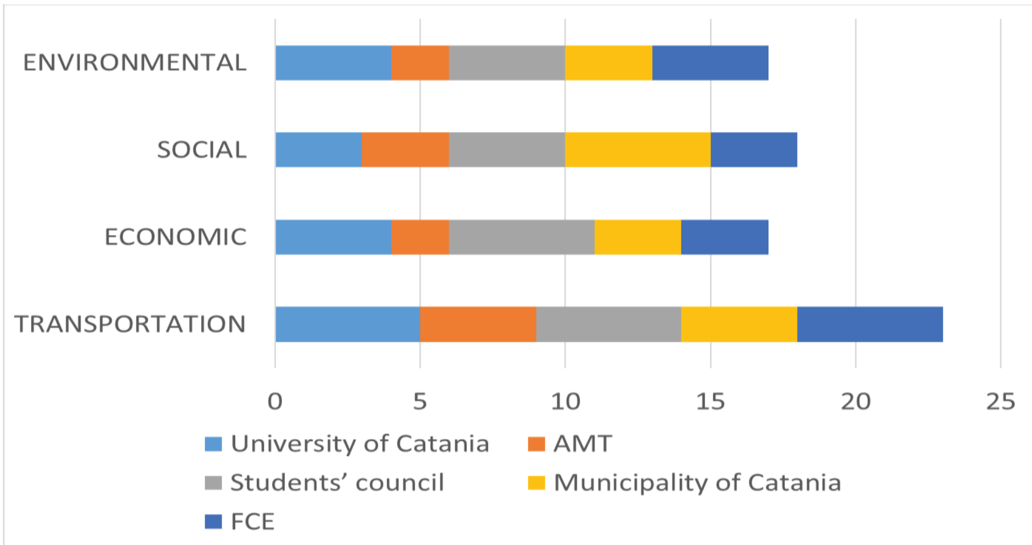
The second stakeholder (AMT Catania), similarly to the first one, considered the transportation impact one of the most important aspect which have to be taken in consideration, especially in terms of capacity and frequency related to each transport system alternative. The stakeholder also considered the social impact associated to the realization of this transit service as the possibility of an urban redevelopment of the metropolitan area. The third involved stake-holder, University Students' Council, has given more attention to transportation impacts, such concern two main aspects of travel time reliability and comfort of the system. As regards economic impacts, the stakeholder referred to general costs. The fourth stakeholder, (Municipality of Catania) assigned the highest level of importance to the social impact in terms of acceptability and perceived security. The last stakeholder, Metro rail company (FCE), focused his attention on transportation and environmental impacts, like the other stakeholders, also taking into account the operational aspects of the system.

Stakeholders' answers about intervention importance and impacts comparison are summarized in TABLE 18 and TABLE 19.

TABLE 18: IMPACTS LEVEL ASSIGNED BY THE STAKEHOLDERS

University of Catania	The intervention is necessary not only because it would be a benefit for University but it would fully justify the realization of metro station, **solving the "last mile problem"**.
AMT	The intervention is necessary because there is a **high demand level and a poor service supply**.
Students' council	The intervention is necessary because students have high difficulties to find a parking lot in University campus and they need a **fast transit service to get to the campus**.
Municipality of Catania	The intervention is necessary because it is quite **impossible to reach the University/Hospital sites by walking or cycling**.
FCE	The intervention is necessary because of **company's objective** and also to achieve the final goal of **traffic reduction and city liveability.**

TABLE 19: IMPACTS LEVEL ASSIGNED BY THE STAKEHOLDERS



The following SWOTs (Table 20, Table 21, Table 22, Table 23) show the main strengths, weakness, opportunities and threats associated to each transport alternatives.

TABLE 20: SWOT ANALYSIS FOR THE ALTERNATIVE BUS

STRENGHTS	WEAKNESSES
-Low costs of implementation -<u>Immediate implementation</u> -<u>Flexibility</u>	-Pollution -<u>High operation and management costs</u> -High costs -<u>Travel time unreliability</u>
OPPORTUNITIES	**THREATS**
-Memorandum of understanding among University, AMT and Municipality of Catania -Possibility of higher level of transit service's performance (increased supply)	- Critical financial issues related to urban bus transit company -<u>Service punctuality because of road traffic</u>

TABLE 21: SWOT ANALYSIS FOR THE ALTERNATIVE MINIMETRO

STRENGHTS	WEAKNESSES
-<u>Capillarity</u> -Good interchange with metro -<u>Frequency</u>	-High operation costs -<u>Visual impact</u> -<u>Rigidity of the system</u> -<u>Environmental and landscape impacts</u>
OPPORTUNITIES	**THREATS**
-Element of attraction: innovation and modernity -<u>Urban redevelopment of the area</u> -Greater number of employees -Low operation costs	-Non-consolidated technologies -Uncertainty of ministerial authorizations for safety issues -<u>Fixed supply</u> -<u>Dealing with a different transit company</u>

TABLE 22: SWOT ANALYSIS FOR THE ALTERNATIVE MONORAIL

STRENGHTS	WEAKNESSES
-Higher capacity	-High implementation and operation costs -Visual intrusion -Rigidity of the system -Environmental and landscape impacts
OPPORTUNITIES	**THREATS**
-Potential to be part of a wider system -Urban redevelopment of a wide area of the metropolitan region -Good interchange with metro	-Financial uncertainty on realization -Dependence on foreign technologies -Political and economic interests -Higher number of stakeholders involved to reach the consensus

TABLE 23: SWOT ANALYSIS FOR THE ALTERNATIVE ROPEWAY

STRENGHTS	WEAKNESSES
-Moderate costs of implementation	-Poor capillarity -Rigidity of the system -Environmental and landscape impacts -Sensitivity to atmospheric conditions -Uncertainty on use by users -Difficulty of increasing extension and capacity
OPPORTUNITIES	**THREATS**
-Exploitation for landscape tourism purposes -Innovation and modernity image -Architectural interest	-Fixed supply -Access and egress rigidity

As regards the first alternative, the economic aspect has an important role. In fact, bus has low cost of implementation, but at the same time high operation and management costs. Furthermore, the travel time unreliability due to mixed right of way must be taken into account.

The second alternative, represented by the minimetro is considered an element of attraction in terms of innovation and modernity. Conversely to the bus, it is a rigid system and if the urban situation changes, the system cannot be adapted.

It is a well-share opinion for the stakeholders, that the third alternative, the monorail represents a good opportunity for an urban redevelopment of a wide area of the metropolitan region, because it could be part of a wider track. It has also a good interchange with metro. Both minimetro and monorail have the economic problem of high implementation and operation costs, and the environmental problem in terms of visual intrusion and landscape impacts. The same considerations are also valid for the last alternative, with the only difference that the ropeway has moderate costs of implementation.

The hierarchy model for this case study is pyramid-shaped. The goal to be reached is represented by the choice of the best transport system to connect Milo metro station with S. Sofia parking. Four alternative ways of reaching the goal, and four evaluation criteria with three or four evaluation sub-criteria for each criteria were incorporated in the hierarchy. Table 7 shows a scheme of the four macro criteria with the associated sub-criteria, associated to a code in order to facilitate the graphic representation.

TABLE 24. CRITERIA AND SUB-CRITERIA DEFINITION FOR THE HIERARCHY MODEL

Criteria	***Code name***	***Sub-criteria***	**Code name**
Transport	C_t	Accessibility	S_{t1}
		Travel time	S_{t2}
		Frequency	S_{t3}
		Comfort	S_{t4}
Economic	C_{ec}	Implementation cost	S_{ec1}
		Economic Risk	S_{ec2}
		Management cost	S_{ec3}
Environmental	C_{en}	Air pollution	S_{en1}
		Noise pollution	S_{en2}
		Visual intrusion	S_{en3}
Social	C_s	Acceptability	S_{s1}
		Urban requalification	S_{s2}
		Perceived security	S_{s3}

Figure 63 schematically illustrates the developed hierarchy model for the choice of the best transport system, with the goal at the top, the four alternatives at the bottom, and the four criteria with their sub-critera in the middle. The one-way arrows indicate the influence between each element of the hierarchy.

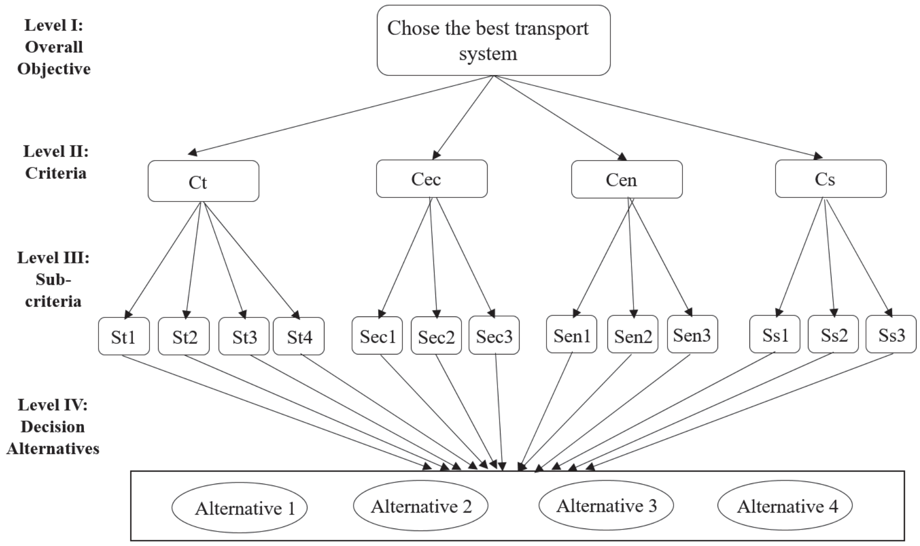


FIGURE 63 TREE ILLUSTRATING THE HIERARCHY OF CRITERIA AND SUB-CRITERIA IDENTIFIED IN THE PROCESS

Once the hierarchy has been constructed, it would be possible to use this hierarchy for analysis via appropriate multicriteria decision-making methods and to get to a final decision based on the results of this process.

4.5.6. THE PARTICIPATION EXPERIMENT

In order to test the decision-making hierarchy and evaluate alternatives from a multi-stakeholder multi-criteria perspective, a participation experiment was set up, by involving University students in a role-playing game. Such experiment has been arranged as a preliminary test of the procedure that, in future, will be carried out with real stakeholders. Forty students of the “Transport Systems” class of the Master Course in “Environmental Engineering” of the University of Catania were involved in the experiment, which took place between May and June 2016. A total of 5 sessions of 2-3 hours each were organized. The students were trained on the complexity of decision-making about transport systems and the role of multicriteria decision technique to support decision-making (two sessions). Two sessions were dedicated to the description of the case study with a detailed analysis of the four transit alternatives.

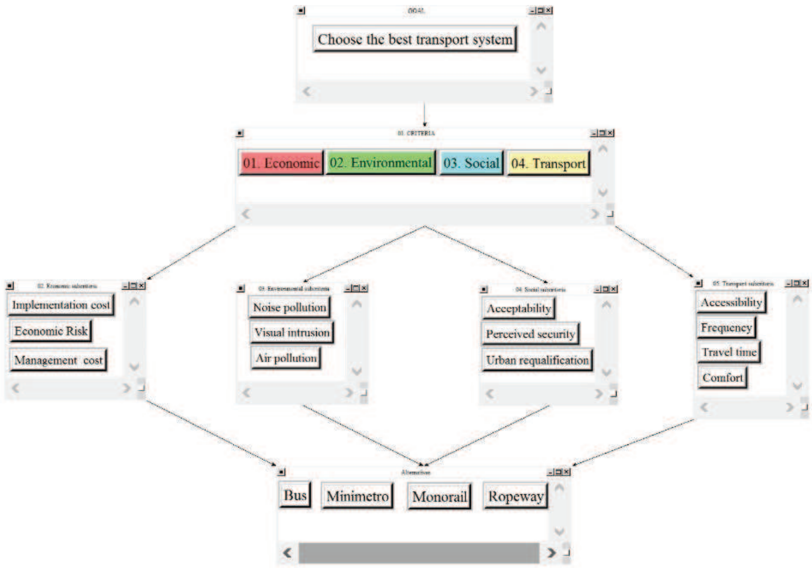


FIGURE 64 HIERARCHY OF THE DECISION PROBLEM IN SUPERDECISIONS.

In the last session, the actual participation experiment took place. They were divided in five groups, each of them representing one of the key stakeholders. The results of the in-depth interviews were provided to them in order to make them identify with the specific role. AHP was performed using the software SuperDecisions©[6].

The first step was to validate the previously developed hierarchy. In this respect, the students shared all the criteria and confirmed it, as shown in Figure 64. Then, the groups were asked to make pairwise comparisons for each level of the hierarchy. The inconsistency of judgments was constantly monitored and kept to the minimum.

[6] www.superdecisions.com

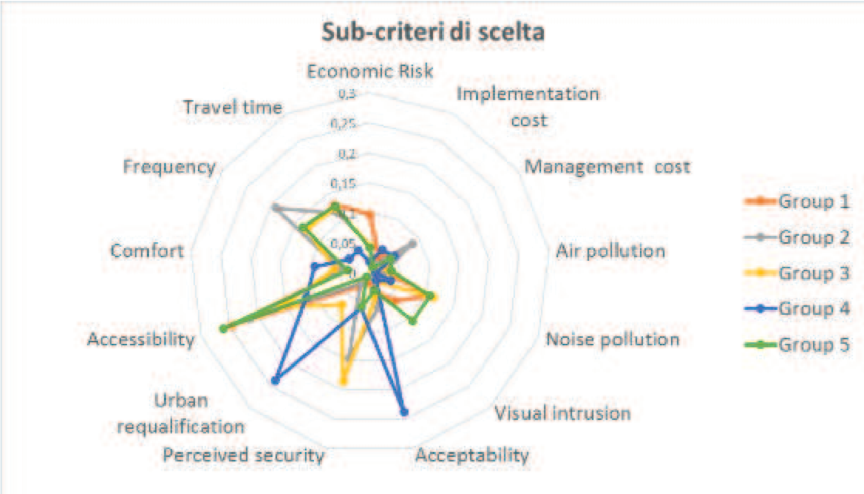


FIGURE 65 AHP RESULTS: (A) SUBCRITERIA PRIORITIES

Results of the pairwise comparisons on criteria and sub-criteria for the five groups are shown in . The first group (group 1), which played the role of the University of Catania (and, specifically, the Rector's delegate in charge for mobility management), gave more importance to the transport impact (criterion) and, in particular, to accessibility, travel time and frequency (sub-criteria).

The second group (group 2), representing the urban bus transit company (AMT), also considered the transportation impact as the most important aspect followed by the social one, especially in terms of accessibility, frequency and perceived security of each transport system alternative.

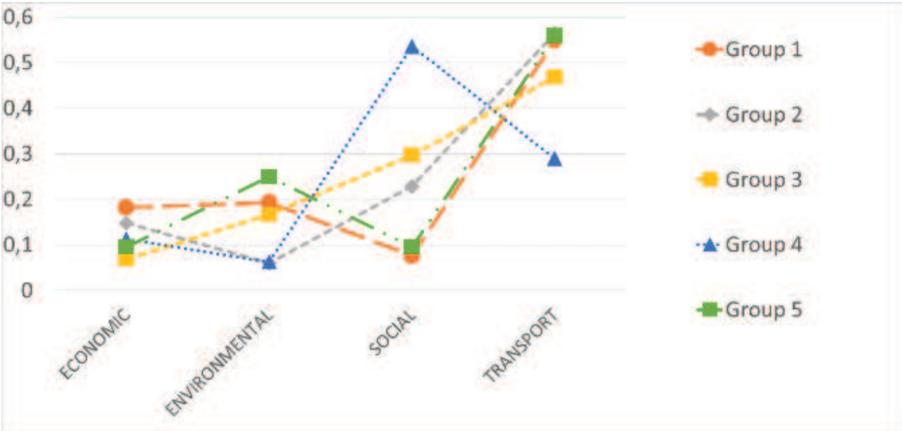


FIGURE 66 AHP RESULTS: (A) SUBCRITERIA PRIORITIES AND (B) CRITERIA PRIORITIES

The third group (group 3), playing the role of a student representative of the University Student's Council, considered important the transport and social impacts, in terms of perceived security, accessibility and travel time. The fourth group (group 4), representing the Municipality of Catania, assigned the highest level of importance to the social criterion, in particular in terms of acceptability of the proposed solutions and urban requalification of the surrounding areas. The last group (group 5), representing the metro rail company (FCE), gave priority to transport impact, in particular in terms of accessibility, followed by the environmental impact referred to noise pollution and visual intrusion. As can be noticed in , there is some heterogeneity in the judgements, even if accessibility is one of the overall most ranked sub-criterion. Globally, transport impacts are considered more important, followed by the social, environmental and economic ones (Figure 66a). These results are clearly in line with the preferences that key stakeholders expressed in the in-depth interviews, showing that students were able to play the roles assigned to them. Finally, priority rankings of alternatives for each group are shown in Figure 67b.

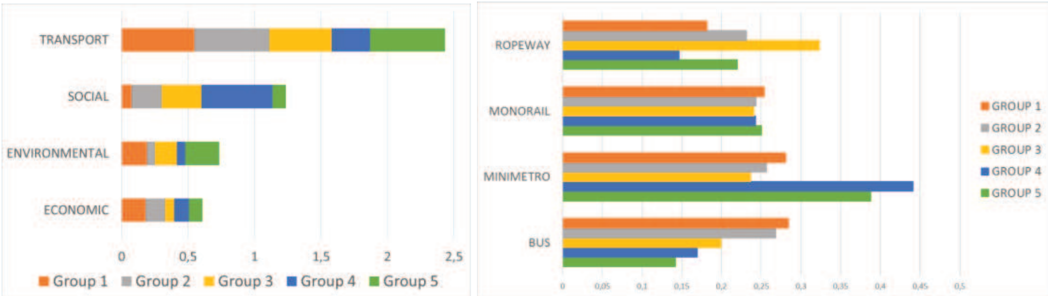


FIGURE 67 PRIORITY RESULTS OF (A) CRITERIA AND (B) ALTERNATIVES.

Minimetro shows the highest priority for group 4 (i.e. Municipality of Catania) and group 5 (i.e. FCE), while *ropeway* is the first ranked for group 3 (i.e. Student's Council). On the contrary, priority rankings for group 1 and 2 (University of Catania and AMT) are quite "flattened". It is worthy of notice that these results rely on students' perceptions about the impacts of each alternative on the different dimensions and that they are not the output of a technical evaluation. Nevertheless, they were well informed about the alternative transport systems and they had a background in transport engineering, therefore they can be considered "sophisticated stakeholders" (Le Pira et al., 2015). In the following, aggregation of individual priorities has been performed and compared with the result of a consensus vote, to derive a collective decision as an output of the AHP procedure.

4.5.7. CONSENSUS VOTE VS MATHEMATICAL AGGREGATION

The last step was to analyze the final results via a consultation process with the five groups representing the key stakeholders. The main aim was to reach an agreement on the best transit alternative. After a discussion about the different priority rankings derived from the five AHP, the whole group decided that there might be a best short-period solution and a best long-period solution. In this respect, *bus* would be a good solution in the short period while *Minimetro* would be the best solution in the long period. This can represent an input for discussion with real stakeholders in the future. The obtained results depend on the sample considered in this study and they could be different if other groups of students were considered. In a real participation process the consensus vote can be altered by more influencing stakeholders, so a stakeholder analysis can be helpful to gain insight into their power/influence in the decision-making process. Subsequently, a mathematical aggregation of the five priority rankings was done using the geometric mean method, in order to make a comparison with the decision for the long period emerged from the discussion. Results confirm that the best solution is the *Minimetro*. However, as opposed to the consensus vote, the second solution is *monorail*, followed by *ropeway* and, lastly, *bus*. This demonstrates that a mathematical aggregation of individual priorities is not always appropriate to obtain a group decision representative of stakeholder interests. Aggregation of individual judgments or, if possible, a consensus vote is to be preferred. Nevertheless, the group ranking derived from simple priority aggregation confirmed what stakeholders evaluated as the best solution, therefore it can be useful to have a global vision of stakeholder preferences.

After a consultation with key stakeholders and a first evaluation of alternatives, a public consultation will be performed via a stated preference survey, to collect citizen preferences for different transport system alternative configurations. The overall goal is to have enough information to guide the final decision, which should be based both on the results of technical evaluations and the one of the participation process.

4.5.8. Conclusions

The hierarchy model for this case study is pyramid-shaped. The goal to be reached is represented by the choice of the best transport system to connect Milo metro station with S. Sofia parking. Four alternative ways of reaching the goal, and four evaluation criteria with three or four evaluation sub-criteria for each criteria were incorporated in the hierarchy, against which the alternatives need to be measured.

In conclusion, this methodology constitutes a very promising future research line in the field of transport planning and decision-making. From the results of the interviews, Hierarchy of the problem has been built, to be (eventually) used for analysis via appropriate multicriteria decision-making methods, representing a first step of a stakeholder-driven decision-making process.

Next studies could be addressed to the application of an AHP analysis by using the build hierarchy, in order to evaluate alternative solutions and to help decision makers find the alternative that best suits their goal. Moreover, a complete online platform of the survey could be implemented in order to address to the public, get a wider sample of answers.

4.5.9. Summary and and degree of implementation

In this study a procedure for structuring a transport decision-making problem about a new hectometric transit system has been presented. Key stakeholders have been involved in the construction of a hierarchy for the evaluation of the different proposed alternative. The AHP method of MCDA has been then used to evaluate priorities in a role-play game performed by students. Levels of application of GIS, PP and MCDA are summarized in TABLE 25.

	Public participation	**Use of GIS**	**MCDA**	**Integration**
Level	Citizens' Active Participation	Important role in the analysis of scenarios; weights are decided out of the GIS	MCDA to support consensus building	High

TABLE 25 Level of application of GIS, PP and MCDA in Case study 5

4.6. CASE STUDY 6: The *InSUPERabile* project

4.6.1. Introduction

The *InSUPERabile* project is a civic initiative born through a Facebook group by Gaetano Emanuele, Catania's researcher at the Faculty of Architecture of Reggio Calabria, that in a few months managed to achieve a representative mapping of architectural barriers in Catania.

InSUPERabile was born in response to a call from the Italian National Institute of Urban Planning (INU) entitled *Progetto Paese Città Accessibili a Tutti*[7], which invited designers to describe solutions that could improve the accessibility of cities. It is a project that wants to demonstrate how by cost-free social networking citizens can participate in reporting city issues. To give an idea of the success, just a few facts: open on January 27, in just one month the Facebook group already had 5,108 members and 126 reports of architectural barriers, four per day.

The mechanism is very simple: the user catches a picture with a smartphone and posts it on the Facebook group, indicating the location, the existing barrier and tagging a municipal administrator which is considered responsible of an intervention. To each post a different score is given, according to the severity of the problem: +5 Inaccessible public building; +5 Inaccessible public square or space; +3 Inaccessible pedestrian crossing; +3 Danger situation; +1 Barrier in pedestrian path creating issues for disabled people. Each member of the group keeps the count for its own global score, basing the game on reciprocal respect and trust; periodically little awards provided by some sponsors are given to the users with biggest scores, in order to encourage the participation to the group.

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[7] http://www.inu.it/citta-accessibili-a-tutti/

Due to the actual spatial dimension of the project, a future development has been designed with the aim to geo-locate the position of the problems reported by the users and to give them a full visualization of the results of the project.

4.6.2. CONCEPTUAL FRAMEWORK

At the beginning of the geo - reference project there were two type of possibility to be faced for the insertion of data into the system:

- Post already published in the Facebook group: there was already a good number of problem's location reported by the group's users;
- Some users might still have wanted to insert their located problems, so they needed a fast insertion procedure.

In order to facilitate the filling of the database used for the geo-location on the map the following system architecture has been conceived (Figure 68). A survey containing the fields of the post have been realized through the use of the platform FORM+, which allows users to upload photos when compiling a survey. The form used for the survey sends answers to a Google spreadsheet, which, through a Json Script updates periodically a Google Fusion Table. Fusion Tables is an experimental data visualization web application to gather, visualize, and share data tables developed by Google which allows a mash-up between spreadsheets and maps. Points, lines, polygons, customer addresses, placenames, countries and more can be mapped in with Fusion Tables, since columns with location data are automatically interpreted. Colors or icons can also be applied based on the type of data. Intensity map for countries, states or provinces, also using KML polygons can be implemented. The map can then be embedded it in a blog, send to collaborators by a link or saved as a KML file to view in Google Earth. By using

Fusion Tables, a map with pop ups provides information about the reported problem for each element. Finally, the map has been embedded into a public website, so it can be seen by the internet public.

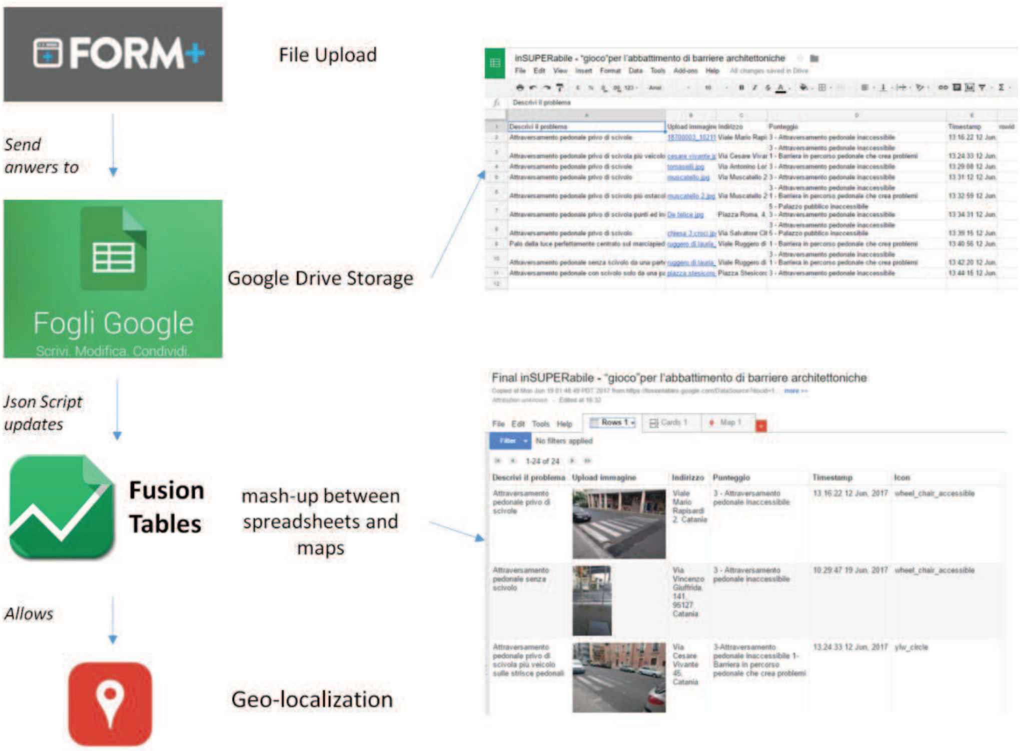

FIGURE 68 ARCHITECTURE FOR INSUPERABILE PROJECT GEO-LOCALIZATION SYSTEM

4.6.3. RESULTS AND FUTURE DEVELOPMENT

The main result of this application was the collaborative public map, showed in Figure 69. The map has been included in the final report of the project which have been delivered to city municipality administration of Catania. For future implementations the map could be imagined as an integral part of the process of signaling by citizens, perhaps through the use of a mobile application.

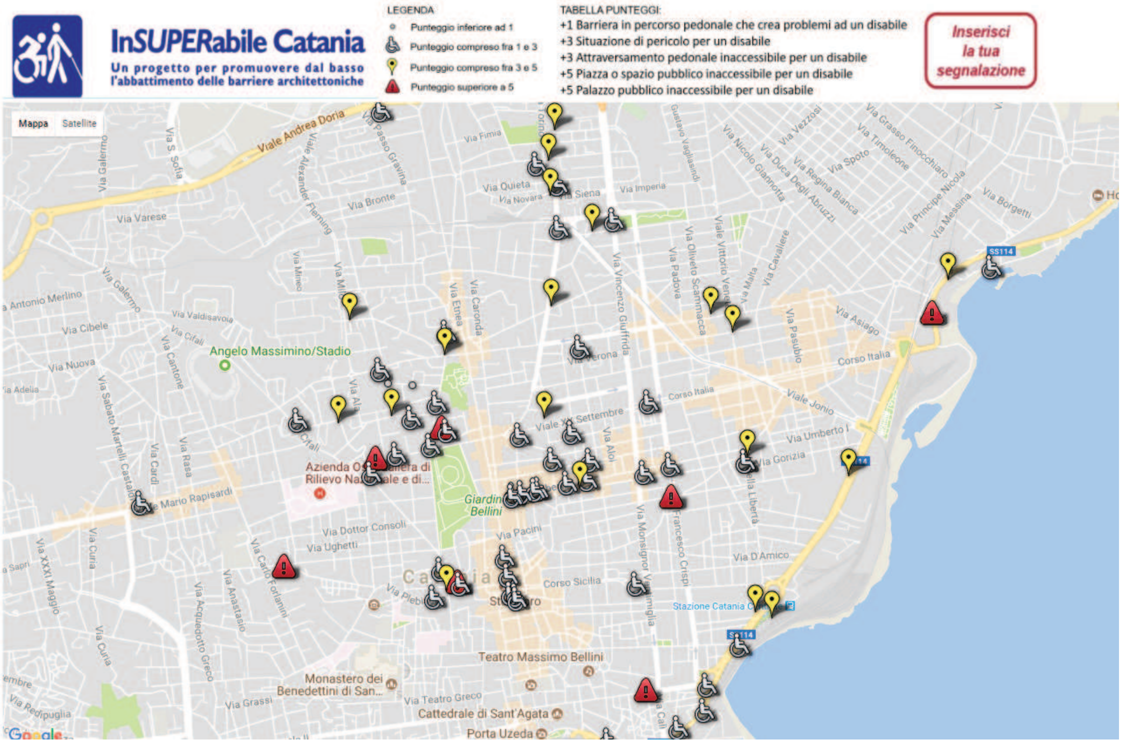

FIGURE 69 MAPS OF PROBLEM FROM INSUPERABILE PROJECT

(http://transportmaps.altervista.org/insuperabile/insuperabilemap.html)

4.6.4. SUMMARY AND AND DEGREE OF IMPLEMENTATION

This study showed a PPGIS initiative which allow citizens to report problems they experiment in their city. Results from this study can be considered as a good starting point for the planning of intervention according to priority levels established by citizens.Levels of application of GIS, PP and MCDA are summarized in TABLE 26.

	Public participation	Use of GIS	MCDA	Integration
Level	Citizens' Active Participation	Important role in the analysis of scenarios; weights are decided out of the GIS	No use of MCDA	2 OUT OF 3

TABLE 26 LEVEL OF APPLICATION OF GIS, PP AND MCDA IN CASE STUDY 6

5. GENERAL DISCUSSION OF RESULTS AND FURTHER RESEARCH

5.1.1. Analysis of results

This chapter presents a general discussion of the results shown in the previous ones in order to link the findings of the diverse stage of research.

A comparative analysis of the six case studies outlined in this work of thesis is shown in TABLE 28. For each case study the following attributes have been analyzed:

- Main goal: in this section the main aim of the application of methodology to the case study is described.

- Location: most of the studies have been conducted for the city of Catania in Italy (four out of six); case study 3 was led for the city of New York (USA), while case study one, which was a hypothetical exercise, analyzed transit in the cities of Santa Cruz de Tenerife (Spain) and Prato (Italy). This last study is the result of a research period conducted during the first year of the PhD course at the *Centro de Investigación del Transporte TRANSyT* of the Universidad Politécnica de Madrid, under the supervision of the Professor María Eugenia López-Lambas.

- Data Sources: the leitmotiv in the collection of study sources was the use of open data, freely available to everyone in order to allow for greater reproducibility of the studies.

- Method: from the comparison of the case studies it is possible to see how Geographic Information System plays an important role in all of them.

- Products: Most of the case studies have as result several thematic maps; case 1 and 5 provides for a priority ranking between alternatives.

- Strengths: main common strengths are the application of mathematical models to support decision making processes; the use of the thematic maps to inform about impacts of interventions; the attempt to include social issues or citizen participation.

- Challenges: A better public involvement and a better integration among the three components (MCDA, GIS and Public Participation) is the emerging challenge in all the case studies (See Table 22).

- Published: most of the studies have been presented at International Conferences and published in proceedings; in particular:

    - Case Study 1 has been presented at the International Conference Urban Transport 2017, held in Rome from the 5th to the 7th of September 2017 and published in the proceedings volume

    - Case Study 2 has been presented at the International Conference on Traffic and Transport Engineering (ICTTE) held in Belgrade from the 23rd to the 25th of November 2016 and published in the proceedings volume

    - Case Study 3 has been presented at the XIII International Conference 'Living and Walking in Cities' held in Brescia from the 15th to the 16th of June 2017 and published in the proceedings volume

- Results presented in Case Study 5 come from two studies presented at the AIIT International Congress on Transport Infrastructure and Systems - TIS 2017 held in Rome from the 10th to the 12th of April 2017 and EWGT 2017 held in Budapest from the 4th to the 7th September 2017

A global representation of the contribution of the three components in each case study is shown in TABLE 27.

TABLE 27 MCDA, GIS AND PUBLIC PARTICIPATION: CASE STUDIES' COMPARISON

	Public participation	Use of GIS	MCDA	Integration
Case Study 1	No citizen involvement, but social issues are included	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	MCDA to evaluate alternatives	Medium
Case Study 2	No citizen involvement, but social issues are included	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	No use of MCDA	Poor or No integration
Case Study 3	Information giving	Important role in the analysis of scenarios; weights are decided out of the GIS	No use of MCDA	Medium
Case Study 4	No citizen involvement, but social issues are included	Predominant role in the analysis of the scenarios; weights assigned according to indicators derived from GIS analysis.	No use of MCDA	Poor or No integration
Case Study 5	Citizens' Active Participation	Important role in the analysis of scenarios; weights are decided out of the GIS	MCDA to support consensus building	High
Case Study 6	Citizens' Active Participation	Important role in the analysis of scenarios; weights are decided out of the GIS	No use of MCDA	Medium

TABLE 28 – CASE STUDIES' COMPARISON

	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5	Case Study 6
Main goal	Hypothetical exercise on multi criteria decision analysis comparison of transit	Investigation of the relation between transport accessibility and social exclusion	GIS approach to evaluate the need of different kind of interventions	Provide design criteria for a cycling network based on the use of GIS	Structuring a transport decision-making problem through a hierarchy by involving key stakeholders	Demonstrate how by cost-free social networking citizens can participate in reporting city issues
Location	Prato/Tenerife	Catania	New York	Catania	Catania	Catania
Data Sources	COST projects results; Free online local transport companies information.	Italian Statistic Institute, General Urban Traffic Plan	theQueensWay.org	Italian Statistic Institute, General Urban Traffic Plan, Openstreetmap	In-depth interviews	Voluntary Geographic Information
Method	Loose coupling integration of GIS and MCDA	Accessibility GIS analysis	GIS analysis and Public GIS visualization	GIS based evaluation	Tight coupling integration of GIS and MCDA	PPGIS
Products	Priority ranking	Accessibility maps, Lorenz Curve and GINI index	Viewshed analysis, Infrastructure and activity analysis, proposal of intervention	Several thematic maps, proposal of intervention	Priority ranking	Collaborative public map
Strengths	Providing ideal solution for cities with particular characteristics	Mathematical approach to social issues through index of inequality.	Public information, bottom up initiative	Use of multilayer GIS to design	Stakeholders' involvement	Citizen involvement
Challenges	This kind of approach does not allow the inclusion of local issues	The scenarios evaluation only consider accessibility as parameter; a MCDA could allow the evaluation of other criteria and include stakeholders' opinions	A Public Participatory GIS would allow citizen to add proposals	This study lacks of public participation by stakeholders	Transferring the role-playing game to real stakeholders	To integrate citizens reports with technical planning
Published	Yes	Yes	Yes	No	Yes	No

If we consider transport scenarios evaluation a process composed of three phases - Individuation of impacts, Identification of indicators and Comparison of alternatives – (Cascetta, 1998), based on our literature and case study analysis, it's possible to evaluate the contribution of each of the three elements – GIS, MCDA, Public Participation – and of their integration in each phase of the process.

In the first phase effects and impacts which are relevant for the decision makers in relation to the objectives of the intervention are identified. In this phase a **GIS analysis** of the study area plays the role of **inhibiting spatial unfeasible alternatives**; a **PPGIS** could allow reports from citizens about the state of the art through the insertion of **VGI**; the **identification of stakeholders** is conducted and basing on these premises a **MCDA technique** is chosen.

When passing to the identification of performance criteria and estimating their values for each scenario alternative, **GIS-Based MCDA** allows the evaluation of **spatial indicators** (while the other ones are estimated through MCDA) and **Group MCDA techniques** are used in **weights assignment by stakeholders**.

In comparing the alternatives, through **PPGIS** it will be possible for stakeholders to be informed on the **spatial impacts** of the different scenarios; then MCDA techniques should be applied to **support consensus building**.

The framework of the contribution of GIS, MCDA and Public Participation in evaluation process is showed in Figure 70.

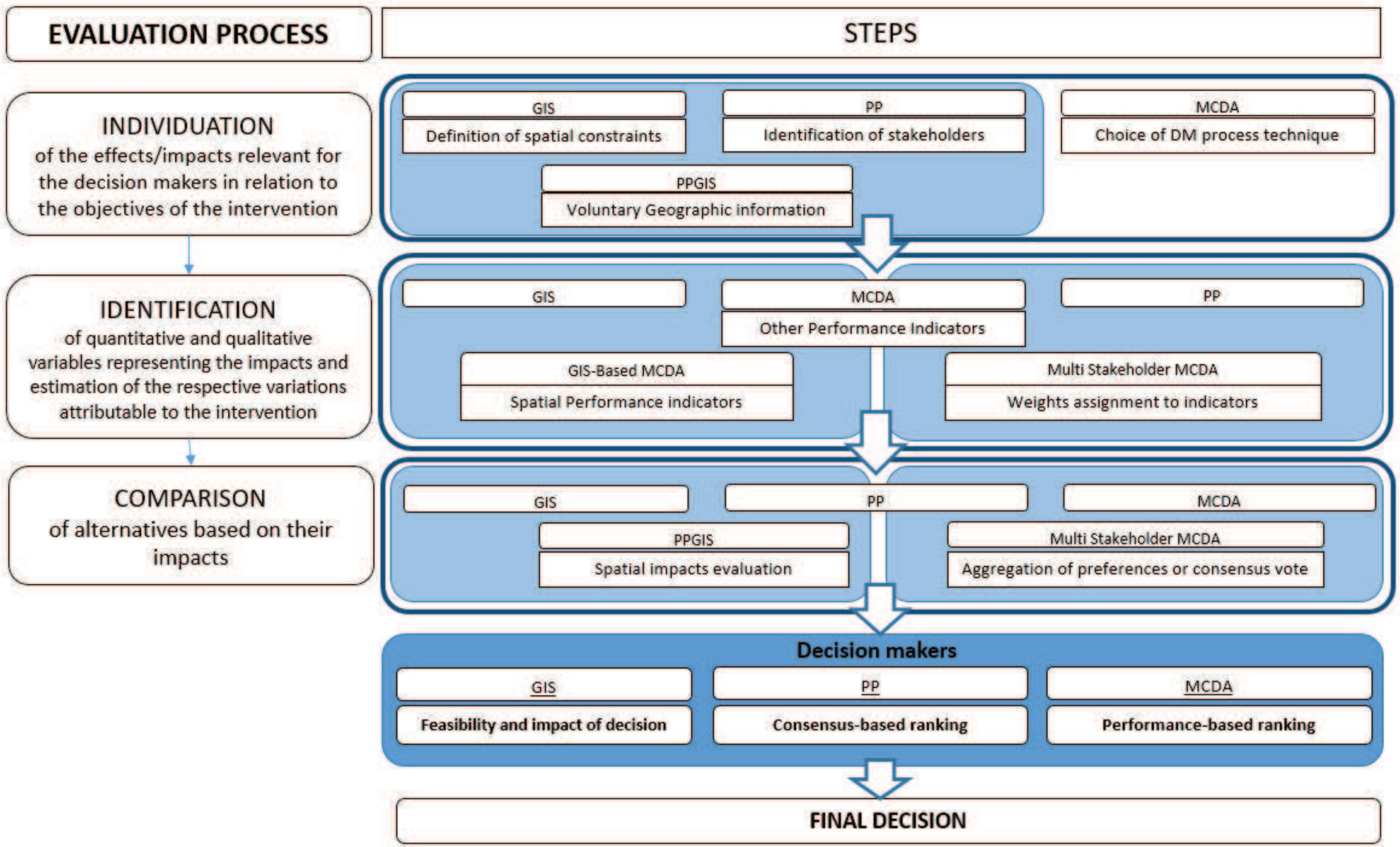

FIGURE 70 FRAMEWORK OF THE CONTRIBUTION OF GIS, MCDA AND PUBLIC PARTICIPATION IN EVALUATION PROCESS

5.1.2. Conclusion and future research

This work of thesis presented a new outline for decision making process including the integration of Public Participatory GIS and MCDA, presenting a methodology for evaluating transport design scenarios that includes economic, social, environmental and institutional sustainability parameters and non-monetizable criteria. The aim of the thesis was to provide a framework for the development of a decision support tool which would permit decisions with a high technical value and widely accepted by citizens. Several case studies have been analyzed, with several level of integration, with the result that even with a low level of integration the process gains transparency and final decision takes into account both transit performance evaluation and consensus by citizens. On the basis of case study results, a framework of integration of GIS, MCDA and Public Participation into a scenario evaluation procedure has been presented. Future studies could address the questions and gaps that come out from this research and from the analysis of the case studies. A first one is the identification of participants to decision-making process: depending on the decision the choice between involving stakeholders or citizens must be taken; at the same time, wide public involvement increases the threats to spatial data quality in the case of Voluntary Geographic Information in PPGIS. In the evaluation of the actors, Social Network Analysis techniques could allow to quantify the social importance of the different individuals in the stakeholders' network. Depending on the actors involved in the decision-making process, other techniques can be introduced to support the procedure: stated preference surveys enhanced by GIS by providing respondents with maps and other spatial and non-spatial information in graphical form may be used to increase respondents' understanding of decision scenarios. A further development of the research is the modeling of the proposed framework within a tool able to integrate all the provided procedures.

Finally, findings of this study pave the way for future research in supporting transport decision-making process; this research can be considered as a first step of a procedure that can support a more diffuse involvement of stakeholders in order to achieve a good social sharing and robustness of policy makers' decisions.

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ANNEX

A. López Lambas M.E., Giuffrida N., Ignaccolo M., Inturri G. Comparison between bus rapid Transit and light-rail transit systems: A multi-criteria decision analysis approach. Conference proceedings of Urban Transport 2017, Rome 5-7 September 2017.

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COMPARISON BETWEEN BUS RAPID TRANSIT AND LIGHT-RAIL TRANSIT SYSTEMS: A MULTI-CRITERIA DECISION ANALYSIS APPROACH

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ABSTRACT
The construction choice between two different transport systems in urban areas, as in the case of Light-Rail Transit (LRT) and Bus Rapid Transit (BRT) solutions, is often performed on the basis of cost-benefit analysis and geometrical constraints due to the available space for the infrastructure. Classical economic analysis techniques are often unable to take into account some of the non-monetary parameters which have a huge impact on the final result of the choice, since they often include social acceptance and sustainability aspects. The application of Multi-Criteria Decision Analysis (MCDA) techniques can aid decision makers in the selection process, with the possibility to compare non-homogeneous criteria, both qualitative and quantitative, and allowing the generation of an objective ranking of the different alternatives. The coupling of MCDA and Geographic Information System (GIS) environments also permits an easier and faster analysis of spatial parameters, and a clearer representation of indicator comparisons. Based on these assumptions, a LRT and BRT system will be analysed according to their own transportation, economic, social and environmental impacts as a hypothetical exercise; moreover, through the use of MCDA techniques a global score for both systems will be determined, in order to allow for a fully comprehensive comparison.
Keywords: BHLS, urban transport, transit systems, TOPSIS.

1 INTRODUCTION

In recent years a large quantity of funds has been invested in the realization of Bus with a High Quality Level of Service (BHLS) systems, which can be defined as a system that “offers to the passenger a very good performance and comfort level, as a rail-based system, from terminus to terminus at station, into vehicle and during the trip” [1].

Yet from this definition it is possible to understand why a great interest has been shown in the comparison between this type of system and the Light-Rail Transit (LRT) system; moreover, when comparing it to the Bus Rapid Transit (BRT) system, which, at its peak performance, can reach up to one million passengers per day [1]. Supporters of the BRT system highlight how rubber tires allow for operation flexibility, which is impossible for a tram system; while those decrying BRT say that such flexibility does not ensure a high quality of service. In the United States, the debate concerning BRT and LRT systems is very tight and supporters of LRT have accused the US Federal Transit Administration of excessively sponsoring systems like BRT only with the purpose to facilitate road transport and oil industry lobbying [2].

The main differences between the two systems are essentially due to the following characteristics:

- BHLS systems allow for more track flexibility;
- LRT vehicles have a longer life than BHLS systems;
- Initial funding for the realization of BHLS systems is generally less than for LRT systems;

- LRT systems can operate safely on rails, in tunnels and on overpasses;
- Access time to LRT stops is generally longer than to BHLS stops;
- LRT vehicles need less space both in stations and on tracks.

The characteristics of a BHLS system that make it more similar to a tramway are to be found in the improvements compared to a classic road for public transport:

- A reduced number of stops;
- Reserved lanes in which it is possible for the bus to achieve a higher speed, without excluding the possibility of operation in a mixed zone; reserved lanes introduction is not dependent "from means of transport riding but from political support which allows to deduct space for cars, offering alternative solutions to car drivers" [3];
- Priority systems at intersections and turn prohibitions for motorized vehicles on the reserved lane;
- High frequency;
- Increased comfort due to the absence of continuous acceleration and braking;
- Information about the real-time position of the vehicle;
- Ticketing outside the vehicle;
- Road-level access through low-floor bus and stations equipped with facilities for passengers.

Marc Le Tourneur, a member of the *Direction de l'Innovation et du Développement of Veolia/Transdev*, argues that the choice between a BRT system and a tramway is mainly related to the number of passengers: a number of less than 3000 passengers/h should lead to opting for the BRT system; a larger number for the tram system [4]. Actually, it is not possible to consider a system absolutely more suitable than the other; both the solutions could be ideal on the basis of a particular scenario. Choice criteria should include each system's available funds, its operation costs, environmental improvements and possible economic developments. Conventional cost-benefit analysis is not always able to take into account all of the wide range of impacts deriving from the competing projects, since it generally provides the decision maker with an economic assessment expressed in a monetary scale. Multi-Criteria Decision Analysis (MCDA) techniques are indeed able to incorporate multiple parameters related to both economic and strategic aspects and they are a good aid for decision makers in identifying priorities.

In this study, MCDA will be used to evaluate the choice between the application of a BHLS system and a LRT one; a spatial analysis via a Geographical Information System (GIS) environment will be used for designing some parameters of the analysis.

2 METHODOLOGY

2.1 Literature review

Through an analysis of recent literature on the evaluation of transport projects, it can be seen that there are several articles reporting growing attention to the use of MCDA techniques; this is due to the fact that MCDA is able to cope with several criteria besides the economic aspects and can also deal with different, often contrasting, decision makers [6], [8], [9].

In particular, the use of compensatory approaches (based on the assumption that a high performance achieved on a criterion can compensate bad performance of another one) is widespread in mobility management, infrastructure and public transport analysis; it is used in the comparison of different road or rail projects [10], [11], the construction of public transportation models [12], integrated planning for public transport and land use development [13], and in the creation of personalized route planning systems [14].

Decision-making problems, as transport system evaluations, require taking into account some spatial parameters of each alternative; integration with GIS can be useful in this perspective. Jankowski [6] distinguishes between two strategies for integrating GIS with MCDA: the first strategy suggests linking them by using a file exchange mechanism (*loose coupling strategy*); the second strategy suggests the full integration of multiple criteria evaluation functions into GIS with a shared database and a common user interface. In Gonçalves Gomes and Estellita Lins [15], a multi-objective linear programming technique integrated in a GIS environment is used to select the best municipal district of Rio de Janeiro State in Brazil, in relation to the quality of urban life. A good example of integration between MCDA and GIS in the transport field is the evaluation of alternatives in transportation planning made by Piantanakulchai and Saengkhao [16] in which a case study of alternative motorway alignments in Thailand was conducted through the application of a compensatory approach.

In our study, a loose coupling strategy will be adopted and compensatory MCDA methods will be applied to evaluate the global score of both LRT and BRT systems.

2.2 Fundamental objectives and related criteria

MCDA techniques allow the evaluation of different project solutions on the basis of a limited number of criteria, through a unique global judgement, giving the decision makers the chance to tend to the most satisfactory opportunity.

In its basic application, any MCDA technique pursues the following steps:

- Identification of the alternatives, which may consist of different project solutions or different elements of a whole project;
- Identification of the objectives;
- Identification of criteria, which are performance indicators related to each objective; they can be both quantitative and qualitative.

In our study, the two different transport systems BRT and LRT will be compared through the application of a MCDA technique, illustrated in sections 2.3 and 2.4. Here we present the objectives to be satisfied, divided into three categories according to their corresponding impacts: transportation impact, economic impact, social and environmental impact.

The main objectives and their associated criteria in the transportation impact category are:

1. Improve safety: the number of interaction points with other road users such as road junctions, roundabouts, pedestrian crossings and right of way;
2. Improve security;
3. Improve accessibility: two different types of accessibility can be taken into account. A a passive accessibility, i.e. the difficulty of access by communities to the transport system, which can be represented by:

$$A_i = \frac{1}{\sum_{i=1}^{n}(P_i * d_i^c)}, \quad (1)$$

where A_i is the difficulty of access by community in the Traffic Analysis Zone (TAZ) of the transport system; P_i is the population in the TAZ i; d_i^c is the distance of TAZ i to the nearest transport system station; c is a parameter reflecting the willingness to use the system; an active accessibility, measuring the easiness of reaching opportunities for people leaving the transport system, which can be measured by Hansen's accessibility index:

$$A_i = \sum_j \left(\frac{B_j}{d_{ij}^a}\right), \quad (2)$$

where A_i is the difficulty of access by users getting off the transport system at the station i; B_j is the opportunities in the TAZ j; d_{ij} is the distance from i to j; a is a deterrence parameter. Nine different types of activities have been taken into consideration to evaluate active accessibility, according to the following categories: parking locations, health places, administrative offices, worship places, food shops and courts, entertainment, education, culture/tourism, tourists' accommodation. The results have been classified into 10 different levels of passive and active accessibility.

4. Minimize travel cost. Generally, the public transport systems, on rail or road, are represented with not-congested network models, which means that they neglect speed reductions due to the phases of boarding and alighting of the passengers at the stops, and also the cost perceived by users in relation to the degree of crowding on board. For systems on totally or partially mixed ways (e.g. tramways, buses, etc.), it is preferred to estimate the commercial speed of the line, which depends not only on the characteristics of the vehicles (maximum speed, acceleration, etc.), but also on road traffic on the mixed way.
5. Guarantee integration with other transport systems. The integration criterion is used to judge how well the structure is integrated with other transport systems and other city structures. Separate underground and aboveground systems are an example of disintegrated structures. Transfer nodes, shared stops, common information for passengers, common tariff, coordinated timetables, shared road sections.
6. Guarantee flexibility. This criterion is related to the potential of renewing elements of the system, such as including other itineraries, displacing the track, moving the stops' locations.
7. Maximize capacity, in order to achieve a higher number of passengers carried at peak hour.
8. Optimize reliability. This criterion is used to guarantee the highest punctuality being in the interest of the operator, public transport management, and passengers.

The main objectives and their associated criteria in the economic impact category are:

1. Minimize infrastructure cost;
2. Minimize operating and maintenance costs;
3. Minimize vehicle purchasing costs;
4. Maximize urban public transport system profitability.

The main objectives and their associated criteria in the social and environmental impact category are:

1. Avoid community severance: community severance, or the barrier effect, happens when the transport system limits people's mobility, instead of facilitating it. Railways, motorways, and roads with high traffic levels or speeds, create physical and psychological barriers that separate communities, with effects on walking and cycling mobility and possible negative effects on individual health and social cohesion.
2. Minimize land use: the land use criterion should be considered in order to assess whether an element of the infrastructure is likely to require more or less space.

3. Improve comfort. This takes into account the social requirements of urban public transport passengers by guaranteeing the optimum travel conditions. It determines the percentage share of the travel performed in good and very good conditions during an entire urban public transport journey. This criterion also takes into account the share of seated travel, i.e. the number of passengers able to occupy seats on the urban public transport vehicles.
4. Minimize energy consumption, basing on kWh produced by both transport systems.
5. Noise pollution. Roadway noise is the prevalent environmental noise in the cities; emissions from vehicles are influenced mainly by traction mechanisms, and by the contact between the wheel and the sliding surface. The noise level N_i to the TAZ i if a transport system would be constructed can be evaluated as:

$$N_i = N_0 - \alpha \log \frac{D_i}{D_0}, \tag{3}$$

where N_0 is the noise level at a standard distance from the centre of the line; D_0 is the standard distance from the centre of the line; D_i is the shortest distance between the line and the TAZ centroid; α is a parameter reflecting type of ground and obstruction from roadside; total weighted noise impact N to neighbouring communities could be represented by [16]:

$$N = \sum_{i=1}^{n} \frac{(\frac{P_i}{\bar{P}})(\frac{N_i}{N_0})}{L_{i,noise}}, \tag{4}$$

where P_i is the population within the community i; $\bar{P}$ is the mean population; $L_{i,noise}$ is the Land use factor related to the noise impact on the community i (equal to 1 in this study).
6. Air pollution, expressed in kg/m^3 using the Gaussian Air Dispersion Model [18].

2.3 TOPSIS

TOPSIS, which stands for 'Technique of Order Preference Similarity to the Ideal Solution', is a goal reference technique that requires a minimal number of subjective inputs (just the weights associated to the criteria; the fundamental idea is that the best solution is the one which has the shortest distance to the ideal solution and the furthest distance from the anti-ideal solution [5].

The TOPSIS method is based on five computation steps [17]:

1. The first step is the gathering of the attribute values of each alternative on the different criteria.
2. Attribute values need to be normalized in order to allow the comparison of different units. Normalization has been made through the application of two different methods. The distributive normalization, which requires that the performances are divided by the square root of the sum of each squared element in a column, according to the following equation:

$$r_{ia} = \frac{x_{ia}}{\sqrt{\sum_{a=1}^{n} x_{ia}^2}} \text{ for } a = 1, \ldots, \text{n and } i = 1, \ldots, \text{m}. \tag{5}$$

The ideal normalization, which requires dividing each performance by the highest value in each column if the criterion has to be maximized. If the criterion has to be minimized, each performance is divided by the lowest score in each column, according to the following equations:

$$r_{ai} = \frac{x_{ai}}{u_a^+} \text{ for } a = 1, \dots, n \text{ and } i = 1, \dots, m, \tag{6}$$

where $u_a^+ = \max(x_{ai})\ for\ all\ a = 1, \dots, n$;

$$r_{ai} = \frac{x_{ai}}{u_a^-} \text{ for } a = 1, \dots, n \text{ and } i = 1, \dots, m, \tag{7}$$

where $u_a^- = \max(x_{ai})\ for\ all\ a = 1, \dots, n$.

3. Normalized scores are then weighted. A weighted normalized decision matrix is constructed by multiplying the normalized scores r_{ai} by their corresponding weights w_i.
4. The distances to an ideal and anti-ideal point are calculated. The decision has been made to assume an absolute ideal and anti-ideal point, defined without considering the actions of the decision problem, A+ = (1, ..., 1) and A− = (0, ..., 0). The distance for each action to the ideal action is calculated using the following equation:

$$d_a^+ = \sqrt{\sum_i (v_i^+ - v_{ai})^2}\ with\ i = 1, \dots, m. \tag{8}$$

The distance for each action to the anti-ideal action is calculated using the following equation:

$$d_a^- = \sqrt{\sum_i (v_i^- - v_{ai})^2}\ with\ i = 1, \dots, m. \tag{9}$$

5. Finally, the closeness, whose value is always between 0 and 1, is given by the ratio of the calculated distances:

$$C_a = \frac{d_a^-}{d_a^+ + d_a^-}. \tag{10}$$

3 CASE STUDY

3.1 Cities involved

For the application of the methodology, as a hypothetical exercise, the tramway of Santa Cruz de Tenerife in Spain and the BRT system of Prato in Italy have been chosen for comparison. These two cities were chosen because of their similar characteristics with regard to geographic and demographic data, and because of the similarities noticed between the two respective transport systems, as it can be seen from the data reported in Table 1. Data used for this study, as well as information regarding the transport system, refer to the year 2013 (see http://www.comune.prato.it/ and http://www.santacruzdetenerife.es/).

The public transport system in Prato includes a railway system and urban and sub-urban bus lines. This road network is based on different bus lines operating in the whole Prato area managed by CAP (Cooperativa Auto-trasporti Pratese). Five BHLS lines – LAM (*Linee ad Alta Mobilità*) – operate in the city: the Blue line (Fig. 1, analysed in this study), Red line, Orange line, Light blue line, and Purple line. The first three serve the urban area, whereas the Light blue line and Purple line link the city centre with the sub-urban area.

Table 1: Summary of the characteristics of the two cities included in the study.

Cities	Area (km^2)	Population (inhab.)	Density (inhab./km^2)	System	Line	Length (km)
Tenerife	150.56	214,477	1363.44	Tram	1	12.6
Prato	97.35	191,070	1962.01	BHLS	Blue	9.61

The main urban transport systems of Santa Cruz de Tenerife consist of collective *guaguas* (bus lines managed by the operator TITSA), and the tramway of Tenerife is managed by *Metropolitano de Tenerife Sociedad Anónima* (MTSA). The Tramway of Tenerife covers a total of 15.1 km and includes two lines, the Línea 1 and 2. The Línea 1, analysed in this study (Fig. 2), opened in 2007, is the main line with 21 stops and a length of about 12.6 km, and links the *Intercambiador de Transportes* of Santa Cruz de Tenerife at the Trinidad station.

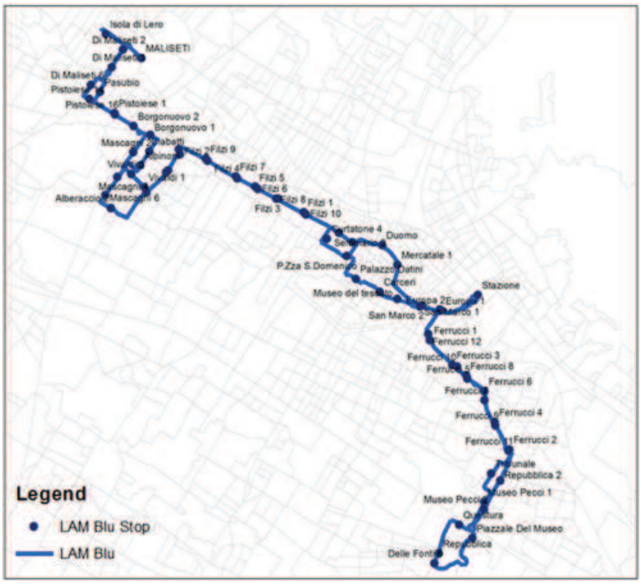


Figure 1: Prato BRT study area.

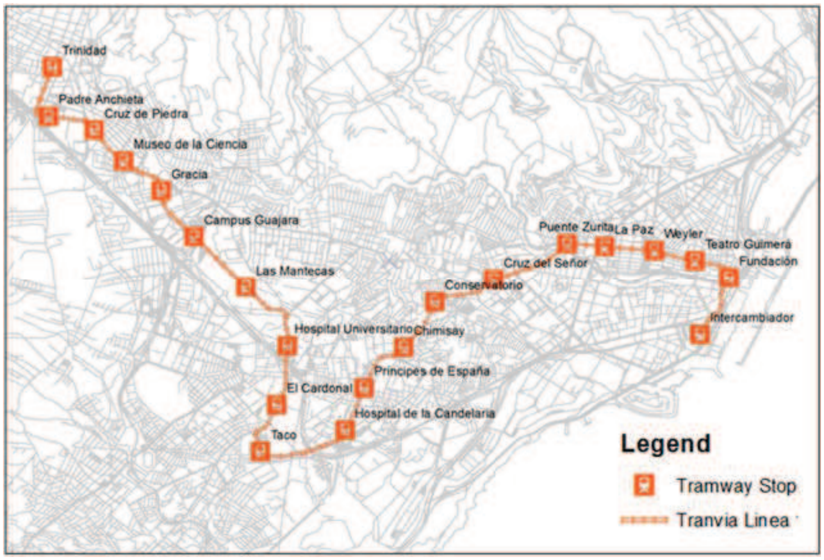


Figure 2: Tenerife LRT study area.

3.2 Weight assignments

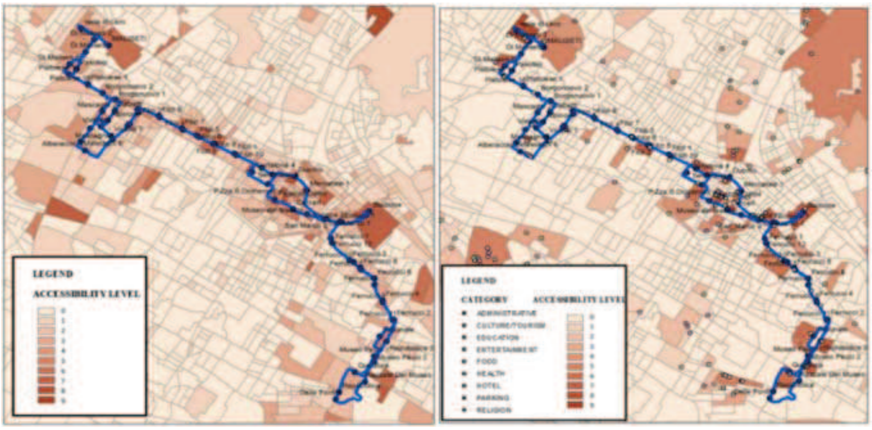
Since it is not possible to involve, at this stage of the study, decision makers and stakeholders of the two communities, it has been decided to assign the same weight to all criteria, making sure that the total sum of the weights would be equivalent to 1.

3.3 Evaluation of indicators

Data on vehicle purchasing costs, profitability and seated travel are not included in this case study; all the other indicators have been evaluated from COST Actions TU0603 and TU1103 [1], [19], and from information given by the operation companies in their websites; the indicators used for analysis are shown in Table 2. The estimation of spatial indicators has been realized through the use of the software ArcMap10.1 in the ArcGIS environment. The final outputs of indicator evaluation are the criterion maps which, with regard to accessibility indicators, are shown in Figs 3 and 4. In order to interpret what is represented in the maps, the values of accessibility indices have been normalized and grouped into 10 different levels (from 0 to 9, with 0 being the lowest accessibility level to 9 being the highest accessibility level). In both cities, it is possible to see how the zones surrounding the transit line always show high levels of accessibility.

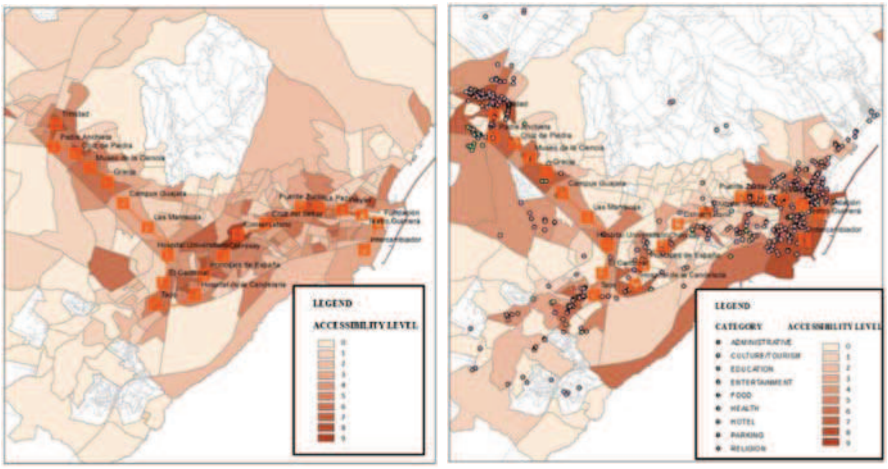
Table 2: Indicators used for TOPSIS method.

City		Tenerife	Prato
Transport system		Tram	BHLS
Criteria	*Unit*	*Attribute*	
Area	km^2	150.56	97.35
Population	Inhab.	205279	190777
Density	Inhab./km^2	1363.44	1959.70
Length	km	12.62	15.10
Interaction points	Number/length	38.00	283.00
RoW	length mixed/length	0.00	0.30
Accidents	Acc./km	1.73	4.37
Criminality	Number/year/inhab.	0.00	
Passive accessibility	INDEX (medium)	0.58	110.50
Active accessibility	INDEX (medium)	1288.59	856.95
Cost	h	0.59	0.80
Speed	Km/h	21.30	18.90
integration nodes	percentage	1.00	4.00
shared stops	percentage	0.44	0.46
information for passengers	yes/no	0.00	1.00
common fare	yes/no	1.00	1.00
coordinated timetables	yes/no	0.00	1.00
shared intermodal sections	Length/tot length	0.00	0.00
Flexibility	yes/no	0.00	1.00
Capacity provided	Pass/h	5400.00	282.86
punctuality	percentage	0.995	0.74
Infrastructure cost	€/km	€ 22,821,638.06	€ 589,400.00
Operating and maintenance costs	€/km	€ 812,500.00	€ 1,300,000.00
Community severance	m/km	0.18	0.00
Energy	kWh/km	6.53	7.72
Noise level	INDEX	42.91	215.40
Air pollution N_{ox}	kg/m^2	0.000001	0.000033
Air pollution PM_{10}	kg/m^2	0.000000	0.000000
Air pollution CO_2	kg/m^2	0.000086	0.000002
Air pollution CO	kg/m^2	0.000000	0.000003



(a) (b)

Figure 3: (a) Passive and (b) active accessibility levels in Prato.

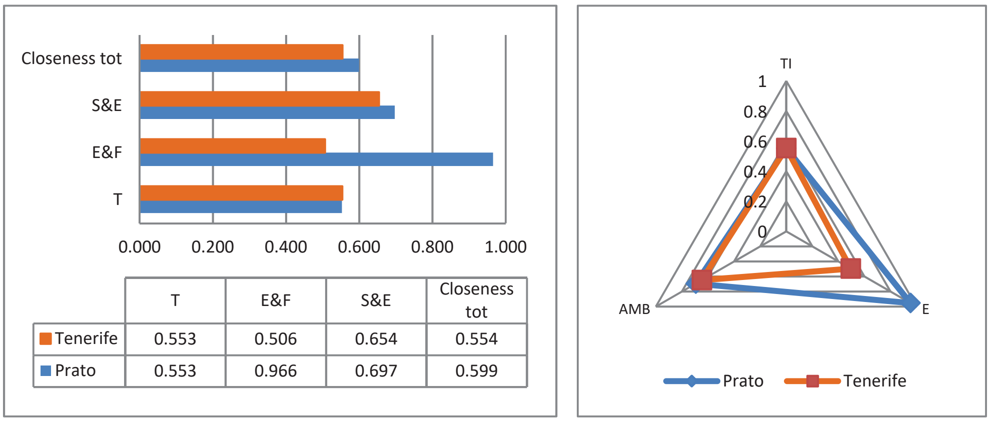


(a) (b)

Figure 4: (a) Passive and (b) active accessibility levels in Tenerife.

3.4 MCDA through TOPSIS approach

The ideal normalization approach has been applied; the technique ranked the two alternatives assigning a better global score to the BRT solution, indicated through the total closeness in Fig. 5(a). Analyzing partial scores, BRT obtained a better score for Social and Environmental impact score (S&E; Fig. 5), a high partial score for the Economic and Financial impact score (E&F; Fig. 5), while in the Transportation impact score, LRT just overpasses BRT. In the radar chart of Fig. 5(b), it is possible to appreciate the closeness of each partial indicator to the ideal solution, with the Economic impact score of BRT standing out among the others, almost reaching the value of 1.



(a) (b)

Figure 5: Ideal normalization TOPSIS (a) results and (b) radar chart.

3.5 Sensitivity analysis

A sensitivity analysis has been conducted in order to identify whether the outputs coming from the method are influenced by the weights assigned to the input factors. Most of the time, in fact, data in multi-criteria decision-making problems are changeable and unstable, and a sensitivity analysis after problem solving can effectively contribute to the choice of the appropriate method to obtain more accurate decisions.

Three more possible weight scenarios of analysis have been assumed: a scenario in which all the impacts have the same weight; a hierarchical scenario in which social impact criteria have the biggest weights and economic impact criteria the smallest ones; a scenario with random weights assigned. Partial scores, global score and their variances (Tables 3 and 4) within the four analysis scenarios have been calculated. Sensitive analysis shows that the solution is robust.

Table 3: Partial and global score comparison within the four different weight scenarios.

Method	Scenario	City	T	E&F	S&E	TOT
TOPSIS ideal	Base	Prato	0.552	0.952	0.694	0.599
		Tenerife	0.553	0.495	0.648	0.554
	Impacts	Prato	0.553	0.927	0.691	0.599
		Tenerife	0.554	0.414	0.641	0.519
	Hierarchy	Prato	0.552	0.9524	0.694	0.600
		Tenerife	0.553	0.4956	0.648	0.554
	Random	Prato	0.552	0.940	0.678	0.598
		Tenerife	0.553	0.489	0.598	0.545

Table 4: Variances of the four analysis scenarios.

	Transportation impact	Economic impact	Social and environmental impact	Total score
Prato	3.72E-06	1.39E-06	6.54E-08	3.16E-06

Tenerife	2.37E-05	1.58E-05	9.29E-08	1.88E-05

4 CONCLUSIONS

After some years of the disposal of tramway lines, we are currently witnessing their great renaissance and a consequent modernization of vehicles and operations that are leading to the increased use of LRT systems. At the same time, a new bus system concept providing high quality service is developing and the competition between the two types of systems is becoming more frequent. In this paper, a comparison between LRT and BRT systems has been conducted with the use of the TOPSIS technique. A case study involving the cities of Prato and Santa Cruz the Tenerife has been presented. The results of the application to a medium-sized city with similar characteristics gave comparable results concerning partial and global scores, indicating that the BRT system is the best solution.

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PUBLIC TRANSPORT ACCESSIBILITY AND SOCIAL EXCLUSION: MAKING THE CONNECTIONS

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Abstract: Social exclusion is a condition affected by different factors: quality of life, low income, inadequate housing conditions, high crime rates, elderly age and ethnic/cultural minority are all crucial aspects that must be considered. The possibility to have a good access, in a spatial sense of the term, to work places, education and healthcare services is a key factor to achieve that the whole population could take part to the society. In many South Italy cities, access to opportunities is mainly guaranteed by private transport, since public transport supply and services are low quality. Public transport should have the main role to overcome the mobility difficulties faced by disadvantaged groups. Accessibility to destinations by public transport can be considered a proper indicator and a simple measure to assess the impact of changes in the transport system on potential users and to evaluate solutions to remove spatial barriers. Accessibility indicators can aid decision makers in the determination of those population categories that are socially excluded and they can also be used to improve transport urban service supply. In this paper transit accessibility measures are evaluated for an urban area using a GIS approach, taking into consideration socio – economic factors from CENSUS data. Moreover, Lorenz curve is used to measure how accessibility by public transport is redistributed among different categories as a result of different alternative transport projects; through the use of this methodology, the Gini coefficients provide a single measure of overall accessibility equity. Methodology is tested in a case study related to the city of Catania.

Keywords: sustainable transport, transport equity appraisal, urban transport, spatial and transport planning.

1. Introduction

In the last few years, cities have been developing fast in more complex and fragmented systems: the reorganization of residential areas, activities and metropolitan services, as well as and the increasing mobility, have distorted rhythms and social dynamics. Vehicular traffic flows and land occupation by parked cars create a barrier effect and a consequent decrease of the possibilities of socialization.
An early form of social exclusion is manifested when individuals possess a poor "mobility capital" (Borlini and Memo, 2011), i.e. their ability to move is reduced, so they are ousted from all those resources located outside of its space range. People too young, too old, unable to drive, or too poor to afford a car or a plane ticket become "second class" citizens, leaning on a public transportation is often unreliable.
Van Wee and Geurs (2011) define social exclusion as the tendency of some people or groups of people to be excluded from a certain minimum level of participation in regional activities in which they wish to participate. The complexity of the phenomenon is evident: it is very difficult to recognize and quantify a minimum level of participation; moreover, the barriers that prevent the ability to participate in civil society are many and not only related to the economic factor. With regard to the field of transport, there is a close relationship between accessibility and social exclusion. The latter is not so much due to lack of services and social opportunities, as to a lack of access to such opportunities.
Preston and Rajé (2007) suggest that social inclusion can be achieved through both the proximity to the activities and services you want (which does not require to support travel costs) and the ability to reach distant destinations within reasonable time, even if with high transportation costs, or both by an intermediate state between those presented.
Lucas (2012) says that inadequate access to transportation and social disadvantage interact more or less directly resulting in what can be defined as "transport poverty". This in turn causes the goods and essential services and opportunities for social interaction to become inaccessible and at the same time cut off citizens from decision-making processes. The social exclusion that results risks triggering a degrading vicious cycle that causes an increase in social inequalities and centralized transport.
One of the policies for the urban mobility of large cities should be to discourage the use of private car when it is not necessary in order to promote new travel behavior and incentives to carry out an extensive and efficient public transport network. While all this is feasible, it must also be assured that the activities and main services are easily accessible by every transport mode. Therefore, a close interaction between the location of urban opportunities and the planning of public transport and of the urban transport system as well is strictly required.
Many people experiment different obstacles to reach opportunities and services: from physical barriers (availability and accessibility of transport) to economic (cost of transport) or urban structure mobility constraints (services located in places which are difficult to access). Until these barriers will not be removed, a significant portion of the population will remain unable to move as they would and, therefore, their opportunities to participate in the life of the communities will remain poor.
Public transport may be able to reduce this mobility gap and therefore to favor social inclusion. In fact, when it's not accessible by the weakest population groups and it's unable to break down the barriers that do not allow the participation to social activities, public transport fails its primary goal: to give access to employment or educational opportunities, medical care services and entertainment venues. In summary, public transport should offer everyone the ability to move and therefore it's a critical issue for social inclusion policies.

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The city of Catania, a medium-sized city (300,000 inhabitants) located in the eastern part of Sicily in Italy, has been for years on the top position of the Italian city for the highest car ownership rate. It appears totally necessary to convert this car possession trend by improving the efficiency of the whole transport system that presents some critical issues as traffic congestion, limited public transport utilization, little diffusion of cycling and walking for systematic trips, inefficiency of the parking management, absence of city logistics measures.
In this paper the relation between transport accessibility and social exclusion will be investigated by means of an approach using Lorenz Curve and Gini coefficient that will evaluate the relative accessibility of census regions in Catania city; methodology will be applied to public transport network and will verify the effectiveness in social inclusion improvements of different transport scenarios.

2. Methodology

2.1. Measuring social exclusion

The equity policies in the field of transport must be supported by a large amount of socio-economic indicators, in order to meet the high level of disaggregation required by social exclusion data.
One of the methodological approaches in the literature is presented by Currie (2010), which makes use of GIS technology by combining the offer of public transport measures with social needs indexes and transport poverty.
The extent of the public transport for each zone is a function of frequency of service and access to stops distance estimated by GIS, while for deeper analysis of the demand for public transport, Currie proposes an aggregate indicator called Transport Need Index. The measure is composed of a summation of social disadvantage indices associated with different weighting, as showed in Table 1. Weights are estimated through a survey of users' travel behavior in the city of Adelaide (Australia), but may not be the same in the case of an Italian city, whose inhabitants have a different travel behavior. Anyway similar indicators can be used to test the correlation among social exclusion and accessibility to public transport.

Table 1
Social disadvantage indicators

Need indicator	Weight
Adults over 18 without cars (Census, 2010)	0.25
Persons aged over 65 (Census, 2010)	0.13
Persons with disabilities (Census, 2008)	0.13
Low income households (lower quintile) (Census, 2008)	0.13
Persons over 15 without a job (Census, 2010)	0.13
Students (Census, 2010)	0.13
Persons 10-18 (Census, 2010)	0.13

Source: (Currie, 2010)

Other indicators of social exclusion, showed in Table 2, are suggested by the Italian Statistic Institute ISTAT (2015):

Table 2
Deprivation index parameters

Parameter
Young people abandoning education and training pathways
Regional poverty index
Population living in rural areas
People at risk of poverty or social exclusion
People in severe material deprivation condition
Overcrowding
Businesses and non-profit institutions that carry out activities with social content
Rate of juvenile crime

Source: (ISTAT, 2015a)

2.2. Measuring accessibility

The concept of accessibility plays an increasingly important role in in transport planning as useful tool to measure the combined effect of locations' proximity and transport connectivity. At the same time, accessibility indicators can incorporate social issues when they measure the level of difficulty experimented by different categories of individuals to reach the economic opportunities or social interaction throughout the area.
However, drawing up a strict and unambiguous definition of accessibility is a complex task. One of the first scholars which considered its importance in the context of spatial planning was Hansen, who defined accessibility as "the potential of interaction opportunities" (Hansen, 1959).

A recent definition that highlights the mutual interaction between land use and transport systems has been provided by Geurs and van Wee (2004). According to the authors, the accessibility can be considered as the measure with respect to which the use of the territory and of transport systems allow groups of individuals to reach activities or locations by a combination of modes of transport.

From these and other definitions in the literature, four major accessibility components can be identified: land use, the transport system, the time factor and the individual dimension (Geurs and van Wee, 2004).

A classification of accessibility measures depending on land use can be done considering the place in question as the origin or destination of the travel. We can therefore distinguish the active accessibility (or origin accessibility), and the passive accessibility (or destination accessibility) (Cascetta, 2009):

- Active accessibility refers to the need to carry out the activities located throughout the area by a user that is in a particular place (generally the resident) and it measures the ease with which he can reach various destinations from an origin. It is useful in locating settlement decisions.
- Passive accessibility refers to the need for the various opportunities that are located in a certain area of the territory, to be achieved by the various users scattered throughout the study area. In other words, it measures the ease with which individuals, business and the services of a target area of the displacements can be reached by the users concerned. It is useful in the location decisions of public services and economic activities.

Most of the formulations in the literature refer to an urban accessibility of active type, whose indicator, in analytical terms, is generally a function of the number of spatial opportunities and the generalized transport cost. In particular, the accessibility indices based on gravitational models provide a measure of the continuous type which weighs the value of the opportunities with respect to a spatial impedance function. The impedance function reflects the effect of decreasing accessibility due to the increase of distance, travel time, or in general of the generalized cost of shipping.

The first application of the gravity model to accessibility measures is attributed to Hansen (1959), which suggested that accessibility across regions was directly proportional to the attractiveness factors (jobs, shops, sports centers, etc.) and inversely proportional to the travel time between the zones, which represents the cost of moving. The Hansen's index has the following form:

$$A_i = \sum_{j}^{n} O_j \cdot f(C_{ij}) \quad (1)$$

Where Oj is the number of opportunities in the zone j and f(Cij) the impedance function among zones i and j. A negative exponential impedance is often used, such as:

$$f(C_{ij}) = e^{-\beta \cdot f(C_{ij})} \quad (2)$$

With C_{ij} generalized cost of travel among *i* and *j* zone and β is a parameter related to the cost, estimated by choosing a destination model. The generic measure of cumulative opportunities can be considered a special case where $f(C_{ij})$ is equal to 1 if C_{ij} is less than the predetermined threshold; it is equal to 0 otherwise.

This type of indicators offers the advantage of requiring a relatively small amount of data (ease of processing and calculation), allowing to differentiate the areas of study and to derive the accessibility indices for each of them. They are particularly useful for assessing the potential of suburban residential areas in allowing access to activities such as shops, schools, workplaces, health care and other services.

2.3. Lorenz curve and Gini index

If we assume the existence of a correlation between accessibility and social exclusion, accessibility indicators can be linked to an economic index, such as the Gini coefficient (which can be calculated as a result of the Lorenz curve tracing) in order to verify the social equity of its improvements.

The Lorenz curve is a simple and effective graphical representation of horizontal inequality, since it was created as an aggregate measure of the distribution of wealth within the population. It lends itself to many applications, from education to biodiversity, quantities that can be combined through the population.

The horizontal axis (Fig. 1) shows the cumulative percentage of the population under examination (from 0 to 100%), sorted according to the increasing value of the indicator, while the vertical axis shows the cumulative percentage same indicator. In the economic field, it is mainly used as a graphical tool for the analysis of inequality of income distribution.

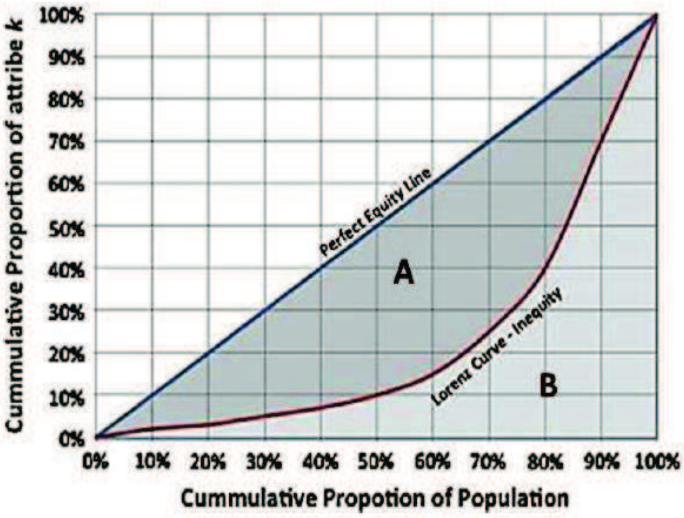


Fig. 1.
Lorenz Curve for a generic attribute k
Source: (Rofé et al., 2015)

In the transport field, social equity considerations are complicated by the fact that not only income plays a role, but also factors such as age, occupation, physical condition and the level of accessibility to services.
In this regard, the use of the Lorenz curve represents an original approach to provide a measure of overall accessibility compared to the entire population (Delbosc and Currie, 2011).
Basing on Fig. 2, Lorenz curve (in red) describes the actual accessibility distribution: each point of the curve indicates the percentage of accessibility owned by a given percentage of population. The blue line at 45° represents the line of equal distribution, i.e. the one corresponding to a perfect distribution of the same attribute. The more the Lorenz curve deviates from the straight line of equal distribution, the higher is the inequality of the distribution of accessibility in the population.
The Gini coefficient, introduced in 1912 by the Italian statistician Corrado Gini, is a mathematical measure of the degree of inequality, related to the area between the Lorenz curve and the straight line of equal distribution (indicated with the letter A in Figure 2). The relationship between this area and the area below the line of perfect equality (A + B in Fig. 2) is the Gini coefficient, which can be mathematically calculated using the following approximate formula in (3):

$$G = 1 - \sum_{k=1}^{n} (X_k - X_{k-1})(Y_k + Y_{k-1}) \qquad (3)$$

where X_k is the generic interval of the cumulative percentage of the population variable and Y_k is the corresponding interval of accessibility cumulative percentage, for $k = 1, ..., n$ and $Y_0 = 0$, $Y_n = 1$.
Gini coefficient can take any value between 0 and 1. A value of 0 implies a situation of complete equality, while a value of 1 corresponds to complete inequality. The lower the coefficient, the lower the inequality of the distribution concerned.
The method described above is useful to analyze the changes over time of the distribution of accessibility in a given region, making it possible to see if inequality is increasing or decreasing. In addition, the Gini coefficient can be compared between different urban realities, obviously using the same methodology for the calculation of accessibility.
However, like any index of its type, it has the limit to remain unchanged if the accessibility of all individuals increases in the same proportion. In fact, being calculated from the relationship between two quantities, it cannot take into account the difference between the absolute values.

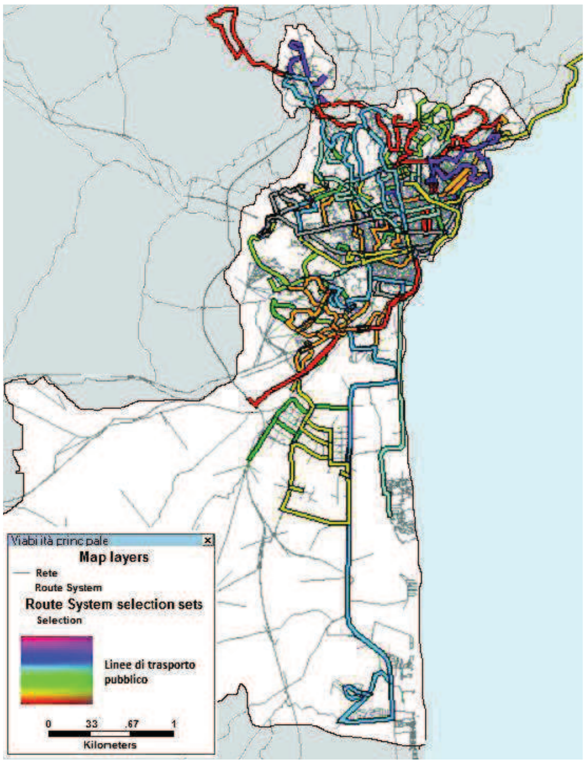
3. Case study

3.1. Territorial framework and transport supply

Catania is a city of about 300.000 inhabitants, located in the eastern part of Sicily (Southern Italy); it has an area of about 183 km*2* and a population density of 1.754,54 inhabitants / km^2 (Istat, 2015b). It's part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania. The main city contains most of the working activities, mixed with residential areas. With reference to the urban area, the transport service is provided by 51 bus lines, a Shuttle line (ALIBUS) connecting the city center with the airport and a second fast bus (called BRT1) connecting a park-and-ride facility on the northern periphery (Due Obelischi) to the city centre (Stesicoro Square). BRT1 is the first of three lines provided by the City of Catania with equipped lanes protected by curbs on the majority of their path and was promoted commercially as *Bus Rapid Transit*. In Catania it is also operated an urban subway line that currently connects the station "Porto" with the station "Borgo" from which continues as a surface long-distance railway line. By 2016 it is expected the undergrounding of the line until the station “Nesima” and it’s also planned the opening of a branch linking the station “Galatea” to Piazza Stesicoro.

3.2. Transport model and scenarios

A mathematical representation of the transport system has been built by the TransCAD modelling tool, a software which combines a Geographic Information System and a set of transport models in one integrated environment.
The zonation used for the city is the one given by ISTAT, which divides the study area in 2480 CENSUS sections. Three different scenarios have been analyzed. The first one, called Scenario 0 (Fig.2), includes 51 bus lines with a speed of 15 km/h; this will be considered as the current scenario and will be taken as base for the comparison with the other two transport solutions. The second one, called Scenario 1, provides for the introduction of three BRT lines and the subway line with the new extension from Borgo Station to Nesima station. The last one called Scenario 2, provides for an improvement of all bus lines speed from 15 km/h to 18 km/h.



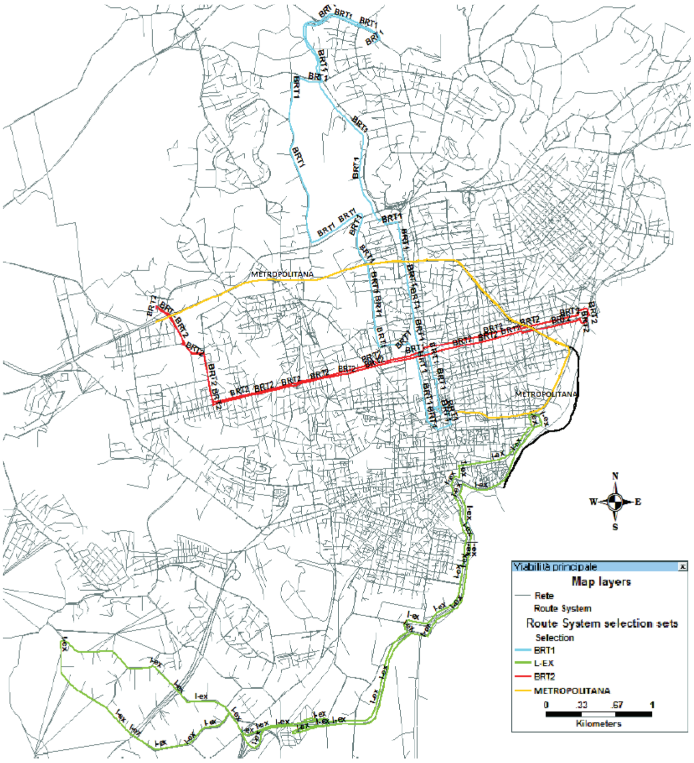


Fig. 2.
Scenario 0 on the left and improvements in the transport system of Scenario 1 on the right

3.3. Accessibility measures

Through the use of TransCAD software, Hansen accessibility measures have been evaluated for the three different scenarios.
The opportunities considered in the analysis include the accessibility of goods and services classified into: Health (hospitals, pharmacies); Education (University, schools, libraries); Places of worship (churches); Entertainment (theaters, cinemas, museums); Restaurants (Restaurants, bars, fast food); Transport services (metro, train station, bus stops). The Hansen Index has been evaluated considering as impedance a function based on the generalized cost of transport and taking into account parameters such as travel time, the cost of travel time, the number of transfers and considering a flat travel fare. The software provides standard values for deterrence index β, based on the selected transport mode and type of opportunities at destination. Values for our study are indicated in Table 3.

Table 3
Deterrence parameter for Hansen Accessibility Index calculation

Scenario	Mode	Destination	β Value
Scenario 0	Bus	Local Centers (No car)	0.082
Scenario 1 and 2		Local Centers (No car)	0.079

The active accessibility of the 2480 zones of the case study has been calculated for the 3 scenarios. Results show that the introduction of the improvements both in Scenario 1 and Scenario 2 provide an increase of accessibility; the amount of improvement for each zone can be deducted by the comparison of maps in Fig. 3, Fig. 4 and Fig. 5. The caption of the maps shows in brackets the number of zones that benefit from increased accessibility.

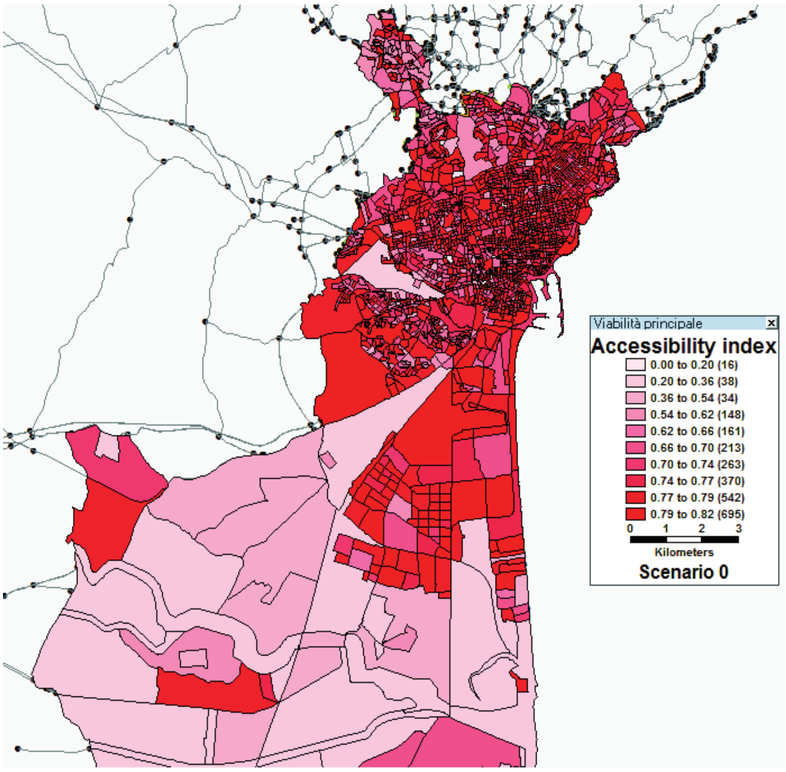


Fig. 3.
Accessibility Map for Scenario 0

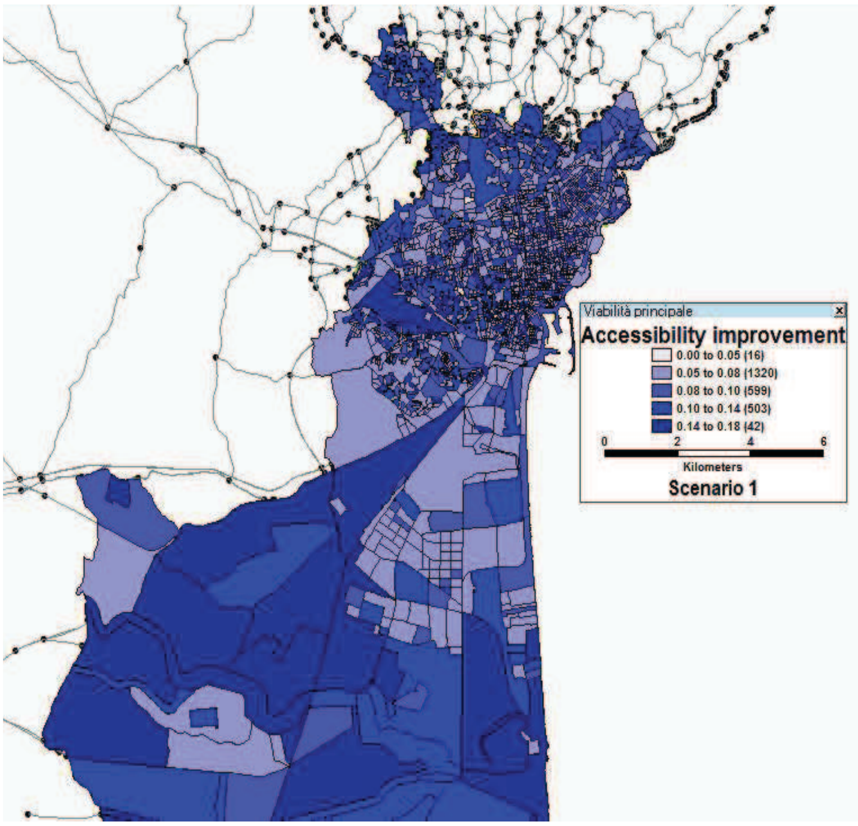


Fig. 4.
Accessibility Improvement Map for Scenario 1

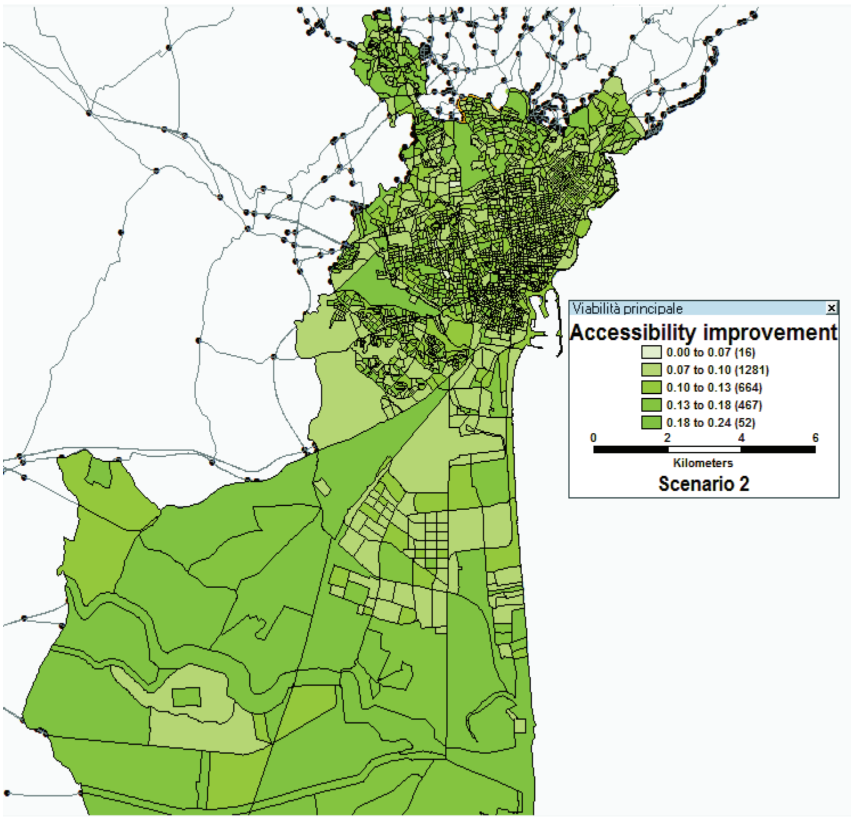


Fig. 5.
Accessibility Improvement Map for Scenario 2

3.4 Lorenz Curve and Gini Index

Lorenz Curve and Gini Index based on Hansen Accessibility measures have been calculated under the 3 scenarios. A graphical representation of Lorenz curves is shown in Fig. 6.
The Lorenz curves for all scenarios are close the perfect equality line (bisector). This does not imply a high level of service public transport, but a low inequality due to a quite uniform service coverage of the whole urban area. Both scenario 1 and 2 produce a significant improvement of equality as it is visible from the increased proximity of each Scenario's curve to the perfect equity line. The distribution of accessibility is quite the same for scenarios 1 and 2, so the relevant curves overlay each other.

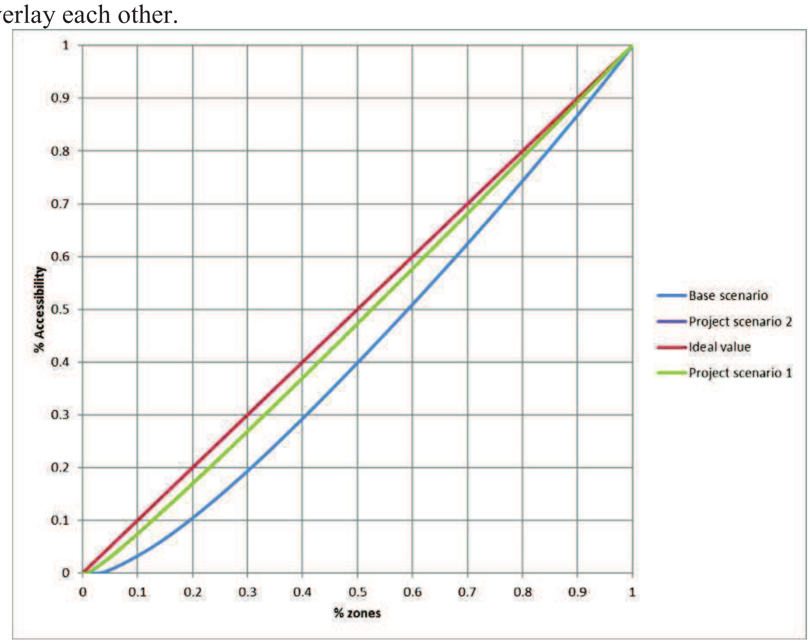


Fig. 6.
Comparison among Lorenz Curve for Scenario 0 and 2

Evaluation of Gini indices, which results are showed in Table 4, confirms the previous results and moreover underlines how Scenario 2 shows slightly better improvements than Scenario 1.

Table 4
Gini Index for the three different scenarios

Scenarios	Gini Index
Scenario 0	0.148485562
Scenario 1	0.046431085
Scenario 2	0.041428445

4. Conclusion

The ability to move and reach places even at great distances, has become an indispensable condition to live well and to integrate into today's society. Mobility is no longer just an option but has become a necessity. However, there are still many citizens who have limited resources or fewer resources than others, and the aim of social inclusion policies is to improve the quality of life of such the weakest sections of the population, in order to reduce exclusion.
Social inclusion is linked to the level of accessibility perceived by the individual, assessed according to the ease of reach of different places, with different availability of transport system. Accessibility awareness by citizens is a key element to coordinate the intervention measures in the field of transport and public services, but also to foster social receptiveness of such measures.
In this paper three different transport accessibility scenarios have been evaluated for the city of Catania. The application of an approach based on Lorenz Curve and Gini Index has showed that the proposed changes in the public transport network design corresponds both to an accessibility improvement and to a major equity of accessibility distribution as well. The methodology described seems to suit well to take decision in transport planning when both accessibility improvement and equity magnitude is crucial the address land use and transport decisions.

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THE *QUEENSWAY* OF NEW YORK CITY

A PROPOSAL FOR SUSTAINABLE MOBILITY IN QUEENS

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Abstract

In the last 50 years many railway lines have been abandoned. The causes of these events might depend on different situations: from the construction of a new high-performance railway track parallel to the pre-existing one to the decrease of rail freight transport demand due to the disposal of industrial areas or also the decrease of rail passenger transport demand due to the improvement of the road.
Recently, especially in Europe, some former railroads have been converted into cycling and pedestrian paths.
In the United States of America, where road transport and private cars have a considerable role in transport system, areas of disused railways are often totally unused, or replaced by road layouts.
Only recently it is possible to notice a few cases of conversion of railway tracks in non-motorized mobility spaces, especially in urbanized areas. Specifically if the former railroad is at a higher level than the surrounding context (because is on viaduct).
The new High Line in NYC is an outstanding example of conversion of a an abandoned into a elevated park. The highway winds the former industrial area of Chelseas in Manhattan and it has driven a rezoning of the entire area, fostering the development through architecture projects.
The HighLine scenario is just a reference case study of this paper, which focuses on the project of conversion of the Rockaway Beach Branch Line

(RBBL) in Queens into a green cycling – pedestrian path. Queens is the easternmost and largest borough of the five boroughs of New York City, geographically adjacent to Brooklyn. It is the second-largest in population , with a census-estimated 2,339,150 residents in 2015, approximately 48% of them foreign-born. Some data: while NYC's standard is 2,5 acres of park space per 1000 people in southern Queens there are just 0,2 acres; about 323, 000 people (73,000 are kids) live less than 1 mile from this path (named QueensWay), 70% of residents living within 1 mile own a car.

For more than fifty years the old RBBL has lain abandoned. During this long period trees have grown and matured along the former railroad, creating a dense canopy and a diverse habitat for birds and other wildlife. Today QueensWay may represent a great opportunity for Queens. The thread of this green infrastructure could link the major parks of the area, offering a safer connection with recreation spaces (especially for the kids) and vibrant commercial strips. The incredible diversity of Queens could turn this linear connection in an iconic cultural greenway.

The QueensWay will be a connector for the neighborhood, although people were used to identify this infrastructure as an element of division because a railway is a strong element of disjunction between two areas.

Because of the America context, the methodological approach (based on data analysis on GIS) is particularly careful to the interaction with heavy road traffic (in proximity there are road intersections having about 4000 veic/hour volume flows along the N/S direction). In addition the track is not located on a viaduct, which means privacy issues for people living along the QueensWay.

Studies about this project has been drawn up in MsAUD (Architecture and Urban Design) 2016/17 activities at Columbia University, NYC, USA.

Introduction

The gradual increase in private mobility, dating back to the second half of the last century in western countries, has caused the shutdown of several secondary railway lines which are rarely used and therefore little profitable to any institution, either owner or manager (Guerrieri and Ticali, 2012). In addition to the decrease of rail passenger transport demand due to the improvement of the road system, the other two causes, that have contributed over the last 50 years to this phenomenon, can be sought in the construction of new high performance railway track parallel to the pre-existing one and in the decrease of rail freight transport demand due to the disposal of industrial areas.

Therefore, it is urgent to consider the issues related to inactive railway lines as there are hundreds of thousands of kilometres of inactive railways (Bertolini and Spit, 1998). One estimate is that it costs substantially less to redevelop an abandoned urban rail line into a linear park than to demolish it. Consequently, the disused railways are potential new pathways and the abandoned stations provide available spaces for new activities, supporting sustainable local development and regeneration processes.

According to this, disused railway sites are becoming a focus of redevelopment projects in many European countries and, recently, some former railway lines have been converted into cycling and pedestrian paths. In the USA, where road transport and private cars have a considerable role in transport system, areas of disused railways are often replaced by road layouts. Only recently it is possible to notice a few cases of conversion of railway tracks in non-motorized mobility spaces, especially in urbanized areas. This is due to the fact that issues such as ecology and sustainability have come to the forefront only in recent years, raising awareness and urging cities to promote environmental protection programs, including the convertion of disused railways within the concept of "soft mobility". Some of the norms and initiatives aimed at maintenance or recovery of the disused railway in the USA are the voluntary agreement *Rail Banking* (1983), the no profit organisation Rail to Rail Conservancy (1986), the transport legislation *Intermodal Surface Transportation Efficiency Act* (1991) and the policy statement of Federal Highway Administration *"Design Guidance on Accommodating Bicycle and Pedestrian Travel"* (2000). Currently, a movement is being developed thanks to a "bottom-up" push, which sees the population aggregated in spontaneous organizations that stimulate, provide ideas, collaborate in the creation and management of greenways.

Although the actuality of greenways' concept is nowadays increasing more and more, thinking the greenway as part of a network infrastructure should be one of the main concept to be taken into account in its planning and designing. The planning process should try to provide sustainable landscapes against disintegrating, space decreasing, urban development and uncontrollable change of area use (Ahern, 1995).

In this view the topic of this paper is a project of conversion of Rockaway Beach Branch Line (RBBL) in Queens into a greenway. This study proposes a methodology characterized by a GIS approach to evaluate the need of different kind of interventions for the realization of the greenway and the requalification of its surroundings.

Greenways and relevant best practices

The greenway literature of the past decade consistently names Frederick Law Olmsted as the father of the greenway movement in America (Little, 1990). He developed the idea of *parkway system*, which leads to taking shape of current greenways (Kent and Elliott, 1995).

The influence of the environmental decades on landscape architecture was most prevalent in the academic environments during the 1960s and the 1970s. Lewis' *environmental corridor* concept was used to plan first a major state wide greenway system with a focus on protecting environmentally sensitive areas, or river corridors (Lewis, 1964).

After 1985, greenways were integrated with space and resource management concepts (Mugavin, 2004). They started to have more comprehensive duties: beyond meet people needs and satisfy aesthetical and recreational requirements of city dwellers, they took on a lot of goals such as preserving habitat, reducing flood harms, increasing water quality, protecting historical sites and education.

Nowadays greenways brought together 2 functions: to form open spaces for public and for recreational uses and to ensure the protection and development of natural resources: many countries around the World have tackled these issues in creative and successful ways (Fig. 1).

Country	Project	Length (km)
France (Paris)	Promenade Plantée	4,9
Belgium	RAVeL Réseau Autonome de Voies Lentes	900
Australia	East Gippsland Rail Trail	96
Australia (Sydney)	Goods Line	0.5
United Kingdom	Bristol and Bath Railway Path	24
USA (Missouri)	Katy Trail	390
USA (Chicago)	Bloomingdale trail	4.3
USA (New York)	High Line	2.33

Fig. 1
Best practices for the requalification of abandoned railway lines worldwide

In recent years an outstanding example of greenway promoted by a bottom-up process is the High Line, a linear park built in Manhattan on an elevated section of a disused New York Central Railroad. In 1999, the nonprofit organization Friends of the High Line was formed by 2 residents of the neighborhood that the line ran through, advocating for the line's preservation and reuse as public open space. The High Line is inherently a green structure: it winds between buildings and constitutes a green elevated walk-path with spaces to stay and to relax in a no-green fully urbanized area. Furthermore, there is a good relationship with some requalified adjacent buildings having a new modified destination of use (Fig. 2 a and b).

As great number of studies recommends new approaches to urban and transport planning as solutions to climate change mitigation (Caprì et al., 2016), the High Line landscape functions essentially like a green roof designed to allow the plants to retain as much water as possible. This can be considered a soft approach seeking to raise awareness on how green infrastructures can play a vital role in create climate-resilient development - a role which is currently not sufficient recognised nor integrated into mainstream planning (Inturri, 2011).

(a) (b)

Fig. 2

Park’s attractions and views of the city from the High Line

Context framework: The QueensWay

The QueensWay is a project of conversion of a former rail line, LIRR Rockaway Beach Branch (RBB), a 3.5 miles stretch which lies abandoned since 1962. During this time, vegetation have sprouted along the former right of wayand illegal dumping has become an increasing problem, with trash and remnants of drug and alcohol use litter the ground (Fig. 3). In 2011, a group of residents living along the former RBB, teamed up to advocate for its conversion into a new linear park, joining in a movement called *The Friends of the QueensWay* (FQW) with the goal of converting the long-abandoned property into a public park. FQW entered into a partnership with *The Trust for Public Land*, the nation's leading nonprofit organization working to create parks and protect land for people.

Thanks to the fundings obtained by the State of New York, in 2013 The Trust for Public Land has commissioned the QueensWay Plan to *WXY* and *dlandstudio*, in order to lead an interdisciplinary team to analyze the economic, social, environmental, engineering and transportation dynamics of the site and surrounding area.

Fig. 3
Vegetation sprouting in the abandoned RBB line

The planning approach was based on community involvement, with five large public meetings, 30 workshops and meetings with community groups, and hundreds of stakeholder discussions. The ideas arising from these sessions, as well as the analysis of the site, helped establish the six themes explaining the vision for the QueensWay:

- Connections + Neighborhoods: the QueensWay is seen as a connector to parks, commercial avenues and facilities; it's also a gateway to neighboring communities;
- Ecology +Education: there are 12 schools within a 5 minute walk of the QueensWay; morevoer visitors can encounter a variety of environments and learn aboutplants, geology, stormwater management, and natural habitats for urban wildlife;
- Safety + Comfort: the QueensWay will provide for the needs of all ages and abilities; it will be carefully designed to avoid conflicts between walkers and cyclists. Particular attention will be given to the preservation of privacy for neighbors;
- Play + Health: sport and recreational programs will be developed in partnership with local associations;
- Culture + Economic Development: visitors to the QueensWay will bring new business to commercial activities located in the surrounding neighborhoods; provision of platforms for performances and public art and the opportunity for adaptive reuse of underutilized buildings will give life to a new cultural offer;
- Care + Stewardship: The community will be engaged through a continued public input process to ensure the park and design meet local needs.

The QueensWay plan divides the park into 6 areas (Fig. 4): 4 integrate activities; 2, called *the passages*, are closer to homes and will be paths for walkers and cyclists.

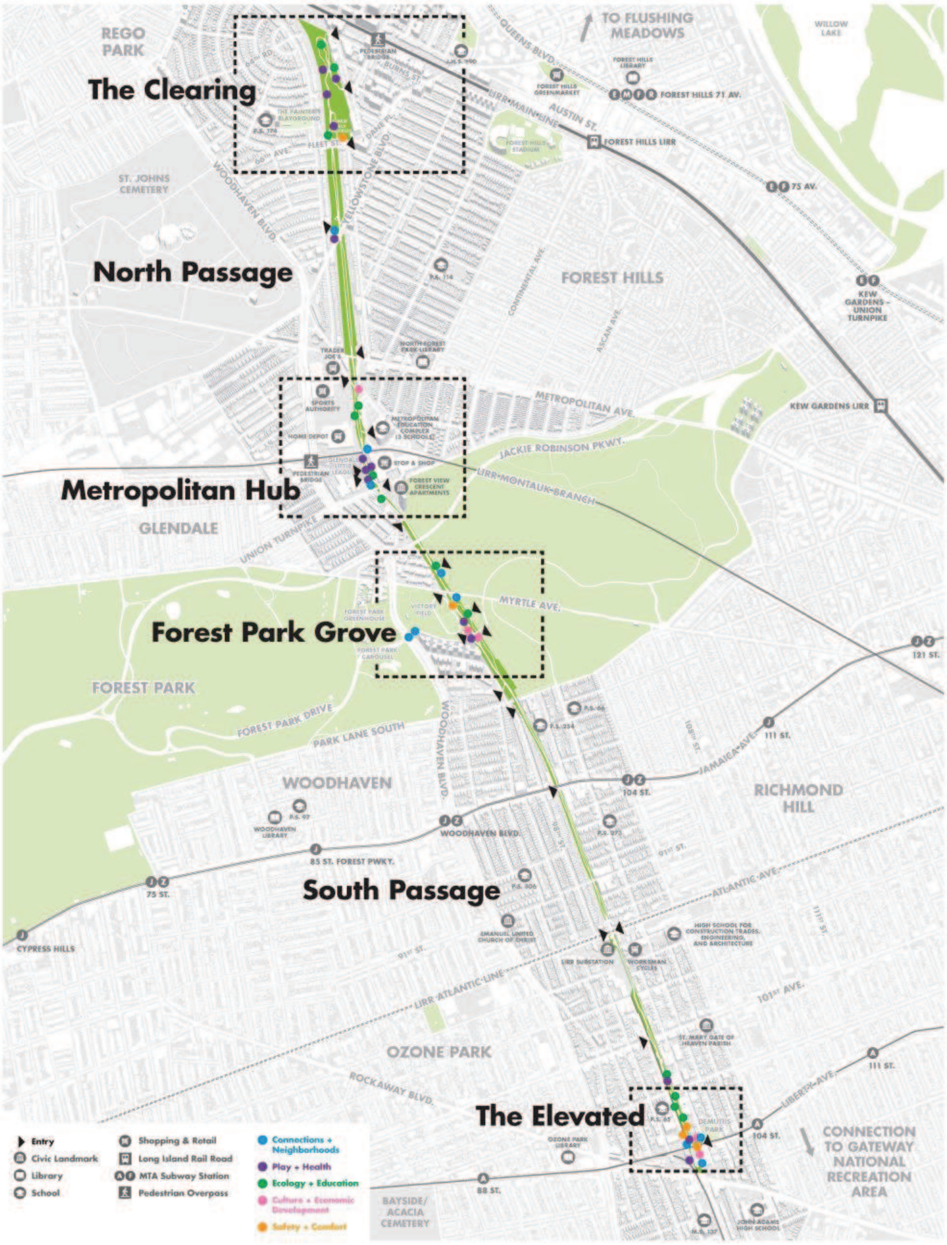


Fig. 4
The QueensWay Plan Map (Source: theQueensWay.org)

A particular attention is put by WXY and *dlandstudio* proposal in a design which try to maximize safety and privacy for neighbors (whose houses are close to the track, Fig. 5) while still giving a good permeability and visibility for park users. A proposed solution for pathways that run by private homes is a design with vegetated buffers at the top of the embankment; secure fencing with planting to provide additional screening are put at the property line to physically and visually separate backyards and homes from park users. Moreover, in order to decrease any visual connection between the QueensWay users and adjacent homes, the pathway can be lowered by excavating the embankment. Finally all the main activity spaces will be located close to non-residential amenities, while the two lenghts that run by homes (North Passage and South Passage), will be used as a walking and cycle path.

Fig. 5
Closeness of track to private houses

Methodological approach

The QueensWay project realized by FQW is a bottom up process involving stakeholder. This paper proposes a GIS approach, based on suitability analysis, useful to evaluate the necessity of the different kind of intervention according to the 6 focus areas defined during the decision

process. Suitability analysis describes the search for locations or areas that are characterized by a combination of certain properties.
GIS allows to obtain suitability scores that can be used to determine hot spots regarding each focus area through the intersection of multiple levels of information. In our case, the approach consist of the superposition of 5 different score layers (one for each focus area) constructed through critera which are depending from spatial characteristics evaluated through the use of a GIS software.

$$S_{fa} = c_1 + c_2 + \ldots + c_i + \ldots + c_n$$

Where S_{fa} is the score for the specific focus area and *i* are the *n* related criteria cocurring to the its construction. The selected criteria for each focus are showed in Fig. **6** .

A buffer of 1 km from the rail line is taken into account as threshold for the analysis of the surrounding land use. The method assumes that each criterion's values are normalized between 0 and 1 according to the following equation:

$$SN_{fa} = \frac{S_{fa-j} - S_{fa-\min}}{S_{fa-\max} - S_{fa-\min}}$$

Where, for each focus area, SN_{fa} is the normalized score, S_{fa-j} is the generic score and S_{fa-min} and S_{fa-max} are respectively its minimun and maximun value. Since the score is a need score a value close to 1 corresponds to an area with more need.
After the evaluation of each score into a layer, the six layers would be combined/overlaid using raster calculation function to get a composite map showing priority hot spots and areas where intervention is not necessary: the final result of our suitability analysis will be a thematic map showing which locations or areas are more in need for a specific focus area.

FOCUS AREA	CRITERIA
Connections + Neighboroods	Number of road crossings Subway stations within 1 km Bus stop within 1 km Number of parks Gateways to adiacent avenues Number of parkings within 1 km Population age
Ecology + Education	Number of schools within 1 km Number of libraries within 1 km
Safety + Comfort	Buffer from neighboring residents' houses Viewshed analysis Number of accessible ramps needed Lighting
Play + Health	Number of sport facilities Emissions from road traffic
Culture + Economic Development	Number of workers Turistic points within 1 km Commercial buildings Number of abandoned facilities within 1 km State of the buildings

Fig. 6
Criteria for each focus area

First Results

This viewshed analysis (Fig. 7) shows which areas are visible from a specific location. Viewshed analysis was performed putting some points on the railroad as observation points. The raster is a DSM (DEM + building eights). The result shows that the future project would guarantee the privacy of people who live nearby the QueensWay infrastructure (especially in the Southern part) and, in the same moment, the QueensWay would offer great views of the Forest Park. Fig. 8 shows that QueensWay would be a great link between the built area of Southern Queens and the Forest Park which is not easily accessible nowadays. In addiction a lot of students could use the QueensWay as daily path to reach their schools or other public facilities. In this way there will be also a decrease of traffic congestion, because a lot of commercial buildings are located nearby the former railroad. Last but not least QueensWay could connect two areas of Queens with different Medium Age. The park would be easily reached by Metro thanks to 5 stops (1 in the Northern part, 2 in the middle, 2 in the Southern part) located within a distance of 300 m from the former railroad (Fig. 9). QueensWay would be the only N-S link between the metro stops which are on 3 different lines.

Fig. 7
Viewshed analysis

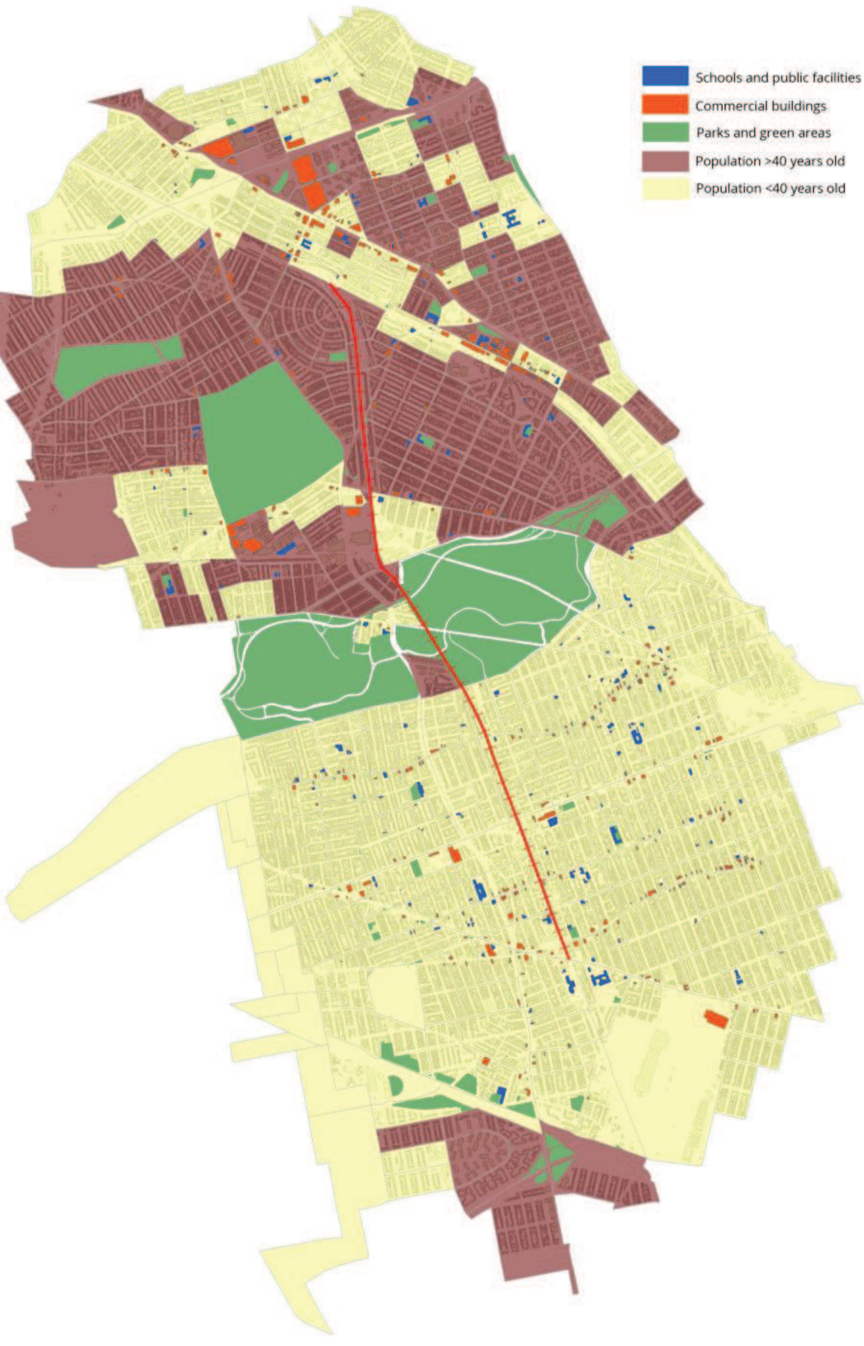
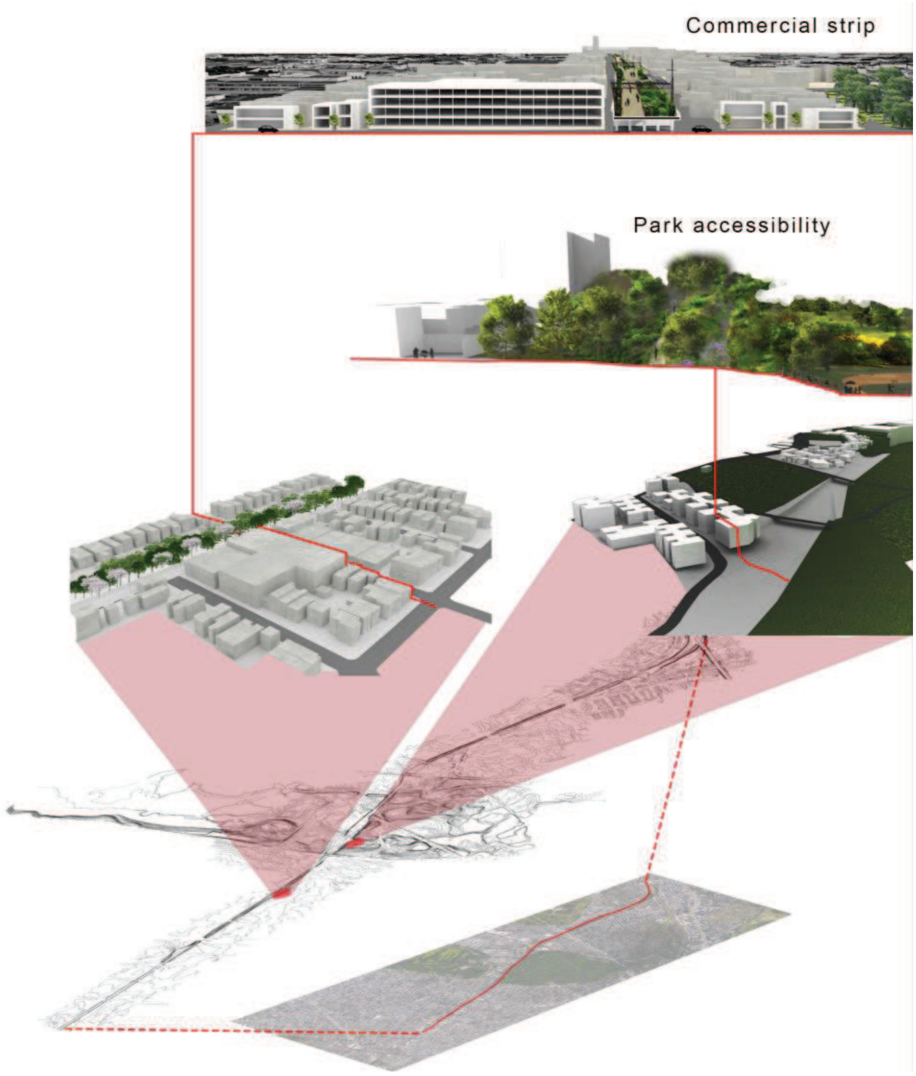


Fig. 8
Activities analysis

Fig. 9
Infrastructure analysis

A proposal of intervention is shown in

Fig. 10, which highlights the importance of accessibility to Forest Park. Connection to parks and commercial areas is one of the main project aims; the reconversion would expect 1 million annual visitors to the QueensWay, based on similar projects and on the annual number of visits to Forest Park (approx. 900,000), assuming that 250,000 of the visitors



will be from outside of Queens bringing new business to local shops and restaurants.

Fig. 10
Proposal of intervention

Conclusions and further research

In the USA, where road transport and private cars have a considerable role in transport system, the disused railway areas are often remained unused, or replaced by road layouts. Only recently more sensibility towards ecology and sustainability have come to the forefront and it is possible to notice a few cases of conversion of railway tracks in non-motorized mobility spaces, especially in urbanized areas.
In this theme, the topic of this paper is a method to improve a project idea of conversion of an abandoned rail line in Queens into a green cycling – pedestrian path. This study proposes a GIS approach, based on suitability analysis, to evaluate the needs of different kind of intervention according to different focus areas. Since community involvement is one of the basis of the proposal project of FQW, in future researches the GIS approach could be integrated with a Multi Criteria Decision Analysis process. This would give the possibility to the community to assign different values to focus areas' criteria and allow the decision maker to obtain priorities of interventions.

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Structuring transport decision-making problems through stakeholder engagement: The case of Catania metro accessibility

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ABSTRACT: This paper presents a procedure for the structuring of a problem hierarchy by involving key stakeholders, rep-resenting a first step towards a participatory decision-making process. The case study regards the building of a new metro station in Catania (Italy), which will be the closest station to a high-demand district where healthcare and university services and a park-and-ride facility are located. Due to the distance and the high slope between the station and the district, a dedicated transit system linking the two nodes is under study, and four different alternatives have been proposed. Key stakeholders have been identified and involved via in-depth interviews. A questionnaire, a GIS map and a SWOT-like graph have been used to present them the problem and capture their preferences and opinions. From the results of the interviews, a first hierarchy of the problem has been built, that can be used for stakeholder-driven multicriteria analysis.

1 INTRODUCTION

1.1 *Stakeholder engagement in transport decisions*

Transport planning and decision-making is not a simple task, since decisions affect multiple actors with conflicting interests, i.e. the users of the transport systems, citizens, transport operators and, in general, all the stakeholders. Today is widely recognized the importance of engaging stakeholders and citizens in the decision-making process, to improve the quality and equity of the decisions made and to limit protests afterwards. A participatory approach becomes fundamental to find an alternative that should be the best trade-off between the "most shared" solution and the "optimal" one. With regards to transport planning, the EU strongly encourages the Member States to adopt innovative plans such as Sustainable Urban Mobility Plans (SUMPs), where participation is considered as a key issue of success for the decision-making process and for the implementation of the plan itself (Wefering et al., 2014).

Stakeholders involved in transport decisions are de-fined as "people and organizations who hold a stake in a particular issue, even though they have no for-mal role in the decision-making process" (Cascetta et al., 2015).

There are different levels of growing involvement, as represented by Arnstein (1969) in the so called "ladder of citizen participation", from the lowest step of "Nonparticipation" to the highest one of "Citizen Power". The five Public Engagement levels proposed by Kelly et al. (2004) ("Stakeholders identification", "Listening", "Information giving", "Consultation", "Participation") have been integrated into the framework of transport planning by Cascetta et al. (2015). Le Pira et al. (2015a) propose a simple scheme to summarize and link the transport planning process with monitoring and participation. The pro-posed decision-making process identifies three main actors and their related roles: planners and experts in charge of analyzing and modelling the transport system by defining the plan structure for the final technical evaluations; stakeholders and citizens that are involved in all the planning phases for the definition of objectives, evaluations criteria and alternatives; decision-makers in charge of the final decision supported by a performance-based ranking and a consensus-based ranking of plan alternatives.

In order to implement an effective participatory approach, it is necessary to understand what kind of tools and methods can help to design and speed up the process of taking a public decision, starting from the first essential phases of stakeholder identification and analysis.

1.2 *Methods and tools for stakeholder engagement*

In general, participation processes require time and money and they are often regarded as compulsory and quite formal steps of the decision-making process. A modelling approach can be used to support the planning and designing of participation processes aimed at consensus building. In fact, knowing in advance the possible results of different scenarios of interaction among stakeholders can be helpful to plan effective participation processes. In this respect, Agent-Based Modelling (ABM) is suitable to repro-duce participation processes involving stakeholders linked in social networks, understanding the role of interaction in finding a shared decision, and investigating some important parameters such as stakeholder influence, degree of connection, level of communication for the success of the interaction process (Le Pira et al., 2015b, 2016).

There are several techniques that can be used and guidelines for stakeholder involvement in transport decisions (Kelly et al., 2004; Quick and Zhao, 2011; Wefering et al., 2014). Multi-criteria decision-making/aiding (MCDM/A) methods, typically used in traditional planning with a single decision-maker, can be extended for group decisions, proving their usefulness in structuring the problem to include dif-ferent criteria of judgments and points of views and dealing with the complexity of decisions regarding transport planning (Piantanakulchai and Saengkhao, 2003; De Luca, 2014, Le Pira et al., 2015a). MCDM/A in transport can largely benefit from the support of Geographic Information System (GIS), due to the intrinsic spatial nature of transport systems and the capability of GIS maps to easily visualize the impacts of transport choices on land use, environment and communities. Public Participation GIS (PPGIS) or Participatory GIS has been developed as powerful tools for supporting non-experts' involvement in transport decision-making process because of the power of visualization, which increases the awareness about the decision to be made (Sarjakoski, 1998; Tang and Waters, 2005; Zhong et al., 2008).

Therefore, a transport plan should be built with the help of quantitative methods to make a transparent, participatory decision-making process. These methods must include the stakeholders' perspectives and judgements in all the phases of the planning process. Besides, it is necessary to integrate different tools, i.e. (i) MCDM/A methods, (ii) engineering and simulation models, (iii) participatory GIS.

Based on this premise, this paper presents a procedure for the structuring of a problem hierarchy by involving key stakeholders, representing a first step towards a participatory decision-making process. The case study regards the decision about a new transit system in Catania (Italy), which should connect a new metro station with a high-demand district. Four different alternatives have been proposed and the key stakeholders have been identified and involved via in-depth interviews. A questionnaire, a GIS map and a SWOT-like graph have been used to present them the decision problem and capture their preferences and opinions. From the results of the interviews, a first hierarchy of the problem has been built, to be (eventually) used for analysis via appropriate MCDM/A methods, representing a first step of a stakeholder-driven decision-making process.

The remainder of the paper is organized as follows. Section 2 presents a short introduction to the expert-based approach used by the authors. Section 3 investigates the case study and illustrates the structure of the questionnaire, showing the application of the in depth interview method. Section 4 comments the survey's results and shows the procedure used to connect stakeholders' opinion to the construction of a decision problem hierarchy.

2 METHODOLOGY

A hierarchy is a stratified system of ranking and organizing people, things, ideas, etc., where each element of the system, except for the top one, is subordinated to one or more other elements. Though the concept of hierarchy is easily grasped intuitively, it can also be described mathematically. Diagrams of hierarchies are often shaped roughly like pyramids, but other than having a single element at the top, there is nothing necessarily pyramid-shaped about a hierarchy. At each step, the focus is on understanding a single component of the whole, temporarily disregarding the other components at this and all other levels. Through this process, the global understanding of the complex decision problem increases. By using the hierarchy, it is possible to integrate large amounts of information into the understanding of the situation, and with this information structure, to form a better and better picture of the problem as a whole.

The structure of the hierarchy consists of an overall goal, a group of options or alternatives for reaching the goal, and a group of factors or criteria that relate the alternatives to the goal. The criteria are further broken down into sub-criteria, sub-subcriteria, and so on, in as many levels as the problem requires.

Through an expert-based approach, involving via in-depth interviews the key stakeholders, it is possible to present the decision problem and to capture stakeholders' preferences and opinions, in order to define the hierarchy model of the problem. In doing this, stakeholders explore the aspects of the problem at levels from general to detailed and then they express it in the multileveled hierarchy. As they work to build the hierarchy, they increase their understanding of the problem, of its context, and of each other's thoughts and feelings about both.

The use of a Web GIS map presenting some of the main spatial characteristic of the project solutions gives a further contribution: it provides to the stakeholder a first quantitative analysis of the main impacts of the different options. This can be considered as a first step towards a tied approach (such as a WebGIS based MCDA), that can facilitate stakeholders in the understanding of a technical evaluation of the project characteristics.

The task of representing the evaluation problem as a network of interdependent elements distributed can be decomposed into the following steps. The first step concerned the evaluation of the criteria. Secondly, the associated sub-criteria have been identified for each criterion. They are chosen depending on the characteristics of the alternatives. Once the evaluation criteria and sub-criteria have been distinct, they have been to organised in a hierarchy.

The use of this kind of method in the solution of MCDA problems would overcome the unsuitability of traditional methods: in this way in fact the final decision taken by the stakeholder will be transparent and participated but it will also ensure a high technical level of the project solution chosen.

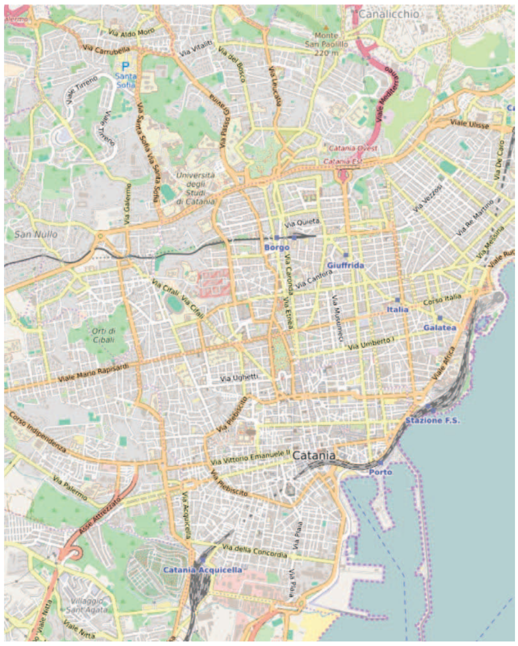

Figure 1. Territorial framework.

3 CASE STUDY

3.1 *Territorial framework and problem presentation*

Catania is a city of about 300.000 inhabitants and it is located in the eastern part of Sicily; it has an area of about 183 km^2 and a population density of 1.754,54 inhabitants/km^2 (Istat, 2015b).

It's part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania.

The main city (Fig. 1) contains most of the working activities, mixed with residential areas. With reference to the urban area, the transport service is provided by 51 bus lines, a Shuttle line (ALIBUS) connecting the city center with the airport and a second fast bus (called BRT1) connecting the parking Due Obelischi with Stesicoro Square. BRT1 is the first of three lines provided by the City of Catania with equipped lanes protected by curbs on the majority of their path and was promoted commercially as Bus Rapid Transit. In Catania it is also present an urban subway line that currently connects the station "Porto" with the station "Borgo" from which continues as a surface long-distance line.

By the end of 2016 it is expected the extension of the line until the station "Nesima" and it's also planned the opening of a branch linking the station "Galatea" to Piazza Stesicoro. In a few months a new subway station, named *Milo*, will be inaugurated. Its position will make it the closest station to an area where some education and health services and a park—and—ride facility (*S. Sofia* parking) are located (Fig. 2). Due to slope and distance between Milo station and S. Sofia parking, the implementation of a transit service linking the two transport nodes has been proposed.

3.2 *Transit alternatives*

3.2.1 *Minimetro*

People mover are modern automatic transport systems on rails, operation is automatic and vehicles are usually equipped with rubber tires circulating on metallic or concrete guides. Main characteristic of this kind of system are a segregated right of way, integral automation, a capacity that can go from very low values up to 3000–4.000 pass/h, a frequency of less than 1 minute and the possibility to overcome slopes of 15%. Between the various typologies of people mover, we are taking into account a particular one, called Minimetro, constructed by the Leitner Ropeways S.p.A.

3.2.2 *Bus*

Urban buses are the most popular means of collective public transport in our cities and their technology is now firmly established.

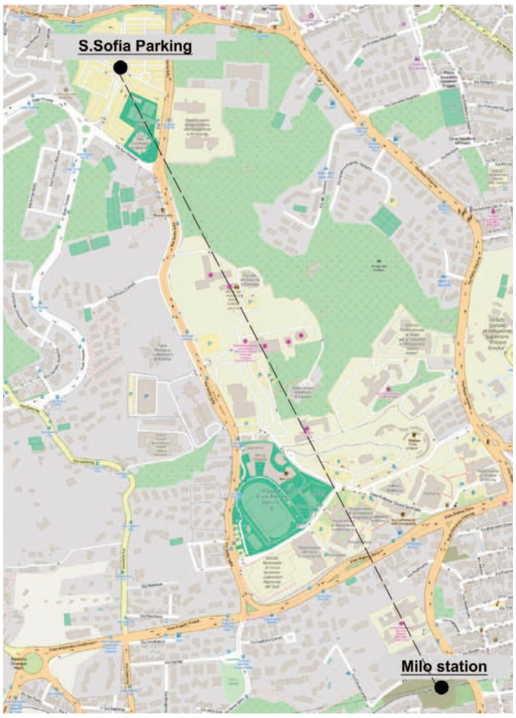

Figure 2. Area of intervention.

Taking into account existing arteries and various boundary conditions along the route Milo—Città Universitaria—S. Sofia, the bus line has been designed: a "tangential" line, which does not enter the heart of the university campus, but rather touches it and has its stops close to the main entrances. Given the fairly linear path (with forward and return lines side by side) and the large spacing between the stops, the system gets close in characteristics to a modern Bus Rapid Transit.

3.2.3 *Monorail*

Etna Rail is the name of a project of monorail designed for the metropolitan area of Catania, including 3 different lines, with the green one tangential to our study area. It is a modular system, designed for the prefabrication of all major components; it can overcome a maximum slope of 12%; the guide can be manual or with a fully automatic system "driverless" from a remote control room; the speed can reach up to 160 km/h.

3.2.4 *Ropeway*

Ropeway, which falls into the category of cable transport, is the most common technology used for public transport services on lines with very high slope (from 10% up). It is a shuttle which consists of a pair of cars (or possibly groups of cars joined together), an ascending and a descending unit, permanently attached to the two ends of the same cable (a steel cable). Vehicles are built according to the transportation needs and characteristics; for the transport of people highly variable capacity cars are employed (from a few people to over one hundred), on the base of suitability to the service (citizens' movements, summer or winter tourism, etc.).

3.3 *Stakeholders involved*

Five stakeholders, representing the main interest groups affected by the intervention, have been involved:

1. University of Catania, in the person of Rector's delegate for mobility management;
2. Urban bus transit company (Azienda Metropolitana Trasporti—AMT Catania), represented by one of its transport planners;
3. University Students' Council, in the person of a representative student of the students' council;
4. Municipality of Catania, represented by an administration consultant;
5. Metro rail company (FCE—Ferrovia Circumetnea), in the person of its general manager.

3.4 *Stakeholder survey*

Before the beginning of the questionnaire, a Web GIS map of the main impacts of the four different alternatives has been shown to the stakeholders.

The map has been composed with the aid of the Open Source software QGIS (2016) by using the free plugin *qgis2web*. The base map references the live tiled map service from the OpenStreetMap (OSM) project. It's made available under the Open Data Commons Open Database License (ODbL). The base map already shows the future subway line track with a dotted line.

Four different layers have been added to the map, showing for each alternative:

- The design track;
- Value of hypothetical capacity (pass/h);
- A noise map
- The location of stops and stations.

Moreover, two more layers show the main interest point of the zone and the Traffic Analysis Zones from Urban Traffic Plan of Catania (PGTU, 2013).

Each stakeholder has been asked with some general information about his company/body: his company position; company's objective and specific abilities; company's main interests in relation to the project; collaboration with other bodies in relation to the project. The stakeholder has then been asked if he would consider the intervention necessary and the reasons of his opinion. Always in relation to the project and to the company's objectives, he has been asked to assign an importance level to four different impacts:

– Transportation impact, related to the ability to meet the demand, considering characteristics related to system performance, such as frequency, speed, etc.;
– Economic impact, related to construction, operation and maintenance costs;
– Social impact, relating to system security, ease of access, acceptability;
– Environmental impact, in terms of air pollution, noise, visual intrusion, etc.

The importance level has been evaluated by the stakeholder with a numeric scale going from 1 (*not important*) to 5 (*very important*).

The WebGIS map with an example of the survey proposed to the stakeholders can be found at the following website:

http://transportmaps.altervista.org/LinkMiloS-Sofia/index.html.

In the final part of the interview the stakeholder has been asked to conduct a SWOT analysis for each alternative, in order to consider for all the transit option:

– its strengths, i.e. the characteristics of the project providing an advantage over others; those should be internal features of the project;
– its weaknesses, i.e. the inherent characteristics that place the project at a disadvantage relative to others;
– its opportunities, meaning the external issues that the project could benefit of;
– its threats, the external elements in the environment that could cause failures of the project.

4 SURVEY'S RESULTS AND HIERARCHY CONSTRUCTION

In this section there are described survey's results and the hierarchy model construction associated to the case study, to be (eventually) used for analysis via appropriate multicriteria decision-making methods.

From the surveys, the fundamental aspects taking into consideration to build the hierarchy have emerged. For the first interviewed stakeholder (University of Catania), the transportation impact results the most uppermost one in terms of accessibility. Furthermore, the environmental and economic impacts were considered important, respectively in terms of pollution and visual intrusion, economic risks and costs distinguishing in implementation and operation costs for each system.

The second stakeholder (AMT Catania), similarly to the first one, considered the transportation impact one of the most important aspect which have to be taken in consideration, especially in terms of capacity and frequency related to each transport system alternative. The stakeholder also considered the social impact associated to the realization of this transit service as the possibility of an urban redevelopment of the metropolitan area. The third involved stakeholder, University Students' Council, has given more attention to transportation impacts, such concern two main aspects of travel time reliability and comfort of the system. As regards economic impacts, the stakeholder referred to general costs. The fourth stakeholder, (Municipality of Catania) assigned the highest level of importance to the social impact in terms of acceptability and perceived security. The last stakeholder, Metro rail company (FCE), focused his attention on transportation and environmental impacts, like the other stakeholders, also taking into account the operational aspects of the system.

Stakeholders' answers about intervention importance and impacts comparison are summarized in Tables 1 and 2.

The following SWOTs (Tables 3, 4, 5, 6) show the main strengths, weakness, opportunities and threats associated to each transport alternatives.

As regards the first alternative, the economic aspect has an important role. Infact, bus has low

Table 1. Impacts level assigned by the stakeholders.

Do you think the intervention is necessary? Why?	
University of Catania	The intervention is necessary not only because it would be a benefit for University but it would fully explain the realization of metro station, solving the "last mile problem".
AMT	The intervention is necessary because there's a high demand level and a poor service supply.
Students' council	The intervention is necessary because students have high difficulties to find a parking lot in University campus and they need a fast transit service to get to the campus.
Municipality of Catania	The intervention is necessary because it's quite impossible to go through the path by walking or bike.
FCE	The intervention is necessary because of company's objective and also to achieve the final goal of traffic reduction and making the community more livable.

Table 2. Impacts level assigned by the stakeholders.

How do you rate those effects? (1 not important, 5 very important)

	Trasportation	Economic	Social	Environmental
University of Catania	5	4	3	4
AMT	4	2	3	2
Students' council	5	5	4	4
Municipality of Catania	4	3	5	3
FCE	5	3	3	4

Table 3. SWOT analysis for the alternative Bus.

ALTERNATIVE 1: BUS	
Strengths	-Low costs of implementation -Immediate implementation -Flexibility
Weakness	-Pollution -High operation and management costs -High costs -Travel time unreliability
Opportunities	-Memorandum of understanding among University, AMT and Municipality of Catania -Possibility of higher level of transit service's performance (increased supply)
Threats	-Financial critically of urban bus transit company -Service punctuality because of road traffic

Table 4. SWOT analysis for the alternative Minimetro.

ALTERNATIVE 2: MINIMETRO	
Strengths	-Capillarity -Good interchange with metro -Frequency
Weakness	-High operation costs -Visual impact -Rigidity of the system -Environmental and landscape impacts
Opportunities	-Element of attraction: innovation and modernity -Urban redevelopment of the area -Greater number of enrollees -Low operation costs
Threats	-Non-consolidated technologies -Uncertainty of ministerial authorizations for safety issues -Fixed supply -Dealing with a different transit company

Table 5. SWOT analysis for the alternative Monorail.

ALTERNATIVE 3: MONORAIL	
Strengths	-Higher capacity
Weakness	-High implementation and operation costs -Visual intrusion -Rigidity of the system -Environmental and landscape impacts
Opportunities	-Potential to be part of a wider track -Urban redevelopment of a wide area of the metropolitan region -Good interchange with metro
Threats	-Financial uncertainty on realization -Dependence on foreign technologies -Political and economic interests -Higher number of stakeholder involved to reach the consensus

Table 6. SWOT analysis for the alternative Ropeway.

ALTERNATIVE 4: ROPEWAY	
Strengths	-Moderate costs of implementation
Weakness	-Poor capillarity -Rigidity of the system -Environmental and landscape impacts -Sensitivity to atmospheric conditions -Uncertainty on use by users -Difficulty of increasing extension and capacity
Opportunities	-Exploitation for landscape tourism purposes -Innovation and modernity image -Architectural interest
Threats	-Fixed supply -Access and egress rigidity

cost of implementation, but at the same time high operation and management costs. Furthermore, the travel time unreliability due to mixed right of way must be taken into account.

The second alternative, represented by the minimetro is considered an element of attraction in terms of innovation and modernity. Conversely to the bus, it is a rigid system and if the urban situation changes, the system cannot be adapted.

It is a well-share opinion for the stakeholders, that the third alternative, the monorail represents a good opportunity for an urban redevelopment of a wide area of the metropolitan region, because it could be part of a wider track. It has also a good interchange with metro. Both minimetro and monorail have the economic problem of high implementation and operation costs, and the environmental problem in terms of visual intrusion and landscape impacts. The same considerations are also valid for the last alternative, with the only difference that the ropeway has moderate costs of implementation.

The hierarchy model for this case study is pyramid-shaped. The goal to be reached is represented by the choice of the best transport system to connect Milo metro station with S. Sofia parking. Four alternative ways of reaching the goal, and four evaluation criteria with three or four evaluation sub-criteria for each criteria were incorporated in the hierarchy. Table 7 shows a scheme of the four macro criteria with the associated sub-criteria, associated to a code in order to facilitate the graphic representation.

Fig. 3 schematically illustrates the developed hierarchy model for the choice of the best transport system, with the goal at the top, the four alternatives at the bottom, and the four criteria with their sub-critera in the middle. The one-way arrows indicate the influence between each element of the hierarchy.

Table 7. Criteria and sub-criteria definition for the hierarchy model.

Criteria	Code name	Sub-criteria	Code name
Transport	C_t	Accessibility	S_{t1}
		Travel time	S_{t2}
		Frequency	S_{t3}
		Comfort	S_{t4}
Economic	C_{ec}	Implementation cost	S_{ec1}
		Economic Risk	S_{ec2}
		Management cost	S_{ec3}
Environmental	C_{en}	Air pollution	S_{en1}
		Noise pollution	S_{en2}
		Visual intrusion	S_{en3}
Social	C_s	Acceptability	S_{s1}
		Urban requalification	S_{s2}
		Perceived security	S_{s3}

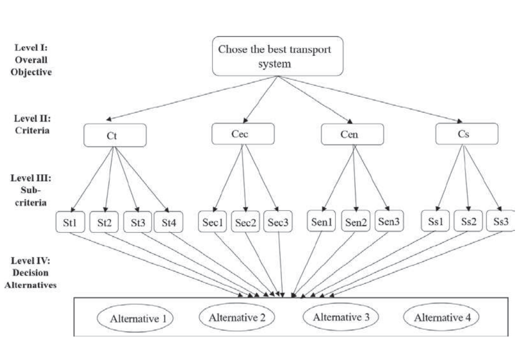

Figure 3. Tree illustrating the hierarchy of criteria and sub-criteria identified in the process.

Once the hierarchy has been constructed, it would be possible to use this hierarchy for analysis via appropriate multicriteria decision-making methods and to get to a final decision based on the results of this process.

5 CONCLUSION

Today is widely recognized the importance of engaging stakeholders and citizens in the decision-making process, to improve the quality and equity of the decisions made and to limit protests afterwards.

This paper presents a procedure for the structuring of a problem hierarchy by involving key stakeholders, representing a first step towards a participatory decision-making process.

The method presented in this paper have been applied to the case study of Catania metro accessibility, specifically regarding the realization of a dedicated transit service linking the two nodes Milo metro station and S. Sofia parking. Four alternatives have been proposed: bus, minimetro, monorail and ropeway.

The decision is based on different criteria, including non-monetary ones, and it should be able both to solve the mobility needs of the district and to improve the quality of life of the whole city.

The method consists on a creation of a stratified system organized in hierarchy in order to focus on understanding a single component of the whole, temporarily disregarding the other components at this and all other levels.

In this view, the key stakeholders belonging to the metro company, the public transport company, the University and the municipality of Catania were identified and involved via in-depth interviews. A questionnaire, a GIS map and a SWOT-like graph have been used to present them the decision problem and capture their preferences and opinions.

The hierarchy model for this case study is pyramid-shaped. The goal to be reached is represented by the choice of the best transport system to connect Milo metro station with S. Sofia parking. Four alternative ways of reaching the goal, and four evaluation criteria with three or four evaluation sub-criteria for each criteria were incorporated in the hierarchy, against which the alternatives need to be measured.

In conclusion, this methodology constitutes a very promising future research line in the field of transport planning and decision-making. From the results of the interviews, Hierarchy of the problem has been built, to be (eventually) used for analysis via appropriate multicriteria decision-making methods, representing a first step of a stakeholder-driven decision-making process.

Next studies could be addressed to the application of an AHP analysis by using the build hierarchy, in order to evaluate alternative solutions and to help decision makers find the alternative that best suits their goal. Moreover, a complete online platform of the survey could be implemented in order to address to the public, get a wider sample of answers.

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Combining Analytic Hierarchy Process (AHP) with role-playing games for stakeholder engagement in complex transport decisions

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Abstract

This paper presents a procedure for the structuring of a transport decision-making problem and evaluation of the solutions proposed from a multi-stakeholder multi-criteria perspective. Analytic Hierarchy Process (AHP) is used as multicriteria decision technique, while a role-playing game is used to reproduce a participatory process where University students act as key stakeholders. The case study regards the building of a new metro station in Catania (Italy), which will be the nearest station to a big University district. A dedicated transit system linking the metro station and the district is under study and four different alternatives have been proposed. Students were initially informed about the objectives of key stakeholders in order to be able to play the different roles. A hierarchy of the problem was built with them and AHP was used to elicit their preferences and evaluate priorities for each stakeholder group. A comparison between a mathematical aggregation of individual priorities and a consensus vote was performed to verify the differences between the two different methods and their compliance with the stated stakeholder preferences. AHP-based participatory procedure proved to be suitable to tackle the complexity of transport decisions.

Peer-review under responsibility of the scientific committee of the 20th EURO Working Group on Transportation Meeting.

Keywords: multicriteria decision-making; stakeholder involvement; participatory process; transport planning

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Peer-review under responsibility of the scientific committee of the 20th EURO Working Group on Transportation Meeting.

1. Introduction

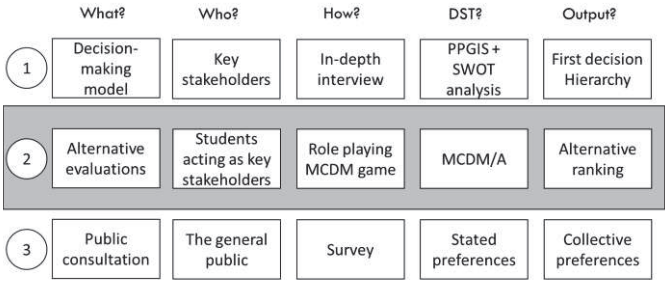
Transport systems are complex socio-technical systems that affect the social, economic and environmental dimensions of a territorial community with several impacts and feedbacks not easy to be foreseen (Cascetta et al., 2015). Further complexity is added by the procedural issues related to construction and operation of the transport systems and mostly for the several actors that interact in different contexts and show different interests. Transport planning is typically a decision-making process based on rationality, aimed at defining and implementing transport system operations (Ortúzar and Willumsen, 2011). It effectively means achieving aims and objectives as a result of a technical and political process, through a set of decisions that will inevitably favor some interests and expectations at the expense of others. In fact, even if a transport plan is meant to increase the net welfare of a community, the benefits will never be equally distributed among its different actors and groups interested in influencing the planning process (De Luca, 2000). Public participation in transport planning is therefore emerging as a basic component to which human and financial resources have to be dedicated from the beginning of the planning process (Cascetta and Pagliara, 2013). The word "public" is usually referred to all those potentially affected by or interested in a decision, i.e. the potential "stakeholders". Stakeholders in the transport sector can belong to different categories, i.e. institutions/authorities, transport users, transport operators, business and unions, local communities, media and financial institutions (Cascetta and Pagliara, 2013) with different levels of competences and interests (Le Pira et al., 2016a). Stakeholder engagement is therefore a necessary prerequisite for the success of a transport decision-making process. Nevertheless, a successful and effective participation process requires the use of appropriate decision-support methods and procedures. In this respect, the use of Public Participation GIS (PPGIS) should be promoted since it allows a simple visualization of the impacts of the solutions proposed (see e.g. Smith, 2002; Tang and Waters, 2005). Ex-ante behavioral analysis is also important to produce insights into stakeholders' behavior and preferences for future scenarios. In this respect, stated preference surveys are well suited to investigate stakeholders' preferences in order to forecast their individual choice behavior related to policy-making (e.g. Gatta and Marcucci, 2016). Since a collective choice is the goal of participation, it can be useful to analyze interaction processes among stakeholders aimed at consensus building. Agent-based simulations provide a useful tool to study communities of autonomous and intelligent agents, such as stakeholders linked in social networks, trying to understand the role of interaction in finding a shared decision (Le Pira et al., 2016a; 2017a; Marcucci et al., 2017). Besides, complex transport decisions requiring the evaluation of multiple and heterogeneous aspects (e.g. environmental, social, economic) need to be tackled with a multicriteria approach. Multi-Criteria Decision Making/Aiding (MCDM/A) methods are widely used in transport planning to include in a comparative assessment of alternative projects their contributions to different evaluation criteria (Figuera et al., 2005). Though stakeholders can be involved both to select the criteria and assign weights, the "rational" approach where transport planning choices are made by analysts is not always sufficient to assure that the final choice will be supported. It is necessary to involve them all along the decision-making process with the support of adequate MCDM/A methods. In this respect, the Multi-Actor Multi Criteria Analysis (MAMCA) (Macharis, 2004) is widely used in transport decision-making to gain insights in stakeholders' objectives and evaluate how the alternatives contribute to these objectives with the possibility of adapting them. There are some useful online tools/software developed to support multi-actor multi-criteria processes (e.g. Stirling and Coburn, 2014; Keseru et al., 2016). Another important aspect to consider is stakeholder interaction that can lead to opinion change and is fundamental to reach shared decisions (Le Pira et al., 2015, Le Pira et al., 2017b). Therefore, an effective participation process should be structured so to foresee the use of MCDM/A and the involvement of different stakeholders in several phases.

Based on this premise, this paper presents a procedure for the structuring of a transport decision-making problem and evaluation of the solutions proposed from a multi-stakeholder multi-criteria perspective. Analytic Hierarchy Process (AHP) is used as MCDM technique, while a role-playing game is used to reproduce a participatory process where University students act as key stakeholders. This represents the second step of a wider procedure to support a stakeholder-driven transport decision, as it will be better clarified in the next section.

The remainder of the paper is organized as follows. Section 2 is a short introduction to the methodology, with a description of the participatory procedure adopted and of the well-known AHP method. Section 3 presents the case study with a description of the decision-making context and the participation experiment. Section 4 shows the results obtained with AHP and from a comparison between the collective result obtained by mathematical aggregation and by a consensus vote. Section 5 concludes the paper by summarizing the main findings and directions for further development of the research.

2. Methodology

The overall participatory procedure consists of three steps and is summarized in Fig. 1. The case study regards the decision about a new hectometric (i.e. short-range) transit system in Catania (Italy), which should connect a new metro station with a University district. In the first step, key stakeholders have been identified and involved via in-depth interviews. A questionnaire, a GIS map and a SWOT-like graph have been used to present them the decision problem and capture their preferences and opinions. From the results of the interviews, a first hierarchy of the problem has been built (Ignaccolo et al., 2017). The second step is described in this paper. A role-playing game is used to reproduce a participatory process where University students are asked to act as key stakeholders and to obtain a ranking of transport



alternatives. In the third step, a public consultation will be performed via a stated preference survey, to collect their preferences for transport system alternative configurations. In the following section, the basic elements of AHP are described together with its potential to support participatory decision-making process.

Fig. 1 The overall participatory procedure (own setup).

2.1. Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a well-known MCDM/A method, developed by Thomas Saaty in the late 1970s (Saaty, 1980). It is particularly useful when decision-makers are unable to construct utility functions, differently from other methods, i.e. those based on Multi Attribute Utility Theory (MAUT) (Ishizaka and Nemery, 2013). Besides, it is easily extendable to group decision-making and, thus, it is useful to support stakeholder engagement in decision-making processes (Le Pira et al., 2015, Le Pira et al., 2017b). It allows to analyze the problem by decomposing it into decision-making hierarchy, including at least three levels, i.e. main objective (or goal), criteria and alternatives. The structure of the problem can be achieved via brainstorming sessions with experts, analyzing studies of similar problems or organizing focus groups (Ishizaka and Nemery, 2013). The elements of each level are compared between each other through pairwise comparisons, based on the importance or contribution of each of them to the element of the upper level to which they are linked. In this way, pairwise matrixes are built for each level. The pairwise comparisons are made expressing a judgment on a qualitative scale that is turned into a quantitative one, from 1 (i.e. equal importance attributed to the two elements) to 9 (i.e. extreme importance attributed to the firs element)[†] (Saaty, 1980). Then, priority scales and weights are derived from pairwise matrixes for each level by using one of the aggregation methods proposed (Saaty and Hu, 1998) and the overall priorities associated with alternatives are evaluated. Individual judgments arising from pairwise comparisons cannot be perfectly consistent, so it is necessary to perform a consistency check. The inconsistency can be measured (and, therefore, monitored) through the comparison between a consistency index derived by the matrix elements with the one obtained by purely random

[†] Reciprocal values are used when the second element is preferred to the first one (e.g. 1/9).

judgments (Saaty, 1980). In general, an inconsistency of less than 10% is accepted. AHP has been widely used to support decision-making in transport planning and management (Piantanakulchai and Saengkhao, 2003; Sivilevičius and Maskeliūnaite, 2010; Mahmoud and Hine, 2013) and in environmental planning (García-Melón et al., 2012; Romero-Gelvez and García-Melón, 2016).

When a group decision is needed, i.e. more than one decision-maker is involved in the decision, it is necessary to define an appropriate procedure to combine multiple preferences into a consensus rating. It can be derived in four ways (Ishizaka and Nemery, 2013), according to the level of aggregation (from judgments or from priorities) and the type of aggregation (mathematical or based on consensus vote). In general, a consensus vote is used when stakeholders are able to agree on the values of the matrices or on the priority vectors; vice versa, mathematical aggregation is adopted. While mathematical aggregation implies transparency and clarity of results, it might not reflect the individual preferences. On the contrary, a consensus vote is more democratic and fair, but also in this case the final group ranking could have a low rate of acceptance, being supported only by a relative majority. According to Le Pira et al. (2016b), the optimal solution should be based on a mixed procedure that combines mathematical aggregations with consensus building, through an interaction process among stakeholders that facilitates a convergence of opinions, in a way to increase the acceptability of the final results while at the same time guaranteeing transparency of the decision process. In this paper, a comparison among mathematical aggregation of priorities and a consensus vote was performed to verify the differences between the two alternative rankings and the correspondence with stakeholder preferences.

3. Case study

3.1. The decision-making context

Catania is a city of about 300.000 inhabitants, located in the eastern part of Sicily (Italy); it has an area of about 183 km^2 and a population density of 1.754,54 inhabitants/km^2. It is part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania (Ignaccolo et al., 2016).

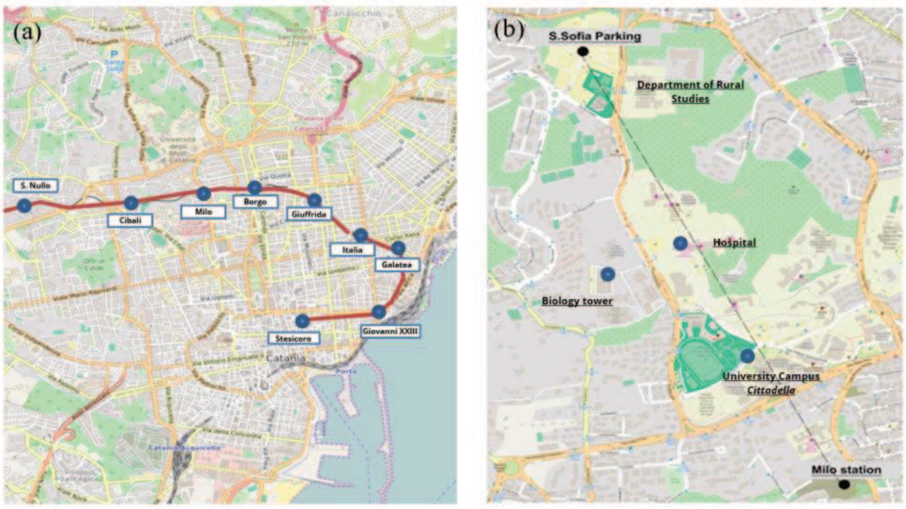


Fig. 2 (a) territorial framework with the metro line; (b) area of intervention (from Milo station to S.Sofia parking) (own setup).

The main city (Fig. 2a) contains most of the working activities, mixed with residential areas. With reference to the urban area, the transport service is provided by 51 bus lines, a Shuttle line (called ALIBUS) connecting the city center with the airport and a second rapid bus (called BRT1) connecting a parking located in the northern part of the urban area with one of the main squares in the historical center. An urban metro line currently links the port of the city (which is very close to the historical center) with the area immediately out of the historical center, from which it continues as a surface long-distance line. The line is expected in the next years to grow from 7 km to 11 km, connecting the city center with the peripheral areas. A new subway station, named “Milo”, has been recently opened. Its position will make it the closest station to an area where important University sites, health services and a park-and-ride facility (S. Sofia parking) are located (Fig. 2b). Due to slope and distance between the station and the University sites, a new dedicated hectometric transit service linking the two transport nodes is under evaluation. Four different transit alternatives are proposed (Ignaccolo et al., 2017):

- a *bus*, which is the most popular mean of collective public transport in our cities with a well-established technology.
- a *Minimetro* or *people mover*, which is a modern automatic rail automatic system, where vehicles are usually equipped with rubber tires circulating on metallic or concrete guides.
- a *monorail* called *“Etna Rail”*, which has been designed for the metropolitan area of Catania, including 3 different lines, with one tangential to the study area.
- A *ropeway*, which falls into the category of cable transport and is the most common technology used to connect areas divided by a very high slope.

A first decision-making hierarchy was built based on the result of in-depth interviews with five key stakeholders, representing the main interest groups affected by the intervention: (1) the University of Catania, (2) the urban bus transit company (Azienda Metropolitana Trasporti – AMT Catania), (3) the University Students’ Council, (4) the Municipality of Catania and (5) the metro rail company (FCE – Ferrovia Circumetnea) (Ignaccolo et al., 2017). A Web GIS map[‡] has been shown to the stakeholders with a representation of the main impacts of the four different alternatives. Stakeholders were individually interviewed, by asking them if they agreed on the importance of the intervention and then to assign an importance level to four different impacts of the alternatives under consideration, i.e. transport, economic, social and environmental impact. In the final part of the interview they have been asked to perform a SWOT (Strenghts-Weaknesses-Opportunities-Threats) analysis for each of the alternatives, in order to elicit their different opinions in terms of strengths (i.e. internal features of the project providing an advantage over others), weaknesses (i.e. inherent characteristics that place the project at a disadvantage relative to others), opportunities (i.e. external issues that the project could benefit of), threats (i.e. external elements that could cause failures of the project). From the results of the survey, it was possible to derive the main elements (i.e. sub-criteria) to build a first decision-making hierarchy. Table 1 schematically summarizes the elements that compose the criteria/sub-criteria levels of the hierarchy, where the goal is the choice of the best transport system and the four alternatives are at the bottom level (more details can be found in Ignaccolo et al., 2017).

Table 1. Criteria and sub-criteria identified in the process

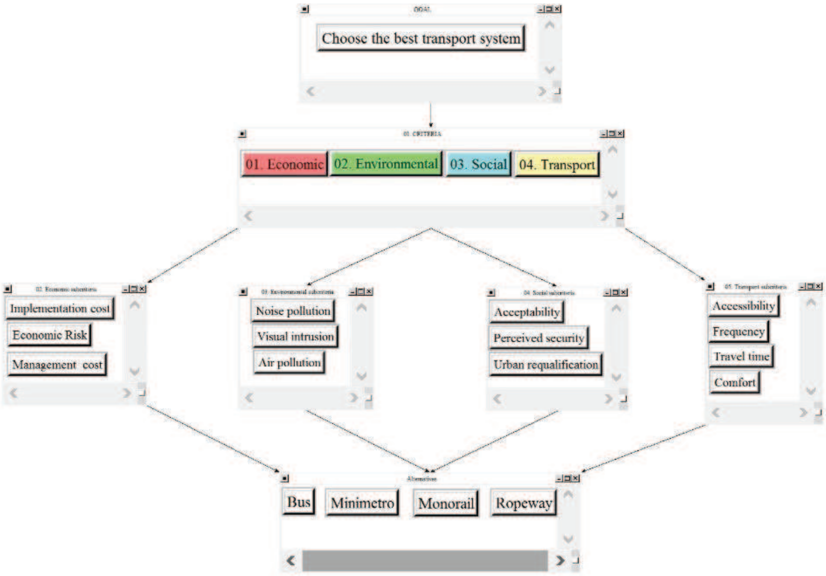
Criteria	Sub-criteria
Transport	Accessibility; Travel time; Frequency; Comfort
Economic	Implementation cost; Economic Risk; Management cost
Environmental	Air pollution; Noise Pollution; Visual Intrusion
Social	Acceptability; Urban requalification; Perceived Security

3.2. The participation experiment

In order to test the decision-making hierarchy and evaluate alternatives from a multi-stakeholder multi-criteria perspective, a participation experiment was set up, by involving University students in a role-playing game. Such experiment has been arranged as a preliminary test of the procedure that, in future, will be carried out with real stakeholders. Forty students of the “Transport Systems” class of the Master Course in “Environmental Engineering” of the University of Catania were involved in the experiment, which took place between May and June 2016. A total of 5 sessions of 2-3 hours each were organized. The students were trained on the complexity of decision-making about transport systems and the role of multicriteria decision technique to support decision-making (two sessions). Two sessions were dedicated to the description of the case study with a detailed analysis of the four transit alternatives. In the last session, the actual participation experiment took place. They were divided in five groups, each of them representing one of the key stakeholders described in section 3.1. The results of the in-depth interviews were provided to them in order to make them identify with the specific role. AHP was performed using the software SuperDecisions©

[‡] The WebGIS map with an example of the survey proposed to the stakeholders can be found at the following website: http://transportmaps.altervista.org/LinkMiloSSofia/index.html

(www.superdecisions.com). The first step was to validate the previously developed hierarchy. In this respect, the students shared all the criteria and confirmed it, as shown in Fig. 3. Then, the groups were asked to make pairwise



comparisons for each level of the hierarchy. The inconsistency of judgments was constantly monitored and kept to the minimum.

Fig. 3. Hierarchy of the decision problem in SuperDecisions.

4. Results

4.1. Priorities results of the participation experiment

Results of the pairwise comparisons on criteria and sub-criteria for the five groups are shown in Fig. 4:

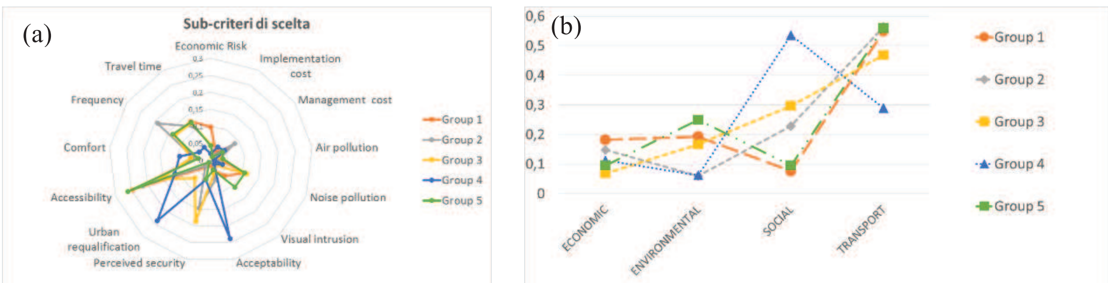


Fig. 4. AHP results: (a) subcriteria priorities and (b) criteria priorities.

The first group (group 1), which played the role of the University of Catania (and, specifically, the Rector's delegate in charge for mobility management), gave more importance to the transport impact (criterion) and, in particular, to accessibility, travel time and frequency (sub-criteria). The second group (group 2), representing the urban bus transit company (AMT), also considered the transportation impact as the most important aspect followed by the social one, especially in terms of accessibility, frequency and perceived security of each transport system alternative. The third group (group 3), playing the role of a student representative of the University Student's Council, considered important the transport and social impacts, in terms of perceived security, accessibility and travel time. The fourth group (group 4), representing the Municipality of Catania, assigned the highest level of importance to the social criterion, in particular in terms of acceptability of the proposed solutions and urban requalification of the surrounding areas. The last group (group 5), representing the metro rail company (FCE), gave priority to transport impact, in particular in terms of accessibility, followed by the environmental impact referred to noise pollution and visual intrusion. As can be noticed in Fig. 4, there is some heterogeneity in the judgements, even if accessibility is one of the overall most ranked sub-criterion. Globally, transport impacts are considered more important, followed by the social, environmental and economic ones (Fig. 5a). These results are clearly in line with the preferences that key stakeholders expressed in the in-depth interviews, showing that students were able to play the roles assigned to them. Finally, priority rankings of alternatives for each group are shown in Fig. 5b.

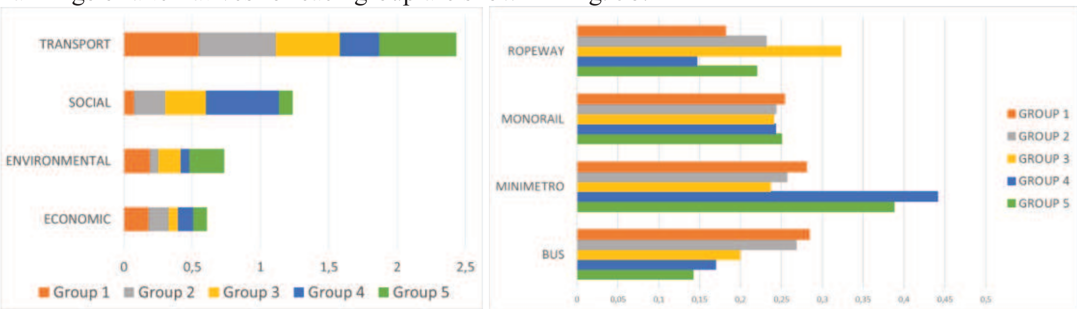


Fig. 5. Priority results of (a) criteria and (b) alternatives.

Minimetro shows the highest priority for group 4 (i.e. Municipality of Catania) and group 5 (i.e. FCE), while *ropeway* is the first ranked for group 3 (i.e. Student's Council). On the contrary, priority rankings for group 1 and 2 (University of Catania and AMT) are quite "flattened". It is worthy of notice that these results rely on students' perceptions about the impacts of each alternative on the different dimensions and that they are not the output of a technical evaluation. Nevertheless, they were well informed about the alternative transport systems and they had a background in transport engineering, therefore they can be considered "sophisticated stakeholders" (Le Pira et al., 2015). In the following, aggregation of individual priorities has been performed and compared with the result of a consensus vote, to derive a collective decision as an output of the AHP procedure.

4.2. Consensus vote vs mathematical aggregation

The last step was to analyse the final results via a consultation process with the five groups representing the key stakeholders. The main aim was to reach an agreement on the best transit alternative. After a discussion about the different priority rankings derived from the five AHP, the whole group decided that there might be a best short-period solution and a best long-period solution. In this respect, *bus* would be a good solution in the short period while *Minimetro* would be the best solution in the long period. This can represent an input for discussion with real stakeholders in the future. The obtained results depend on the sample considered in this study and they could be different if other groups of students were considered. In a real participation process the consensus vote can be altered by more influencing stakeholders, so a stakeholder analysis can be helpful to gain insight into their power/influence in the decision-making process. Subsequently, a mathematical aggregation of the five priority rankings was done using the geometric mean method, in order to make a comparison with the decision for the long period emerged from the discussion. Results confirm that the best solution is the *Minimetro*. However, as opposed to the consensus vote, the second solution is *monorail*, followed by *ropeway* and, lastly, *bus*. This demonstrates that a mathematical aggregation of individual priorities is not always appropriate to obtain a group decision representative of stakeholder interests. Aggregation of individual judgments or, if possible, a consensus vote is to be preferred. Nevertheless, the group ranking derived from simple priority aggregation confirmed what stakeholders evaluated as the best solution, therefore it can be useful to have a global vision of stakeholder preferences.

5. Conclusions

This paper combines Analytic Hierarchy Process (AHP) with role-playing games to support stakeholder engagement in complex transport decisions. where students played the roles of key stakeholders, representing their interests with the final aim to select the best transit system solution out of four possible alternatives. AHP is widely used to support transport decision-making processes requiring the evaluation of alternatives from multiple criteria. Its usefulness for group decision-making is here demonstrated, since it allows to elicit and compare stakeholder individual judgments and pave the way for consensus building among stakeholders. The procedure here described is part of a wider participation process, with the final aim of selecting the best transit alternatives adopting a multi-stakeholder multicriteria perspective. After a consultation with key stakeholders and a first evaluation of alternatives, a public consultation will be performed via a stated preference survey, to collect citizen preferences for different transport system alternative configurations. The overall goal is to have enough information to guide the final decision, which should be based both on the results of technical evaluations and the one of the participation process.

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