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Transportation Research Procedia 5 (2015) 175 – 185
Transportation Research Procedia
www.elsevier.com/locate/procedia

SIDT Scientific Seminar 2013

Multi-Criteria analysis to support mobility management at a university campus

Giovanni Longo[a] *, Giorgio Medeossi[a], Elio Padoano[a]

[a]*University of Trieste, Dept. of Engineering and Architecture, P.le Europa 1, Trieste 34127, Italy*

Abstract

The mobility referred to the University is a significant part of the urban mobility in Trieste. Therefore a specific project was performed to analyze the main problems, to understand the preference structure of the users and to define some possible solutions to improve the accessibility of the University and to reduce urban congestion, mainly through sustainable transport modes. The survey pointed out features and preferences of different user groups, which were explicitly considered in the AHP assessment framework, and allowed to define criteria and to fix the weights. Also the presence of more than one decision maker was explicitly included in the hierarchy, to model the different impact of different user groups on the decision makers. As a result, the ranking of the alternatives has been defined, which has been taken into account by the decision makers for their planning choices. From a methodological point of view, the specific structure of the AHP hierarchy allowed to model the decisional problem even if a more complex ANP approach would be perhaps more suitable to consider interactions between nodes in this group decision problem.

Peer-review under responsibility of the Società Italiana dei Docenti di Trasporti (SIDT).

Keywords: AHP; mobility management; survey; alternative assessment.

1. Introduction

The University represents by far the largest institution in Trieste (a middle-sized European City in the North East of Italy), with around 25,000 people in a city of about 200,000 inhabitants. The University is split into 17 locations

* Corresponding author. Tel.: +39-040-5583576; fax: +39-040-5583576.
E-mail address: longo@dica.units.it

Peer-review under responsibility of the Società Italiana dei Docenti di Trasporti (SIDT).
doi:10.1016/j.trpro.2015.01.019

within Trieste, generating urban movements of residents, the inter-urban trips of daily commuters as well as the short daily transfers and weekly long distance trips of weekly commuters. Moreover, the behaviour of the administrative employees is quite regular and significantly different from the professors and research personnel, while the students show very varying arrival and departure times as well as systematic transfer among multiple locations during the day.

The mobility related to the University campus is therefore a significant part of the urban one and it is of concern of several stakeholders.

Accordingly, the mobility manager of the University decided to analyze it and, possibly, to identify the main issues and to propose possible solutions to improve the accessibility of the University and, at the same time, to reduce urban congestion. As known, Mobility management is the study of home-to-work displacement habits, aiming at an improvement of the current situation through initiatives that promote sustainable means of transport and solutions alternative to cars and motorbikes. Together with traffic reduction, important targets of mobility management are the solution of parking shortage and energy savings.

Based on the information collected during an extensive survey, a list of proposals was defined. The set of measures was widespread, from the improvement of transit services to new parking places for cars and scooters, from additional on-line administrative services to new fare schemes and non-conventional transport services.

According to Italian regulation, there are more than one decision maker in the urban mobility field: Trieste Municipality, Province of Trieste, FVG Region, and of course the Rector for the University. For this reason to suggest a list of priorities to the decision makers, it was decided to try to rank the improvement measures taking into account the criteria, which were considered of key importance by the decision makers and the users. It is noteworthy that different decision makers or user groups perceive the effects of an action on the mobility system from different perspectives, therefore the levels of importance of the criteria may differ for different groups or decision makers. Further, each decision maker may perceive the priority of a possible action depending on the effects on the interest (or user) groups which have the strongest connections with them.

In order to build such a ranking, a particular model based on the Analytic Hierarchy Process (AHP) approach was developed and applied. This model is describe in detail in the following sections.

The paper is organized as follows: the next paragraph describes briefly the survey then a methodological framework is set. In the fourth paragraph the application of the methodology to the case study is discussed and finally some conclusions are drawn.

2. The survey

An extensive survey, concerning the mobility from and to the campus of the University of Trieste, was carried out which revealed both the questions to be solved and a set of possible improvement actions.

Certainly, a quantitative survey is needed to provide analysts with data about mobility habits, willingness to modal change and other customs, derived from a statistically significant sample. Nevertheless, before committing in such a vast initiative, it is crucial to understand all aspects of the question – including those not strictly related to transports. Qualitative surveys serve this purpose. For this reason a qualitative analysis of university staff and students' mobility attitudes was carried out through the use of focus groups, involving three categories of students separately to gather the most complete information.

Twenty students were involved in the focus group analysis, divided into three groups that discussed the problem separately. Each group was composed of students attending the university at various course years (excluded those newly enrolled), 19 to 25 years old, attending the athenaeum either at its central campus (50%) or at any of its detached buildings (50%). 50% of them were women, 50% men. Excluding from the current analysis occasional students, those not attending regularly, workers and home students, the target population was split into three groups, depending on their mobility habits:

- 6 students living in Trieste;
- 8 long-stay commuter students (one move to/from Trieste per week, weekdays spent in Trieste);
- 6 daily commuters (no nights spent in Trieste).

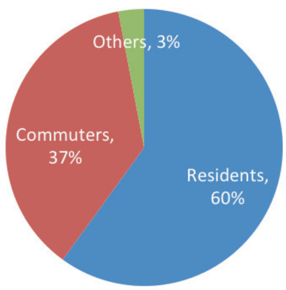
Focus groups were lead by a specialized team, who stimulated the discussion on their perceptions about transportation through questions and evaluation sheets, following a general pre-defined outline. The aim was to highlight their opinions, attitudes and habits. These analyses pointed out, for instance, how actions on external factors can influence transport issues and suggested some issue to be better analyzed in the quantitative survey. The qualitative survey on the employees was performed through a short questionnaire by e-mail on the same topics.

Based on these results a web-based survey was designed and conducted. It was carried out through the web using the CAWI methodology (Computer Assisted Web Interview) in order to provide the opportunity for all "users" of the University (staff and students with a regular registration) to participate in the survey. This method allows managing the interviews (many contemporary interviews, selection of the right questions through the questionnaire according to previous choices, and so on) and it is cheaper than other existing technologies.

The questionnaire included 72 questions divided into six main groups:

- compliance with privacy regulation;
- user classification in respect of role within the University, place of residence/domicile, vehicle availability;
- trips features for a normal working day (origin, destination, time of departure and arrival, transport mode choice, …);
- judgment on safety, importance of different issues in the modal choice, role of different decision makers, …;
- suggestions and comments;
- socio-demographic classification of users.

In total 3976 valid questionnaires were collected showing a significant acceptance among both personnel and students (average response rate: 16,11%). The collected data represent an important source of information about O/D volumes and modal split, but also about problems, behaviours and preferences of the different users. The figure 1.(a) shows for example the distribution of users among resident, commuters and others while in the figure 1.(b) the actual average modal split for university users is presented (see Longo, 2011 for more details).



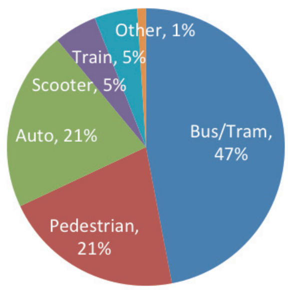


Fig. 1. (a) Distribution of users; (b) Modal split.

3. The evaluation process: some basic methodological aspects

The survey allowed to identify some measures that, according to the respondents, can improve the mobility to and from the university's sites. The objects and contents of such proposals are rather different, including the improvement of transit services, new parking places for cars and scooters, additional on-line administrative services and new fare schemes, nonetheless they represent the users' main concerns on which to base the planning of the actual actions to improve mobility. In order to present the decision makers (Trieste Municipality, Trieste District/FVG Region and the University Rector) with a list of priorities, it was decided to rank the improvement measures taking into account the criteria which were considered of key importance by both decision makers and users. It is noteworthy that different stakeholders (decision makers or user groups) perceive the effects of an action on the mobility system from different perspectives, therefore the levels of importance of the criteria may vary among them (Banville, Landry, Martel, & Boulaire, 1998).

In a recent article, Xenias and Whitmarsh (2013), extending other authors' research on public perception on transport policies and technology (see Schwanen, Banister, and Anable (2011) for a recent review), explore the evaluation of different technological and behavioural alternatives of transport by experts and non-experts. The results of that study show that while attitudes towards some solutions vary with level of expertise (differentiating citizens from experts), the evaluation of other options depends on environmental values or identity that can vary among members of the same group. Admittedly, the experts' contribution to the decision process can assure the technical soundness of the solutions, but it is also decisive to account for the viewpoints of the users of the mobility system in order to inform and improve the final decisions and make them acceptable (Eriksson, Garvill, & Nordlund, 2006, 2008; Siebenhuner, 2004). Further, as remarked by some studies (Bai, Lai, Chen, & Hutchinson, 2008; Jones, 2012; Lupo, 2013), decision makers may relate the priority of a possible solution to its effects on their target interest (or user) groups; for example, Lupo (2013) points out that the performance evaluation of public transport must reflect the viewpoints of the different service stakeholders (transport users and local community).

As far as urban mobility planning is concerned, many political actors and stakeholders are involved in the decision process, thus the design and evaluation of solutions must account for several points of view and criteria. In this respect, multi-disciplinary approaches to decision aiding, such as multi-criteria decision analysis (MCDA), offer several advantages over conventional economic methods. In a noteworthy study, Bristow and Nellthorp (2000) examined different transport appraisal methods employed in the European Union and found that while direct outcomes on the transportation system can be effectively evaluated by standard economic methods, MCDA can be more effective to capture and assess environmental and social impacts. This was confirmed in other papers by Tudela, Akiki, and Cisternas (2006) and by Browne and Ryan (2011): these authors concluded that MCDA is appropriate to account for public opinion explicitly and to carry out a transparent and participatory decision making process.

As for the study here presented, a MCDA approach was used for ranking the improvement measures (set of candidates); more specifically a model based on the Analytic Hierarchy Process (AHP) approach was developed and exploited. The AHP (Saaty, 1980) has been applied since the 1980s to support the evaluation and selection of alternative courses of action in the transport field. Many applications concern infrastructural projects or technology, nonetheless there are studies which deal with urban mobility or urban transportation investments in a broad sense (Campos, Ramos, & de Miranda e Silva Correia, 2009; Pak, Tsuji, & Suzuki, 1987; Teng & Tzeng, 1996); conversely, the use of the AHP to support the analysis of specific portions of the urban mobility system (like historical areas, large hospitals or university campuses) and the evaluation of interventions on accessibility conditions are lacking (Miralles-Guasch & Domene, 2010).

The success of the method can be attributed to several of its features, such as the effectiveness of the hierarchical representation of a decision problem, the ability to assess uneasily measurable factors and the straightforward compensatory approach. As remarked by Saaty (2004), such aspects can be explained by the analyst to the decision maker with limited effort, becoming a solid ground for the mutual understanding and validity of the evaluation process. Some studies (Berrittella, Certa, Enea, & Zito, 2008; Longo, Medeossi, Strami, & Padoano, 2011; Whitmarsh, Swartling, & Jäger, 2009) observed that if candidate solutions are explored by a panel of experts and evaluated against criteria that are expression of the stakeholders' objectives and concerns, the technical soundness and the transparency of the process can be assured. Indeed, the evaluation of strategic decisions is often a discussion process in which several stakeholders participate directly or by means of nominated experts or representatives. In order to reach a valid and useful decision, it is then critical to promote the actual contribution of the key stakeholders (decision makers and users) to the analysis and evaluation activities, for example developing an open "space of discussion" or a project group framework (Koskinen & Pihlanto, 2007; Padoano, 2013; Paschetta & Tsoukiàs, 2000; Shang, Youxu, & Yizhong, 2004).

On the grounds of the aforementioned methodological considerations, the AHP model discussed in this article aimed at supporting the discussion among decision makers through an explicit representation of the user groups, evaluation criteria and improvement measures (solutions) in the hierarchy. Moreover, criteria were prioritized taking into consideration the viewpoints of the mobility system users, while a panel of experts performed the evaluation of the performance of solutions on the criteria. In this view, technical expertise and evaluation models play an important role for making sound decisions. The model and the results are discussed in the next section.

4. The AHP model: structure and results

The evaluation process is characterised by several actors with different roles. The representatives of local administrations or public institutions are the actual decision makers while the users of the university premises can influence them and, in the specific, were explicitly surveyed by means of the focus groups and questionnaire. Several evaluation criteria were identified through the survey. The improvement measures, which were individuated by the focus groups, cannot be considered as "alternatives" but as candidate solutions to be ranked according to the users' criteria so as to select few of them in view of a detailed technical and economic feasibility study.

The hierarchy built in the case study consists of five levels (Figure 2). This node at first level represents the shared vision of the main objective to be achieved, which was stated as "Improve the accessibility of the university campus". It is worth noting that such sentence summarizes one of the topics discussed in the focus groups, namely what were the sectors of intervention to improve mobility for a better accessibility of the university campus.

The second level includes the decision makers: these actors are legitimate in making the actual decisions concerning the mobility referred to the university's campuses. They have an active participation in the multi-actor decision process in which "university mobility" is the "meta-object" (Ostanello & Tsoukias, 1993); in this view, the decision makers are concerned with issues and put forward arguments, which mainly depend on their institutional role, that are related, albeit sometimes instrumentally, to university mobility. The Mayor of the city of Trieste is the principal decision maker in regard to urban mobility problems and solutions and is mainly concerned with the effects on residents of any modification to the urban mobility system. The university Rector can exert considerable pressure on public plans and decisions that affect the university's users, considering the key role of this institution in the local economy and society. The university mobility system has a pivotal role for such actor not only because of its outcomes on campus accessibility, but also for the possible benefits that the application of sustainable or innovative mobility solutions can have on the university image. Two other administrations that participate in this decision process are the Province of Trieste, which has responsibility for the planning and management of public transport, and the Regional Government of Friuli Venezia Giulia, which can assure financial support for the implementation of plans and projects and is interested in the effects that prospective solutions could have on regional mobility. As these two actors usually coordinate their interventions and decisions regarding local mobility questions, they are grouped in a single model object at the first level of the hierarchy.

The explicit representation of the decision makers in the hierarchy, which has been used in some previous studies (Saaty & Forman, 2003), allows to assess the importance or influence of each actor against the main goal and to take into consideration the judgments of importance expressed by each decision makers in regard to the objects of the lower levels.

The third level is made up of the users of the university's campuses and mobility system. Five user categories were identified that group subjects with similar accessibility needs and travel behavior (Longo, 2011). They are:

- Resident academic staff are University employees (professors and researchers) living in Trieste;
- Commuting academic staff are University employees (professors and researchers) living outside Trieste, who perform a daily trip between residence and University and vice versa.
- Administrative staff are University employees mainly living in Trieste due to stricter time constraints according to their contract;
- Resident students who live in Trieste and usually may have a higher vehicle availability than commuting students;
- Commuting students who do not live in Trieste (both daily and weekly commuters) and mainly use public transport.

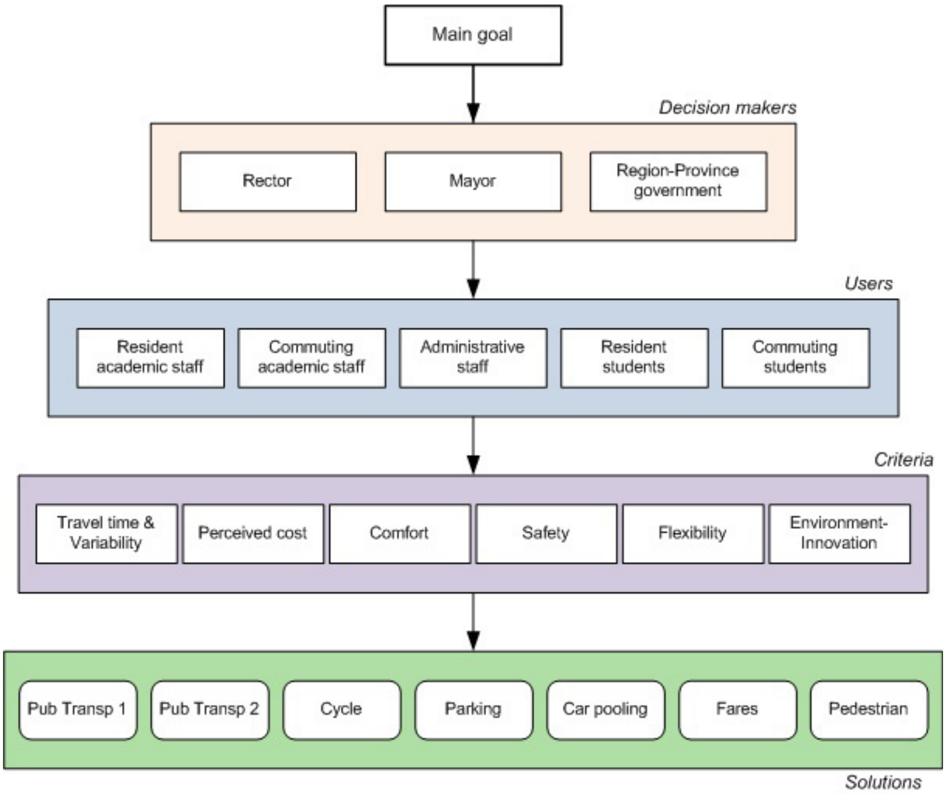


Fig. 2. The model hierarchy.

The fourth level includes the criteria that are taken into consideration by the surveyed users when they evaluate a mode of transport:

- Travel time and variability; this criterion accounts for the users' estimation of door-to-door travel time, including the search time for parking, and the variability due to delays or traffic congestion;
- Cost, as perceived by the user;
- Comfort; this aspect takes into account the foreseeable number of changes and the walking distance between the university and the parking place or the bus stop;
- Safety (and Security); this criterion includes the perceived risk of incidents and security from crime risk;
- Flexibility, in terms of the opportunity to arrive and depart at the desired time;
- Image and Environment, which includes all aspects that improve the perceived quality of transport, such as the adoption of innovative technologies and the containment of environmental impacts.

The bottom level of the hierarchy contains the improvement measures (solutions) that were initially proposed and discussed in the focus groups in the first stage of the survey and that were better defined after the quantitative survey. The candidate solutions are:

- "Pedestrian", which includes the improvement of some pedestrian paths that are used to connect the University and the most important transit stops;
- "Bicycle", which include the creation of new bicycle lanes between the railway station and some University buildings and the relative parking facilities;
- "Parking", to increase parking facilities around the University main buildings;

- “Car Pooling”, which includes the development of an application to create and manage this service especially for the areas that are not served by public transport;
- Public Transport 1 and 2. Indeed, given the high number of proposals concerning the public transport system, two sets of measures were considered: one focused on commuters (mainly to improve the public transport supply at interurban level to increase the accessibility of the University for non-resident users) and one on residents (mainly at urban level with a modification of some existing lines and new services in the evening and during the night);
- “Fares”, which includes a set of measures aimed at reducing the price of bus tickets or introducing monthly cards for students and employees.

The AHP model was implemented by means of the Superdecisions software package. The levels of preference or importance to a set of nodes, at any level of the hierarchy, in respect to a node in the adjacent upper level of the hierarchy were assigned, thus obtaining a “local” evaluation. Then, through the hierarchical structure, the synthesis of those evaluations was made so as to obtain the values of preference of the bottom level elements against the main goal. The first analytical stage of the evaluation was performed using different approaches because of the different sources of information: administration officers, transport experts and data collected through the survey. As already mentioned, two evaluation approaches were used, both of which can be implemented through the software: pairwise comparisons and direct entry of performance values.

The influence on the main goal of the three decision makers was assessed according to the existing regulation and on the basis of a set of interviews. During this interview, the following question was asked to a number of experts in respect to each pair of decision makers: “Considering the main goal, namely ‘Improve the accessibility of the university campus’, who has the greater influence in the goal achievement and to what degree?” The strength of the influence was assigned by means of Saaty’s nine-level verbal scale, in which the verbal judgements go from ‘A is as influent as B’ (with a corresponding numerical value of ‘1’) to ‘A is extremely more influent than B’ (with a corresponding numerical value of ‘9’ in favour of A). The results normalised by cluster (namely, the set of nodes at the same level) are reported in Table 1. According to what was expected, the Mayor of the city plays the most relevant role in the definition of the interventions to improve the urban mobility; after that also the importance of the authorities, which are involved in the management of public transport has been recognized. In this field, the Rector importance is really low and he may only try to present problems and suggest solutions which should be decided by the other decision makers.

Table 1. Decision makers and weights

Decision maker	Weight (influence on Main goal)
Rector	0,07
Mayor	0,65
Region-Province Government	0,28

In order to rank-order the user groups, the same experts were interviewed and asked to pairwise compare, using Saaty’s verbal scale, the user groups against the decision makers. The question structure was: “Considering the decision maker X and user groups A and B, what user group has the greater influence on that decision maker and to what degree?” The interviewee assigned levels of influence between 1 and 5 during pairwise comparisons and was particularly even in judging the influence of users on the Mayor (see Table 2, in which the values represent the influence of the row element with respect to the column element). The overall results (taking into account all decision makers), normalised by the cluster of user groups, are shown in Table 3.

Table 2. Influence of “users” on the Mayor.

	Res academic	Com academic	Admin staff	Res students	Com students
Resident academic staff		2	1	1	2
Commuting academic staff			1/2	1/2	1
Administrative staff				1	1/2
Resident students					2
Commuting students					

Table 3. Overall influence of “users” on decision makers.

User groups	Weight (influence on decision makers)
Resident academic staff	0,19
Commuting academic staff	0,11
Administrative staff	0,17
Resident students	0,29
Commuting students	0,24

In the analyzed context, the influence of residents is higher than the commuter’s one, not only because their number is higher as shown in the figure 1.(a), but mainly because their influence on the Mayor is higher (as they are his voter). Among commuters, the relative importance of students is higher than the one of staff because of their number and because they come from a wider area within the region (their influence on FVG Region actor is higher).

The quantitative survey allowed to weigh the criteria, by using the results of a specific section of the questionnaire that was dedicated to analyze the relative importance of each criterion for the different user groups. Table 4 reports the values of importance, in respect to all user groups considered, normalised by the cluster of criteria.

The results show that the most important criteria are (as expected) cost (mainly for students) and time (mainly for employees). Safety and security are not perceived as so important in Trieste, that is a quiet town; moreover comfort is more important than flexibility and also the environmental aspects are considered.

Table 4. Importance of criteria.

Criteria	Weight (level of importance for the users)
Travel time and variability	0,27
Perceived cost	0,34
Comfort	0,11
Safety (and Security)	0,04
Flexibility	0,09
Image and Environment	0,15

The improvement solutions were assessed by a group of expert who used direct measures and modeling (in the case of public transport 1 and 2) or pairwise comparisons (in the other cases) to come, after discussion, to a shared evaluation of their performance against each criterion. Table 5 shows the overall performance values of the solutions normalised by cluster.

Ultimately, the results obtained for each cluster were synthesised in the AHP model thus producing the global performances of the candidate solutions, which are reported in Figure 3.

Table 5. Overall performance of the alternatives.

Candidate solutions	Performance (normalised by solution cluster)
Public transport 1	0,09
Public transport 2	0,10
Cycle	0,19
Parking	0,22
Car pooling	0,18
Fare revision	0,12
Pedestrian	0,10

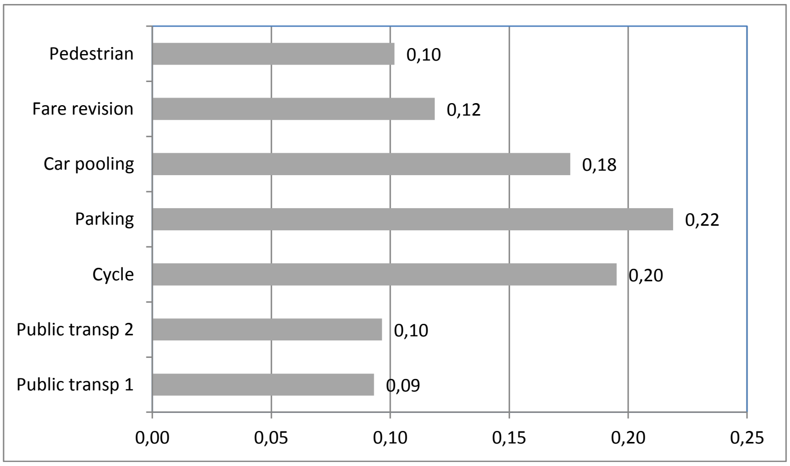


Fig. 3. Results of the assessment.

The results of the assessment process show that the 'Parking' solution ranked first followed by the 'Bicycle' and 'Car pooling'. Although the results differ from the expectation of a classic mobility management study (Longo, 2011), they appear reasonable in the context of the University of Trieste. Indeed the campus is very well connected to the public transport system, which is one of the most dense and used urban public transport network in Italy. Therefore, the high level of quality of public transport, as perceived by users, collocates further improvements of it at the bottom of the ranking as other mobility components are presently considered more problematic. In particular, the parking facilities at most locations appear extremely scarce and, similarly, no bicycle lane or parking is provided, thus explaining the importance that users and decision makers give to actions aimed at their improvement.

5. Conclusions

The specific features of a University campus made it quite difficult to define and mainly perform the assessment of mobility improvements. There are different users groups with different behaviours and preferences, there are a number of decision makers who consider in a different way the judgments of different users, the problems involve urban and interurban levels. A specific survey allowed to collect data, which have been useful to focus these issues and to define alternatives and assessment approach.

The specific structure of the AHP allowed to model the particular decision context; in fact the explicit representation of the decision makers in the hierarchy allowed to assess the influence of each actor against the main goal and to take into consideration also the different importance expressed by each decision makers in regard to the objects of the lower levels (users with their specific preferences). Therefore the AHP approach (simple, well known and understandable) gave good results even if the decision context was quite complex. Moreover the specific survey allowed to point out the preferences of the users and to define the weights of criteria.

The final results, which are at first glance in contrast with the usual goals of mobility managers (as the most attractive alternative is to increase parking facilities and transit improvement are at the bottom of the ranking), are really coherent with the context where the high level of quality of public transport, as perceived by users, make further improvements less attractive while other mobility components are presently considered more problematic. The Rector has carried out actions, which are in line with the results of the study. He has started a series of initiatives aimed at offering a practical implementation of solutions, starting from the cheaper ones, though the creation of an active discussion with the other decision makers.

From a methodological point of view, further developments of the research will focus on a more detailed analysis and modelling of the interactions among the elements of the hierarchy (e.g. between users and decision makers) by means of the Analytical Network Process. In fact, the information collected during the survey could allow the identification and weighing of their mutual influences. Moreover also performing the evaluation in a group decision setting would be interesting to compare the results an discuss advantages and disadvantages with reference to a specific case study.

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