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spatial equity; accessibility; High-Speed Rail investments

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AN ANALYSIS OF SPATIAL EQUITY CONCERNING INVESTMENTS IN HIGH-SPEED RAIL SYSTEMS: THE CASE STUDY OF ITALY

Summary. It is recognised in the literature that spatial accessibility is a measure of spatial equity and can be represented by the ease of travelling from an origin to a given destination via a given mode or set of transport modes. Although urban areas can benefit from improvements in accessibility when a new high-speed rail line is built, equity issues may arise.

This manuscript describes a methodology for evaluating equity impacts due to an extension of the High Speed Rail network in Italy. A joint Revealed/Stated Preference survey has been carried out, collecting socioeconomic and travel data. Specifically, nine hypothetical scenarios have been submitted to Italian users aiming at understanding the motivations for not choosing the High Speed Rail as an alternative. The main outcome is that the access/egress travel costs connected with the High Speed Rail have a strong impact on spatial equity.

The main policy implications of this study are that investors in high-speed rail should not only take into account the economic benefits brought by them, but also the spatial imbalance that these systems can bring.

UN'ANALISI DELL'EQUITA' SPAZIALE RELATIVA AGLI INVESTIMENTI NEI SISTEMI FERROVIARI AD ALTA VELOCITA': IL CASO ITALIANO

Abstract. È riconosciuto in letteratura che l'accessibilità spaziale è una misura di equità spaziale e può essere rappresentata dalla facilità di viaggiare da una origine ad una destinazione mediante un dato modo o insiemi di modi di trasporto. Anche se le aree urbane possono beneficiare di miglioramenti in materia di accessibilità, quando una nuova linea ferroviaria ad alta velocità viene costruita, potrebbero sorgere questioni di equità.

Questo documento descrive una metodologia per valutare l'impatto sull' equità connessa all'estensione della rete ferroviaria ad alta velocità in Italia. E' stato effettuato un sondaggio sulle Preferenze Rivelate / Dichiarate, attraverso il quale sono stati collezionati dati socio-economici e di spostamento. In particolare, sono stati presentati agli utenti italiani nove scenari ipotetici volti a comprendere le motivazioni che li hanno indotti a non scegliere l'alternativa ferroviari ad alta velocità. Il risultato principale è risultato essere che i costi di accesso/egresso connessi al sistema ferroviario ad alta velocità hanno un forte impatto sull'equità spaziale.

Le principali implicazioni politiche di questo studio sono che gli investitori in sistemi ferroviari ad alta velocità dovrebbero prendere in considerazione non solo i benefici economici portati da loro, ma anche lo squilibrio spaziale che questi sistemi possono portare.

1. INTRODUCTION

The tension between efficiency and equity in transport infrastructure development has always been one of the major debates since equity effects started to be part of the project evaluation procedures [13]. Policy decisions on transport infrastructure investments often require knowledge of the benefits generated from using these infrastructures on a detailed regional level. Three different scenarios, for the future of European transport infrastructure, have been proposed by Masser et al. [6] - efficiency, equity and sustainability. Many papers have been proposed to deal with this debate, especially for road transport [3 – 5]. On the other hand, in the literature there is a lack of contributions concerning high-speed rail (HSR) and spatial equity.

Spatial equity or spatial accessibility is a measure of the ease of traveling from an origin to a given destination via a given mode or set of transport modes.

Transport could represent a factor of social exclusion since a lack of accessibility prevents people from participating in work, educational activities, community events, etc.

Some previous interests can be identified for analyzing the potential relationship between transport systems and social exclusion. This is, for example, the case of the UK, since a renewed interest in ameliorating the effects of social exclusion was observed after the election of the Labour government in 1997. A Social Exclusion Unit (SEU) was established to monitor and influence policy across all Whitehall Departments. In 2002 the Unit turned its attention to travel, transport and access, seeing these as processes implicated in the reproduction of social exclusion. In this respect, they pointed out that "recent years have seen a growing recognition that transport problems can be a significant barrier to social inclusion" [11].

Urban areas can benefit from improvements in accessibility when a new HSR line is built [8]. These improvements can foster locational advantages and increase the attractiveness of the cities served. However, equity issues can be present, as the main accessibility benefits are mainly concentrated in urban areas with an HSR station, whereas other locations obtain only limited benefits.

However, HSR system extensions may contribute to an increase in spatial imbalance, leading to more polarized patterns of spatial development. Equal rights of access to different services have been the subject of many researchers for years and several theories have emerged. Sociologists, philosophers, planners, economists, engineers, geographers and education scientists have addressed the question of equity within their particular discipline. Three theories can be considered. These are the egalitarian, where everyone has equal rights or for a particular service; the utilitarian, where the aim is to maximise the total welfare of the society, the libertarian, where the aim is to retain the existing status quo between those better- and worse-off, together with an attempt to improve the situation of those worse-off as much as possible after everyone has secured one's fundamental rights. These principles have also been applied in the context of transport infrastructure appraisal. A paper by Thomopoulos et al. [13] represents an example. They consider that "spatial equity refers to the geographical location of an individual, group or region affected by a transport infrastructure project". The main contribution has been that of developing a framework offering an additional support tool to decision makers for differentiating choices based on their views on specific equity principles and equity types. It is also a valuable tool for evaluators to assess predefined equity perspectives of decision makers against both the project objectives and the estimated project impacts.

The achievement of equity in the distribution of public resources is very important for planners. Equitable distribution entails locating facilities and services so that as many different spatially defined social groups have access. In his paper Talen [12] proposes a method with which planners can generate and evaluate "equity maps" of resource distribution through which they can explore the spatial relationships between public facilities and socioeconomic characteristics.

A study carried out in Spain by Monzon et al. [7] shows the role played by the selection of the commercial speed. Indeed, an increase from 220 km/h to 300 km/h in a given corridor results in significant negative impacts on spatial equity between locations with and without an HSR service.

The same authors propose an assessment methodology for HSR projects following a twofold approach, i.e. addressing issues of both efficiency and equity. The procedure uses spatial impact analysis techniques and is based on the computation of accessibility indicators. Efficiency impacts are

evaluated in terms of increased accessibility resulting from the HSR project, with a focus on major urban areas; and spatial equity implications are derived from changes in the distribution of accessibility values among these urban agglomerations [8].

Church et al. [2] proposed seven categories of social exclusion related to transport and the one related to geographical exclusion is the closer to the concept of spatial equity. Indeed, the authors' geographical exclusion prevents people from accessing transport services, especially those living in rural areas or peripheral urban estates.

In a paper by Pagliara and Biggiero [9], following the work of Church et al. [2], the motivations fostering the choice of HSR by Italians were analysed together with the factors inhibiting them from the use of this service.

The results of a Revealed Preference survey have shown that for those who have not chosen HSR, the main reason is the geographical exclusion, i.e. the low accessibility to the departure/arrival station. It follows the economic exclusion, i.e. the cost of the HSR ticket. The fact that both criteria are greatly perceived by low-income classes can be interpreted by the location of residences of these classes of travellers. For the higher cost connected with the use of the residences, it is clear that those having higher incomes live in city centres, which, in general, are served by a good public transport system and by taxis as well. Indeed, a good public transport system can allow an easy access to the departure/arrival station. This phenomenon is confirmed by the low impact that accessibility has among those choosing HSR (only 6.10%). It can be supposed that these people have rarely perceived a problem in access to the HSR station.

Some of the previous results have been confirmed by a further Revealed Preference survey in the UK. In this case the main motivation for those who have not chosen HSR is the economic exclusion, followed by the low accessibility to the departure/arrival station. In addition, the results of the study suggest that the introduction of a new transport mode, available in a few points of the territory, brings social inequality, mainly perceived in terms of economic and geographical exclusion. Without thoughtful policies, HSR systems will encourage a hyper-mobile society that may abandon people without access to the fastest transport modes.

The objective of this manuscript is to describe a methodology for evaluating the equity impacts on the population due to an extension of the HSR network in Italy.

This paper is organised as follows. In section 2 the case study of Italy will be presented together with the description of the survey. In section 3 results are presented. In section 4 some inferences on the relationship between HSR and equity issues are reported. In section 5 conclusions and further perspectives are described.

2. THE CASE STUDY

The development of the High Speed/High Capacity (HS/HC) project in Italy is still a "work in progress". Apart from the already operating sections (Rome-Naples, Turin-Novara, Milan-Bologna, Naples-Salerno, Novara-Milan and Bologna-Florence), other lines will be inaugurated in the coming years. This project has been very expensive; the cost of the section Turin-Milan-Naples has been around 32 billion Euros and it has represented the biggest investment in infrastructures in Italy after the "motorway age". The "Direttissima" (HS line) between Rome and Florence was opened in 1981 and it represents the first example of HS rail link in Italy.

The national Italian network and operations are all owned by Ferrovie dello Stato (State Railway) Holdings, a fully government-owned company. It has three key operating subsidiaries: Trenitalia operates all freight and passenger trains, including the high-speed trains; RFI (Rete Ferroviaria Italiana) manages the infrastructure; and TAV (Treno Alta Velocità SpA) is responsible for the planning and construction of the new HS infrastructure [1].

Since 2012 a new private company named Nuovo Treno Viaggiatori (NTV) is competing with Trenitalia on the same HSR network. This represents a unique case in the world since two operators, one public and the other private, are competing on the same HSR network.

2.1. The methodology

A survey has been carried out interviewing Italians. In the first part of the questionnaire, the Revealed Preference (RP) exercise, socioeconomic data about the users together with information concerning their trip (i.e. origin/destination, transport mode chosen, travel time and cost) have been collected. In the second part of the questionnaire, a Stated Preference (SP) exercise has been employed. Specifically, 9 hypothetical scenarios have been submitted to the respondent with the objective of understanding the transport mode that was chosen within a given context and to see whether HSR was the preferred alternative (or it was an element of spatial exclusion). Considering a fractional factorial design, each alternative has been represented by 4 variables, each of them with four levels. These are access/egress travel time to/from the departure/arrival station, total travel cost, High Speed Rail travel cost, and travel cost of the chosen transport mode. The choice of the three levels for the variables access/egress travel time and cost aims at catching possible effects more or less than linear not identifiable with the two levels variables definition.

Once the variables were defined, the survey design was implemented. The questionnaire was placed on the Google Drive platform. The objective was that of studying the impacts on the population in terms of spatial equity after a possible extension of High Speed Rail network. Specifically the aim is to analyse the perception of inequality due to HSR in terms of travel performances characteristics and therefore to identify some directions to suggest in order to solve the problem.

The survey was submitted to Italian users having 5 different transport mode alternatives, i.e. car, bus, airplane, Intercity/Regional train and HSR.

In Table 1 the SP variables and their variation' levels with respect to the actual values have been reported.

Table 1

SP variables and their levels

	HSR			**Other RP modes**
	Access/Egress Time	Access/Egress Cost	Ticket Cost	Travel Cost
Levels	-20%	-20%	-20%	+20%
	-50%	-50%	0	0
	0	0	-	-

To the users not choosing HSR, some hypothetical scenarios have been proposed representative of the transport mode alternative to choose. For each scenario, the user is asked to change transport mode in favour of HSR. The total number of scenarios is 9: scenario n. 9 corresponds to the actual scenario and the remaining 8 are hypothetical, obtained by combining the attributes' levels. In the case under analysis, the total number of scenarios would have been 36. However, by applying the fractional factorial design, 9 scenarios have been submitted to the respondent. Each scenario comprises the alternative HSR and the chosen transport mode. In Table 2, all the scenarios are reported.

Scenario n. 9 represents the actual scenario since all the levels are equal to 0, and it is considered as the base for comparison it with the others.

Scenario n. 7 represents the most advantageous since the levels of the three variables concerning the HSR alternative assume their minimum value in terms of percentages although the level of the cost variable of the other transport modes is equal to 0.

In Scenario n. 1 the increase of accessibility is assumed together with a decrease of the performances of the actual transport mode performances.

The questionnaire was available to respondents between March and May 2015. To each web module, created with Google Drive, a worksheet has been associated and managed with Google Spreadsheet, which is able to register the values introduced by the users.

Table 2

The SP scenarios

Scenario No.	HSR variables			RP chosen mode variables
	Access/egress time	Travel cost	Ticket cost	Travel cost
1	-20%	-50%	0	+20%
2	-20%	0	-20%	+20%
3	-50%	0	0	+20%
4	0	50%	0	+20%
5	-20%	-20%	0	0
6	0	-20%	-20%	+20%
7	-50%	-50%	-20%	0
8	-50%	-20%	0	+20%
9	0	0	0	0

The total number of questionnaires collected was 810. The data were used to analyse the variables influencing the choice of HSR and to understand whether and in which way a more "equal" spatial distribution of accessibility to HSR stations could have been advantageous.

A sample correction procedure was necessary in order to reduce the sample bias matching the actual distribution of the Italian population (from the mobility Census data) in terms of gender and age percentages.

3. SOME RESULTS

From Table 3 it is possible to observe that men travel more than women; concerning age, only 13% of people more than 55 years old prefer to move.

Almost 50% of the sample is made up of people employed or students; the level of education is quite high, as 44% have a degree.

Concerning the average household income, it is possible to deduce that most of the respondents have a medium/high income and only 6% have declared a high income (>3000 Euro). Probably due to the manner of questionnaire submission, the education level seems to be high: people with a degree represents almost 50% of the sample.

From table 4, it is possible to deduce that the main trip purpose is Work (32.7%), followed by Tourism (14.6%), Leisure (9.3%) and Study (7.4%). There is a high percentage of users travelling for Other Purposes (36.1%).

Concerning the transport mode, Car is chosen by 37.1% of the users and HSR by 36.8%; therefore, the latter represents the competitors and the main chosen transport modes (see Table 5).

From Fig. 1. it is possible to notice that the trips by HSR and by Car are mainly round-trips. This implies that the decrease in travel times due to HSR allows the return in the same day, while the elasticity in the choice of the "timetable", i.e. "no timetable" for the use of Car, justifies the choice of this transport mode. The opposite is true for Plane.

HSR has been mainly chosen for the reduced travel time (68.6%), followed by the comfort (15%) (see Table 6).

The results in Fig. 2 show that females prefer IC/Reg trains and HSR. Men, instead, prefer Car, Bus and Plane.

Table 3

Socioeconomic characteristics of the sample

Characteristics	Levels	%
Age	< 24	17.2
	24-34	18.2
	35-55	51.8
	> 55	12.9
Gender	M	44.4
	F	55.6
Nationality	Italian	99.1
	Other	0.9
Education	Primary School	0.1
	Secondary School	5.7
	High School	50.0
	Bachelors Degree	13.8
	Masters Degree	21.9
	Doctorate	8.4
Occupation	Employee/ School Teacher	23.3
	Student	21
	Executive/ University Professor	4.5
	Freelance	24.5
	Other	26.7
Monthly household income	0-500€	32.3
	500-1500€	37.2
	1500-3000€	24.7
	> 3000€	5.8
Life condition	Alone and economically independent	35.6
	Alone and economically supported by family	8.9
	With family	55.5
Household income	0-500€	9.9
	500-1500€	34.5
	1500-3000€	39.0
	> 3000€	16.6

Table 4

Trip Purpose

		%
Trip purpose	Work	32.7
	Study	7.4
	Tourism	14.6
	Leisure	9.3
	Other purposes	36.1
TOTAL		**100**

Table 5

Transport mode chosen

Transport mode	**%**
Car	37.1
Bus	6.5
Plane	8.7
Intercity/Regional Train	10.9
HSR	36.8
Total	**100**

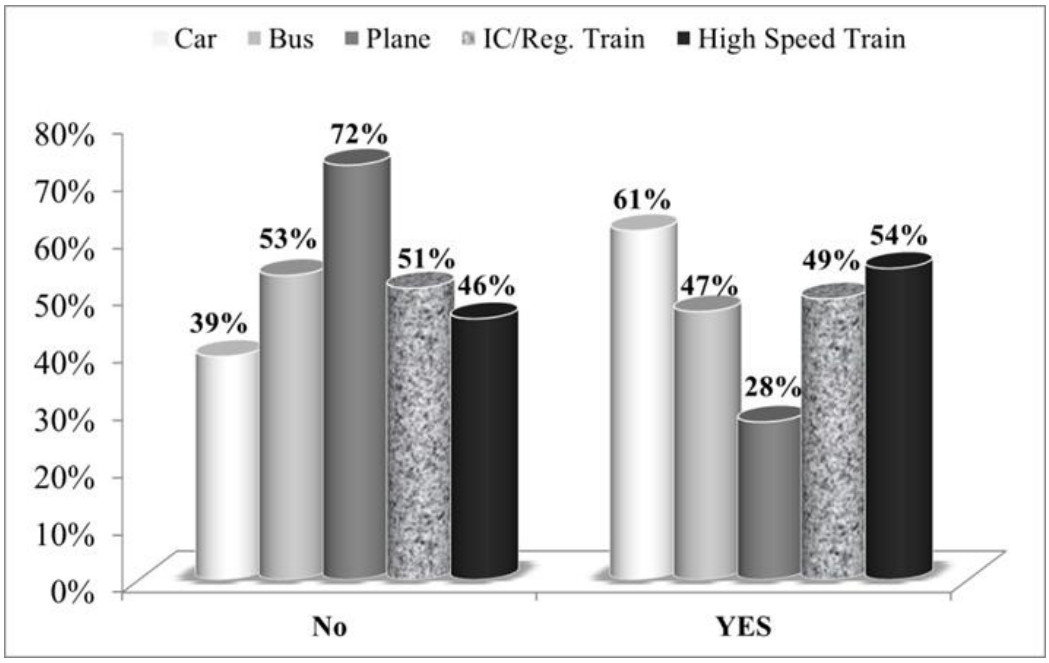

Fig. 1. Round trip in the same day by transport mode
Fig. 1. Ritorno in giornata vs modi di trasporto

Table 6

Motivations for choosing HSR

Motivation for choosing HSR	%
Environmental Impact	-
Safety	0.3
Comfort	15.0
Travel Time	68.6
Travel Cost	9.4
Accessibility of the station	6.7
Total	**100**

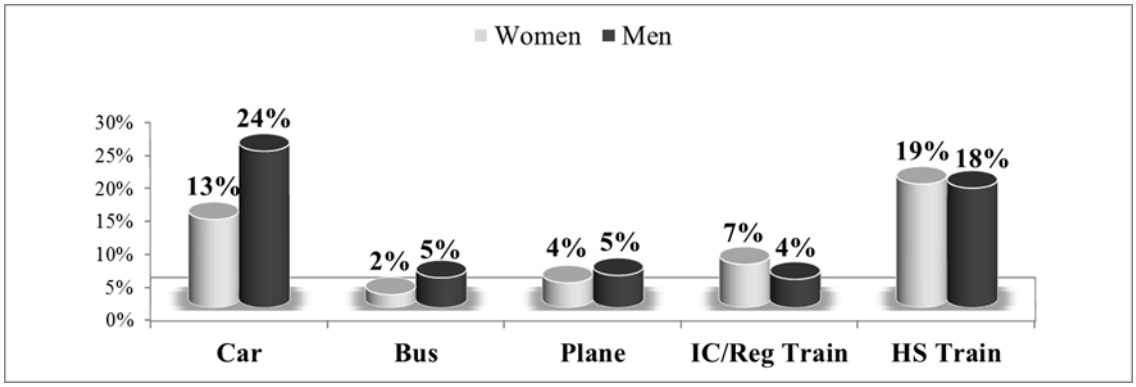

Fig. 2. Transport modes vs gender
Fig. 2. Modi di trasporto vs genere

Females seem to prefer rail transport and airplanes, unlike males who prefer cars (see Fig. 3). This is probably due to the relevance given to the perceived security—females perceive trains and planes as secure modes since main stations and airports are guarded. Fig. 3 shows the age effect on the mode choice for long trips. While young people seem to spread over the different modes, HS and car become the two prevalent modes as age increases. This can be due to the car elasticity in departure/arrival time and in origin/destination places and to the brief travel time of the high-speed train w.r.t. the other modes.

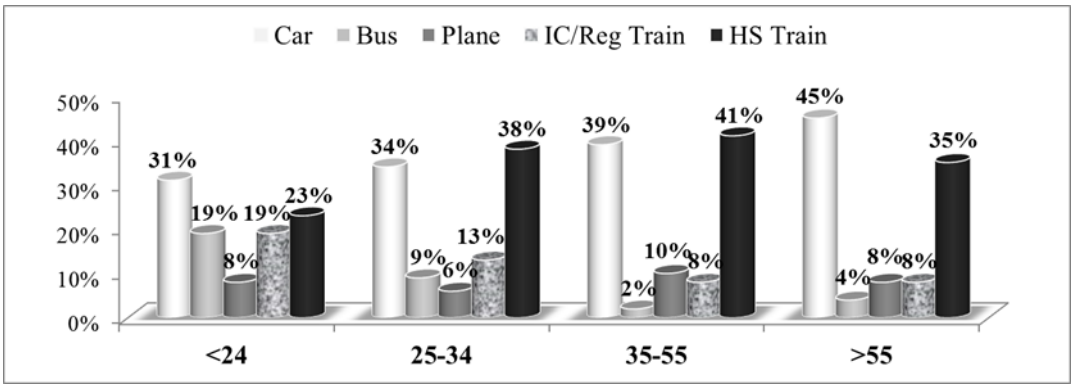

Fig. 3. Transport modes vs age
Fig. 3. Modi di trasporto vs età

This is confirmed by the diagram of Fig. 4 in which students, typically young, choose all available modes to travel while HS and car prevail for the other occupations.

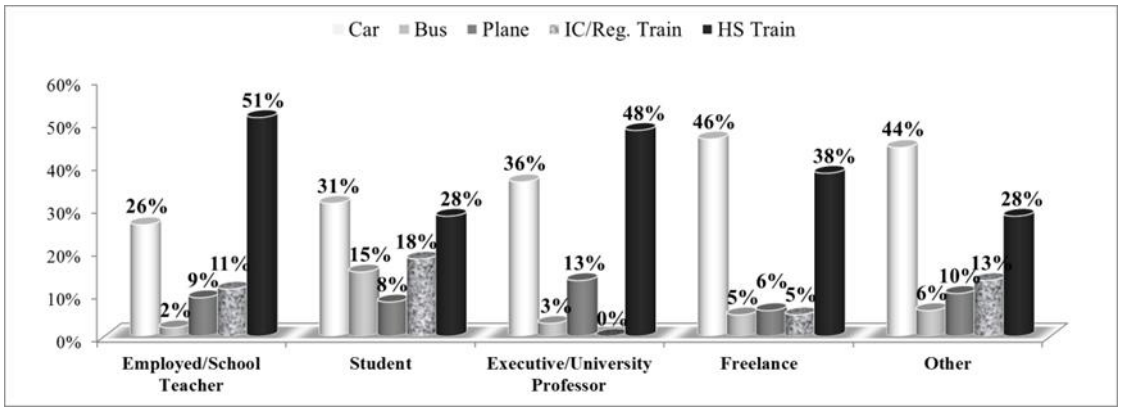

Fig. 4. Transport modes vs occupation
Fig. 4. Modi di trasporto vs occupazione

By crossing transport mode and income data (see Fig. 5), it appears the transport mode choice is homogeneous for medium-high-income people. On the other hand, there is a shift towards the less expensive public transport modes for low-income people. What is surprising is that Car has the same percentage regardless of income and this confirms that this transport alternative is often a necessary transport mode because of the low accessibility of public transport stations (including HSR ones) from the origin and/or destination. Concerning HS train, it is chosen by high-income people, which is not surprising. Aereo (Plane) is not considered a real transport alternative for short and medium trips, which is an expected result.

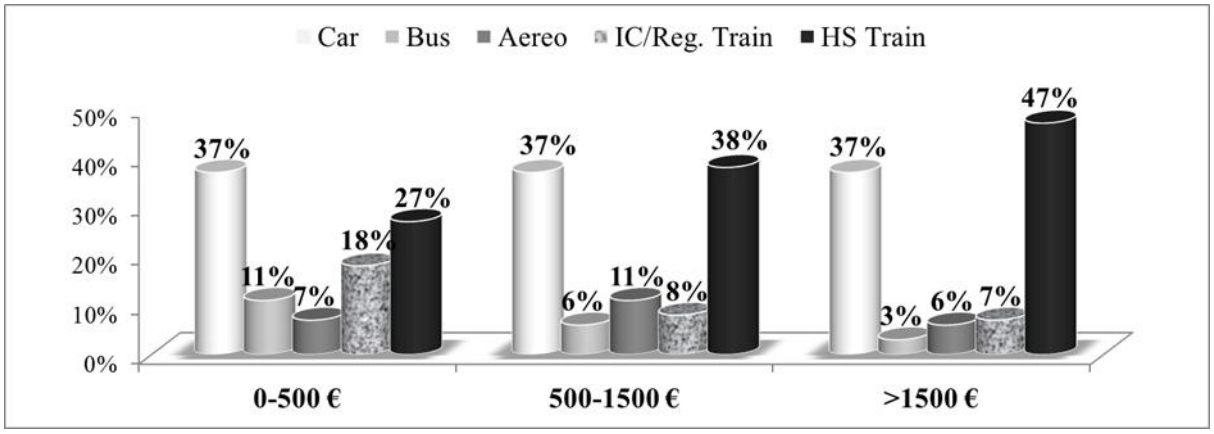

Fig. 5. Transport modes vs income
Fig. 5. Modi di trasporto vs reddito

4. SOME INFERENCES ON THE RELATIONSHIP BETWEEN HSR AND EQUITY ISSUES

A further investigation is here proposed on some of level of service (LoS) variables, taking into account their effect on the choice of HSR, with the objective of highlighting equity issues. In particular, for access and egress LoS variables, more levels of variation have been considered to match also non-linear effects on the percentage of HSR choice.

Concerning the variable Access/Egress travel time, it is possible to notice a less than linear effect of users' choice (see Fig. 7). Moreover, the level-of-service referred to -20% and to -50% is almost equal and respectively 63% and 64%. This means that the threshold value has been defined, beyond which there are no evident variations of users' choice. It follows that a decrease of only -20% would bring a positive response from HSR users.

The case of the Access/Egress travel cost is different (see Fig. 6) for which a more than linear trend is evident. In this case, the threshold effect is observed only at the -50%, where the HSR choice increases to 72%.

A decrease of only 20% of the Access/Egress travel time matches a positive response of 63% compared to 55% in the case of the Access/Egress travel cost.

The top two graphs of Fig. 6 show, then, that the user is strongly affected by the geographic/economic exclusion factors.

On the other hand, by considering the ticket cost, a minimum reduction of 20% is sufficient to get an increase of HSR users, assuming that the ticket cost is the main trip cost. By comparing the ticket cost variable with Access/Egress travel cost variable, a small decrease of the HSR ticket cost (20%) shows a yes percentage of the 70%, whereas a decrease of 50% of the Access/Egress travel cost is necessary to obtain the same yes choice percentage (72%).

The last concern on this figure relates to the travel cost variable with which it is possible to study the effects on the HSR choice rate of possible increases in travel costs on the non-HSR transport modes. The results show that an increase of 20% of the cost does not greatly influence a transport shift in favour of HSR.

Since the private transport (Car) is prevailing w.r.t. to other transport modes, the objective is to understand whether the effects noticed above are the results of users 'choices or if they are an interpretation of them. Specifically, a CAR users' systematic effect is evaluated. In Fig. 6 and Fig. 8, the same threshold values discussed before can be noted. The only difference is that the yes percentages of the public transport variables are a bit higher than those of Car, especially for the ticket cost variable and Access/Egress cost variable. This is probably due to a higher sensitivity of public transport users towards a cost increase. A further consideration is the ticket cost variable for the level "-20%", for which there is a difference of 7% (67% for CAR vs 74% for public transport), probably due to the different perception of the ticket cost of public transport users (for which a possible decrease of the HSR ticket cost is naturally more perceived) compared with Car users (not used to buying a ticket).

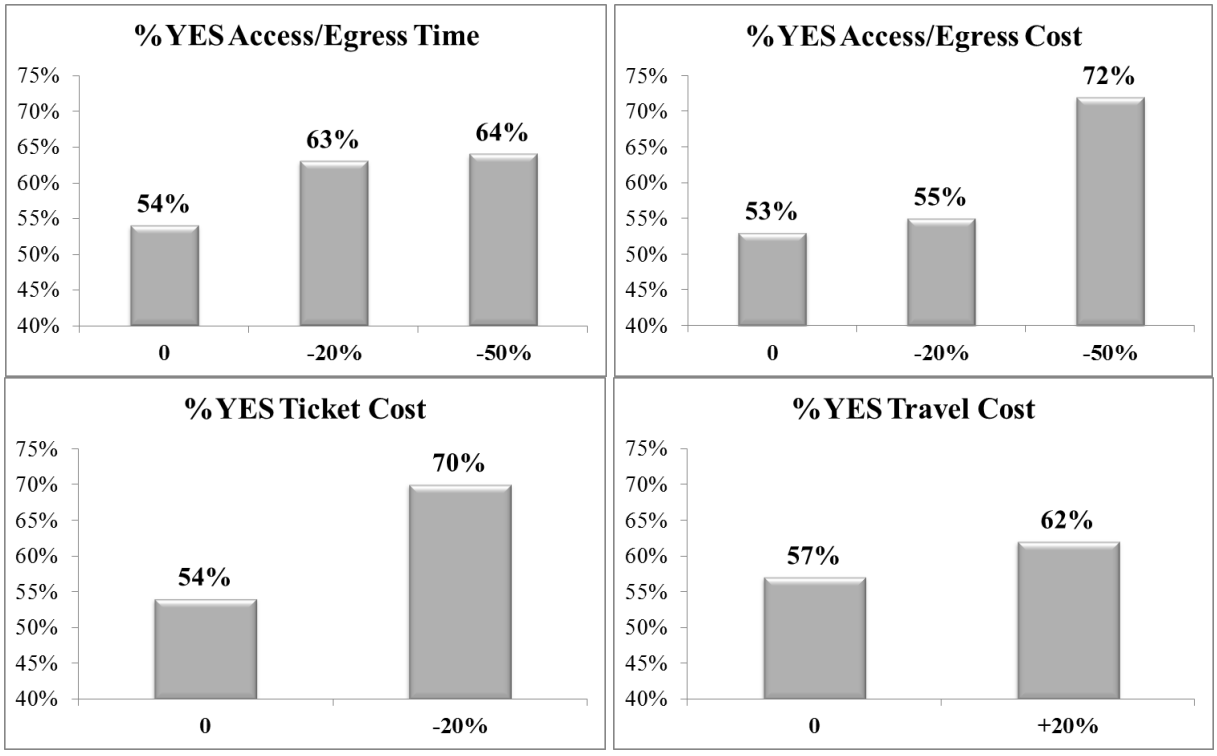

Fig. 6. Yes percentages of all variables
Fig. 6. Percentuali di si di tutte le variabili

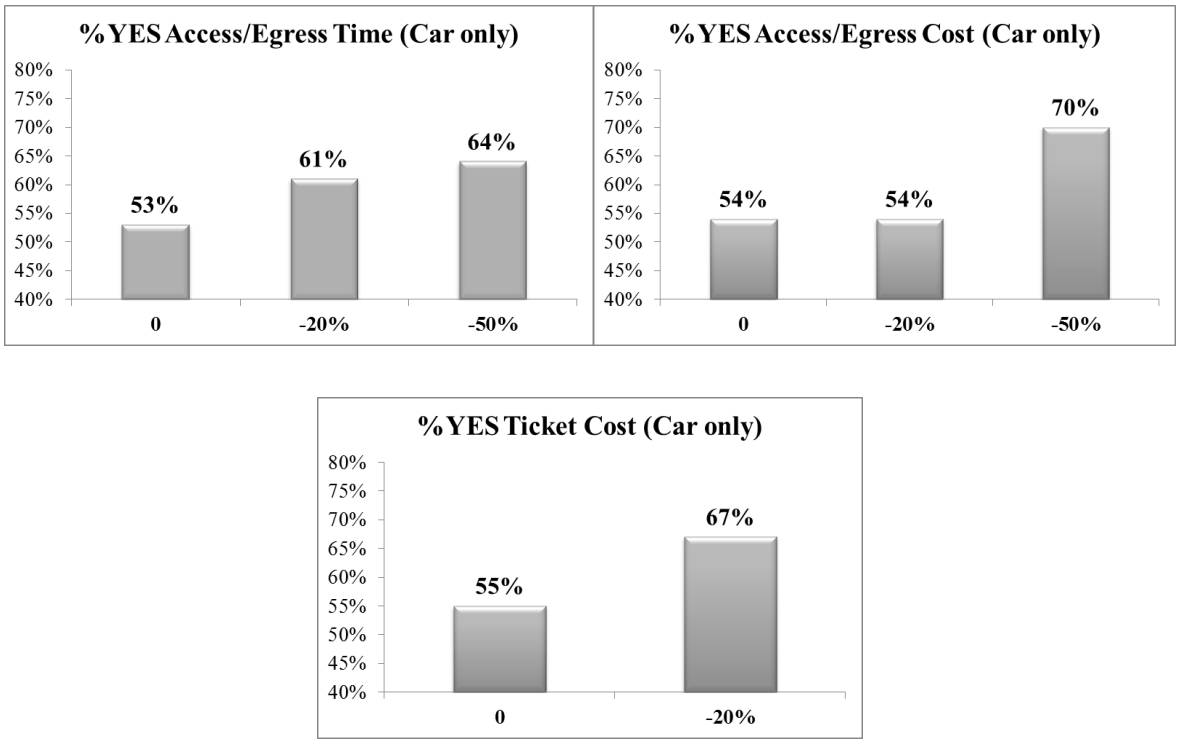

Fig. 7. Yes percentages of Access/Egress Travel Time, Access/Egress travel cost and Ticket Cost related to Car
Fig. 7. Percentuali di si tempo di Accesso/Egresso, costo di Accesso/Egresso e Costo del biglietto relativamente all'auto

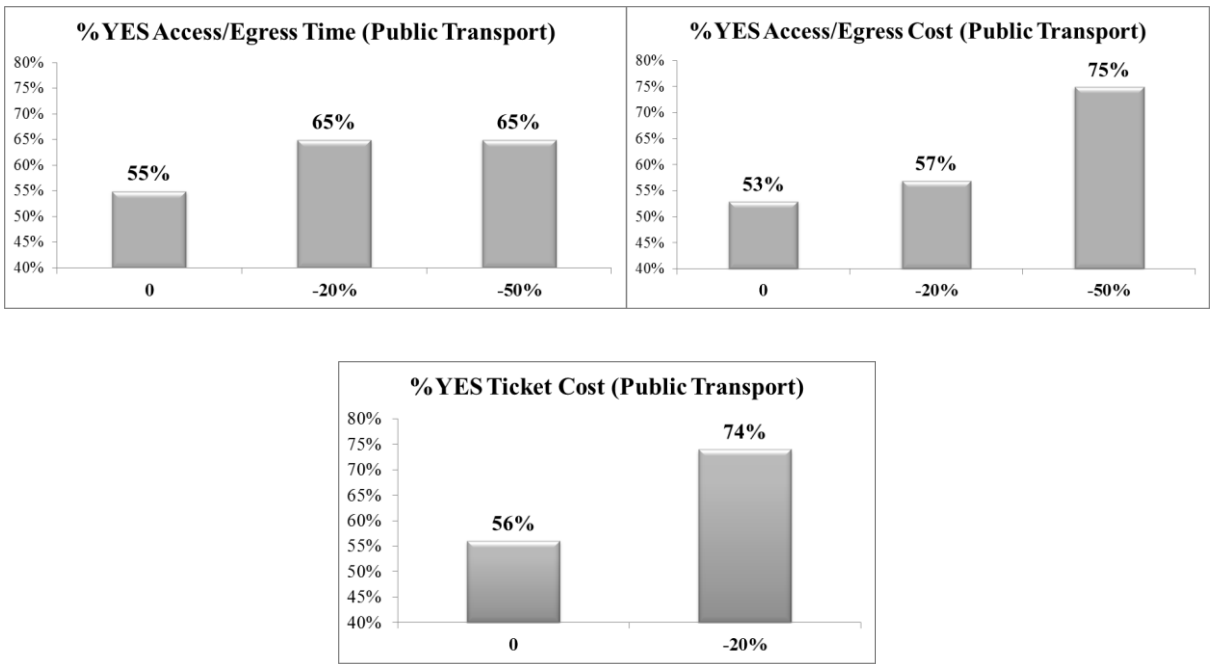

Fig. 8. Yes percentages of Access/Egress Travel Time, Access/Egress travel cost and Ticket Cost related to PUBLIC TRANSPORT modes
Fig. 8. Percentuali di si tempo di Accesso/Egresso, costo di Accesso/Egresso e Costo del biglietto relativamente ai modi di trasporto pubblico

In Fig. 9 the variability of users' choices has been investigated in relation to income in order to verify the possible relevance of economic exclusion. The elaborations show how the decrease of the Access/Egress travel time can have an impact on income classes. The yes percentages seem to be homogeneous for all income classes and this highlights that the problem of geographic/economic exclusion is perceived by all users regardless of their income.

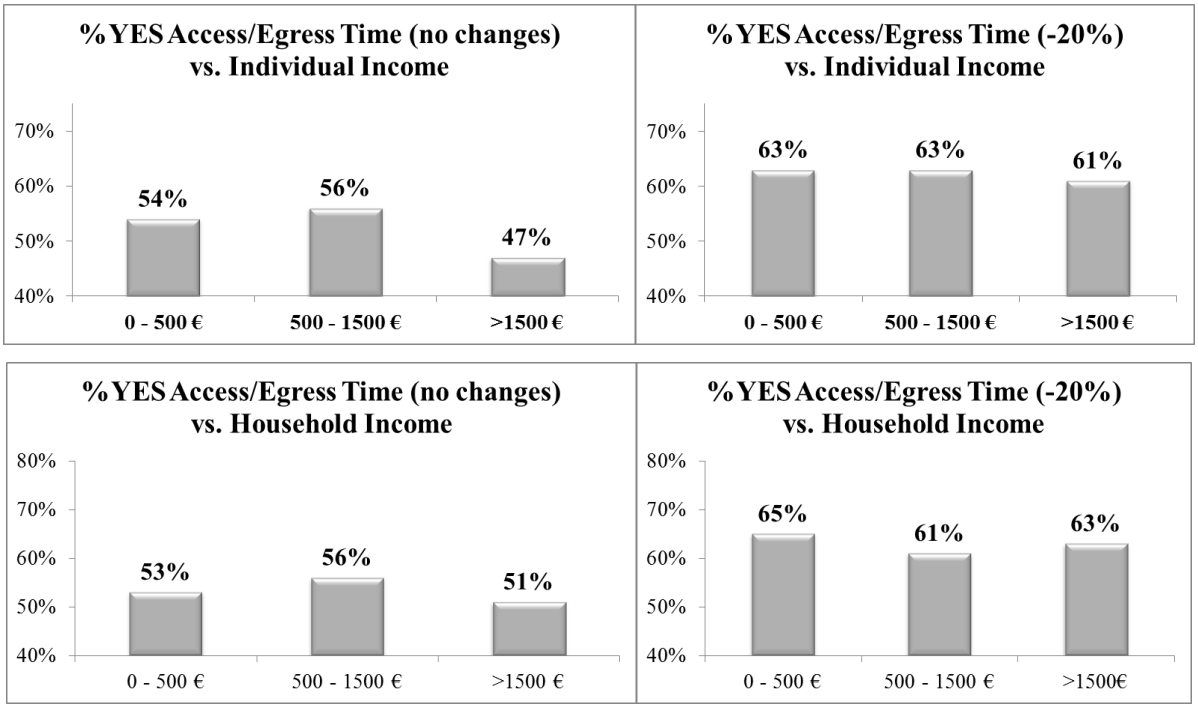

Fig. 9. Yes percentages of Access/Egress travel time (actual situation and level "-20%") vs individual and household income

Fig. 9. Percentuali di si tempo di Accesso/Egresso (situazione attuale e livello "-20%") vs reddito individuale e familiare

Similarly to the previous case, Fig. 10 shows that Access/Egress travel costs of the actual situation are similar with a percentage of almost 50%. This is confirmed in the hypothetical scenario with a percentage of almost 70% although there is a peak of 72% for the low-income class. It follows that the economic exclusion effect has been caught.

In general, users' sensitivity to the Access/Egress travel times and costs seems not to depend on income; moreover, the problem of the geographical exclusion related to the HSR has been highlighted.

The same trend has been found for ticket cost variable and for travel cost variables.

5. CONCLUSIONS AND FURTHER RESEARCHES

Planners claim that local, regional and national spatial plans are crucial for achieving spatial equity [10].

As the quality of life grows, the role of cultural facilities in urban areas is becoming more important. However, due to various reasons, the location of these facilities shows the geographical imbalance between urban regions. Even though the provision of road network can improve this kind of urban problem, in many countries, the provision of urban infrastructure plays a role that highlights the cultural gap between regions and socioeconomic classes.

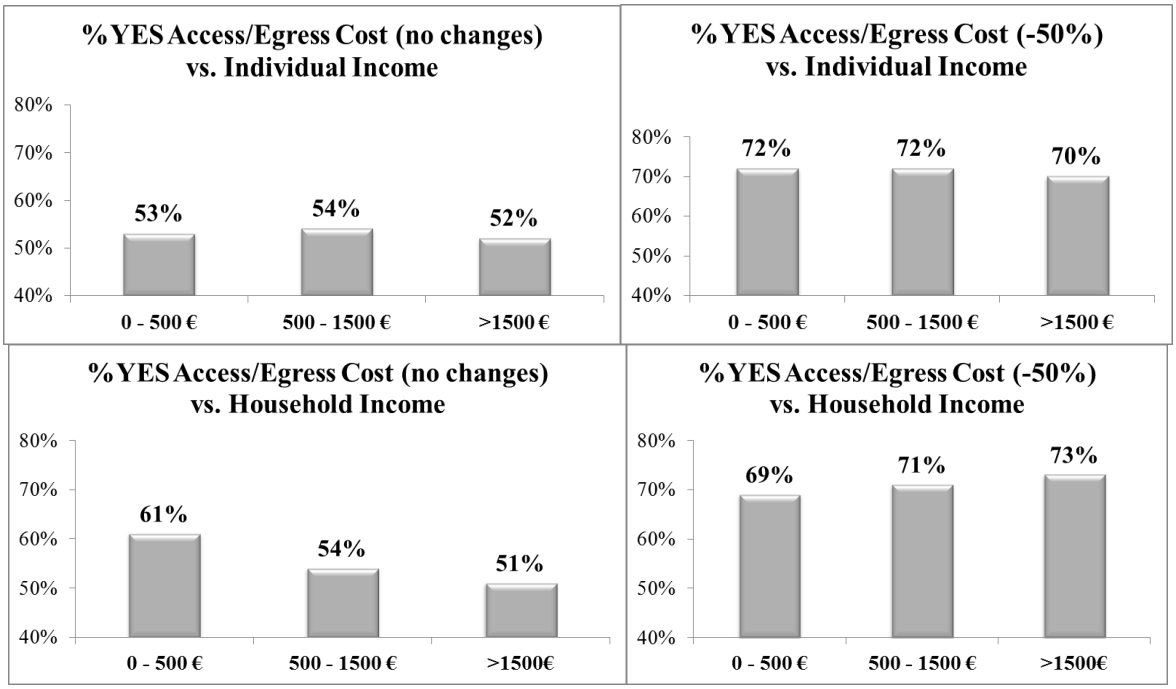

Fig. 10. Yes percentages of Access/Egress travel cost (actual situation and level "-50%") vs individual and household income

Fig. 10. Percentuali di si costo di Accesso/Egresso (situazione attuale e livello "-50%") vs reddito individuale e familiare

The analysis proposed in this manuscript has shown that in Italy the problem of economic/geographic exclusion exists and it is perceived by users. Indeed a high sensitivity is registered for the Access/Egress travel costs and also for the HSR ticket costs since the latter represents an important variable in the travel cost. A medium-high sensitivity for the Access/Egress travel time is perceived as well. Moreover, it seems that there is a limited knowledge about HSR attributes and a low sensitivity for increasing travel costs of the transport mode chosen, which can recommend investments in HSR systems by reducing ticket costs and, even more important, access/egress travel times and costs rather than a policy of car usage limitation by increasing costs.

Future perspectives will consider an application of a statistical analysis, such as CATANOVA, for discrete/classification variables to assess the conclusion described above and in specification and calibration of a mode choice model and the application of the methodology proposed in this contribution to other case studies.

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