Estimating the Run Choice Behavior in High Speed Rail (HSR) Mode-Service: A Revealed Preference Survey

Giuseppe Musolino and Domenico Sgro(✉)

DIIES, Università Mediterranea of Reggio Calabria, 89100 Reggio Calabria, Italy
domenico.sgro@unirc.it

Abstract. High Speed Rail (HSR) passenger services cause competition with other rail services, and other modes of transport. The paper presents the structure of a Reveled Preference (RP) survey which has been submitted to travelers in an Italian HSR context. The objective of the survey is to analyze the travelers' choice behavior, among the services, the runs and the ticket levels. Hence, the survey investigates the main behavioral variables of HSR travelers to be adopted for the calibration of discrete choice models in the dimension of run and ticket. The RP survey is organized in several sections to collect different types of data: data about the chosen run (day of travel, number of the run, departure and arrival time); socio-economic data about the traveler and his/her family; data about the purpose and frequency of the trip; data about the chosen ticket. This work is aimed at supporting transport planners and decision-makers in the evaluation of future investment in HSR lines and services, and to analyze the travelers' behavior, by means of methodological and modelling tools to assess the potential HSR travel demand.

Keywords: High Speed Rail (HSR) · demand analysis · run choice behavior · survey · Revealed Preference (RP)

1 Introduction

The extension of High Speed Rail (HSR) lines around the world considerably increased in the last decades. Currently, on the one hand the HSR lines result to be more than 120,000 km. On the other hand, the number of passengers which have been travelled with the HSR services achieved 778,9 billion of passenger-kilometres in year 2021. The main country which contributes to this result is China with 606,4 billion of passenger-kilometres [1].

The design of an HSR line and the organization of the services is dependent of several factors [2–5]. The effects of HSR on passenger mobility have been investigated by means of the travel demand models, which may be segmented into three components [6–8]: diverted, induced and economic-growth. In the context of diverted demand, the fare structures of HSR services play a key role in either intra-modal and inter-modal levels of competition for the intercity passenger mobility. The demand models are part

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2026
O. Gervasi et al. (Eds.): ICCSA 2025 Workshops, LNCS 15894, pp. 420–433, 2026.
https://doi.org/10.1007/978-3-031-97648-3_28

of the Transport System Models (TSMs) [9–11], which simulate a transport system where transport supply and travel demand interact and generate the flows and the performances of the transport system.

In the context of intercity trips and intra-modal competition of HSR, the run choice models estimate the travelers' choices among the available runs, where the relevant attributes generally belong to the class of level of service, for instance the fares, the components of trip time (e.g. departure/arrival times), the company.

The data necessary for the choice models' calibration are traditionally obtained by means of surveys [11, 15]. The surveys may be classified according to different criteria, based on: (a) the level of aggregation of the observed variables: aggregated or disaggregated; the nature of choice: Revealed Preference (RP) or Stated Preference (SP).

The paper presents the structure of a RP survey, which has been submitted to users travelling along the Rome-Milan relationship (Italy) during April 2025, in order to observe the choice behaviour of travelers.

According to the above considerations, the structure of the paper is the following. Section 2 concerns the theoretical background of the run choice models. Section 3 describes the existing classes of survey for collecting data concerning passenger mobility. Section 4 specifies the structure of the questionnaire submitted to the travelers in the experimental context. The last section contains some final remarks.

This work is aimed at supporting transport planners and decision-makers in the evaluation of future investment in HSR lines and services, by means of methodological and modelling tools to assess the potential HSR travel demand and possible future investments in HSR infrastructure and services.

2 Run Choice Model

In the behalf of the TSM framework [9–11], the travel demand models estimate the users' behavior in relation to (congested) costs on the transport network.

Travel demand models may be differently classified in literature. There are two main approaches: aggregate models, where variables are related to group of users (e.g., average origin-destination demand flow of passengers in a reference time period); and disaggregated models, where variables are related to the behavior of single user in terms of different choice dimensions (e.g., making the trip, destination, mode-service, departure time, path, or run).

Aggregated travel demand models may be segmented into three categories. Statistical-descriptive estimate the demand flow among relationships by means of attributes of the socio-economic and level-of-service class. Time series use historical data to estimate demand flows with fixed characteristics (e.g. origin-destination). Partial-share simulate the user choice through a procedure of partial sequential choices, or steps; the more current example regards the multi-stage models, including trip generation, trip distribution, time choice (arrival/departure), service choice, path/run choice.

Disaggregated travel demand models are generally based on discrete choice theory, which have been specified with different formalization of discrete alternatives and related perceived utility, in term of random utility [12], fuzzy utility [13], and quantum utility [14] approaches. From a general point of view, random utility models vary in relation

to the perceived utility function, that may be specified according to different functional correlations among, for instance, the levels of choice (hierarchical or factorial), different hypotheses on the formation of choice set of alternatives, and lastly different hypotheses about the distribution of random residuals.

Travel demand models in the context of High Speed Rail (HSR) mode-services may be classified into three main components [6, 8 (and references included)]. The diverted demand is the number of passengers attracted to HSR from other transport modes and/or other rail services. The induced demand is the number of passengers travelling with HSR due to changes in trip frequency and destination. The economy-based demand is the number of passengers travelling with HSR due to the changing structure of the economy, which in its turns generates new trips. The three components are generally estimated before the opening of a HSR line with ex-ante modelling approaches, or after the opening of a HSR line by means of before-after approaches.

According to the above classification, there are several papers in literature which specify, calibrate and validate discrete choice models regarding the three modelling components. The diverted demand is the most investigated among the three components of the demand, whereas the induced component is studied in few papers for the complexity to be identified. Therefore, there is a lack in the literature about the economy-based component, which requires the development of Spatial Economy Transport Interction (SETI) models [16] to be estimated.

As far as concern the diverted demand, several choice dimensions are investigated by plenty of papers, such as the mode, service, company, and run. A set of papers which deal with this topic are reported here. Yao and Morikawa (2005) [17] analyze the intercity travel demand by means of a specification of a multi-level discrete choice model on the dimensions of mode/service/run. The considered modal alternatives are bus, car, airplane. The model uses data provided by RP and SP surveys and aggregate data and has been tested in a Japanese case study. Cascetta et al. (2011) [18] analyse the impacts of the HSR services along the Italian relationship Rome-Naples. The paper concerns the diverted demand analysis towards HSR services from other transport modes and other rail services (e.g., Intercity services). It has been specified a discrete choice model on the dimensions of mode-service-company-run for different trip purposes, such as "home-based trips" and "non-home-based trips". The data has been provided by a RP survey submitted to users travelling by car and with conventional and HSR services. Cascetta and Coppola (2012) [19] work on the national transport competition in the case of a new HSR operator entering. It has been specified and calibrated a discrete choice model, hence a multi-level nested logit model, on the dimensions of mode-service-run for different travel purposes (e.g., business). The data was provided by traffic counts and RP/SP surveys submitted to users between the years 2009 and 2011. Roman and Martin (2014) [20] deal with the simulation of passenger choices between two modes of transport alternatives, hence HSR and air services. In order to achieve the objective, two models have been specified and calibrated, thus the multinomial logit and the mixed logit. Cross elasticity is specified, however not calculated.

The discrete choice models commonly used for the estimation of the users' choices in the path dimension are based upon the specification of Mansky (1977) [12]. In the

context of run choice, the probability that a user i chooses a run r, $p^i(r)$, is calculated as the product of two components:

- probability that a user i chooses the set of alternative runs, I_v: $p^i(I_v)$;
- probability that a user i chooses the run r, given the set of alternative runs, I_v: $p^i(r|I_v)$;

where:

r is the perceived run ($r \in I_r$);

$\mathbf{Z} = \{1, 2, \ldots, r, \ldots\}$ is the set containing a finite number of runs (elementary alternatives);

$\mathbf{G} = \{I_1, I_2, , I_v, \ldots\}$ is the set containing all the sets of runs.

The probability of choosing a run r, considering the two components of probabilities, may be calculated as (Mansky 1977) [12]:

$$p^i(r) = \sum_{Iv \in G} p^i(r) \cdot p^i(r|I_v) \tag{1}$$

Transport users might perceive the sets of runs r, $I_v \in \mathbf{G}$, with different probabilities $p^i(I_v)$. It is reasonable that users perceive a limited number of sets $\mathbf{S} \subseteq \mathbf{G}$. This implies that the probability is $p^i(I_v) > 0$ for the perceived sets $I_v \in \mathbf{S} \subseteq \mathbf{G}$ and the probability is $p^i(I_v) = 0$ for the non-perceived sets $I_v \notin \mathbf{S}$.

In the extreme case where one set, $I_v^* \in \mathbf{G}$, is perceived, the probability $p(I_v)$ in Eq. (1) is calculated as:

$$p^i(I_v) = p^i(I_v^*) = \begin{cases} 1 & \text{if } I_v \in \mathbf{G} \\ 0 & \text{if } I_v \neq I_v^* \text{ and } I_v^* \in \mathbf{G} \end{cases} \tag{2}$$

According to Eqs. (2), (1) is specified as follows:

$$p^i(r) = p^i(r|I_v*) \tag{3}$$

It is possible to estimate the quantity $p^i(I_v*) \in [0, 1]$ with choice set perception models, which allow to construct the perceived choice sets (formation level), thus to estimate the quantity $p(I_r)$ associated to each perceived choice set by the user (extraction level) ([21] and references included).

The probability $p^i(r)$ may be specified by means of several categories of discrete choice models existing in literature: random utility models, fuzzy utility models, or quantum utility models. (see Vitetta, 2025 [22] for a comparison among the different categories).

The discrete choice models that rely upon random utility theory [11, 23, 24], are based on the assumptions that a user i chooses the run r, among the set $I_v \in G$, which maximize the associated perceived utility, $U^i(r)$**.**

Considering that the utility, $U^i(r)$, is a random variable, it is not possible to establish with absolute certainty which run will be chosen by the user i. However, it is possible to specify the probability, $p^i(r|I_v)$ that the run $r \in I_v$ chosen by user i is greater than the perceived utility associated to the other run r', $U^i(r')$', with r, $r' \in I_v$:

$$p^i(r|I_v) = \text{Prob}\,(U^i(r|I_v) > U^i(r'|I_v)) \quad \forall\, r' \neq r,\, r \in I_v \tag{4}$$

3 Survey Methods

The census knowledge of trips of each user with her/his own characteristics require so high costs that they are not sustainable by analysts and transport modelers. Therefore, travel demand is estimated by means of surveys on a sample of users.

The methods for surveying passenger (and freight) mobility may be classified in two main categories: disaggregate and aggregate (Fig. 1). The setting of the survey concerns the definition of the location of the detectors and the sampling of the elements to be monitored. The monitoring activities are generally executed by means of ICT tools in the case of aggregate surveys, whereas they are generally executed with the support of interviews to travelers in the case of disaggregate ones. The aim of the disaggregate surveys is the acquisition of data about the trip behavior of individual users; while the aggregate surveys consist in the acquisition of traffic flow data on specific links/nodes, or paths, of the transport network. In both the categories of surveys the attributes estimated rely to socioeconomic characteristics of users, land use, characteristics of users' trips and behavior, and level-of-service of transportation network (e.g. travel costs).

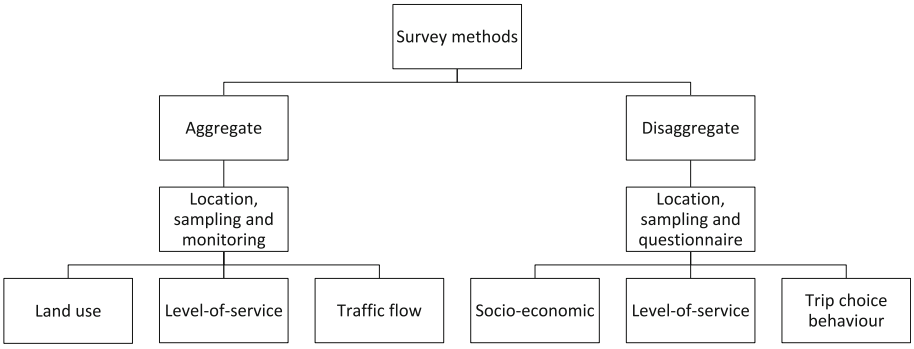

Fig. 1. Classification of survey methods

3.1 Aggregate Survey

The aim of the aggregate surveys is to obtain data about mobility of people inside a given study area.

Location and Sampling. The setting activities concern the correct identification of the elements (links/nodes or paths) of the network to be monitored and their number, in order to obtain a sample of elements which is representative of the whole network (universe). The above element is particularly important in the case of origin-destination matrix updating from traffic counts.

Monitoring. The monitoring consists in the counting and classification of users travelling on the elements of the transport network. These operations are generally executed by means of different Information and Communication Technology (ICT) tools.

A review of monitoring methods of vehicular traffic flow, where vehicles may be private (e.g. cars) or collective (e.g. buses), is reported in the Guide Lines authored by the Italian Ministry of Transport and Infrastructures [25].

Mobility of people (and goods) is generally monitored on two elements of the network: link/node sections and (multi-modal) paths.

The monitoring of on link/node sections may be executed with manual or automatic techniques. The manual techniques consist in travellers/vehicles counting and classification by human operators, that are employed in case of surveys of short time (e.g. hours, days) and on few links/nodes. The automatic techniques are supported by ICT tools and are employed in case of long time extension surveys (e.g. weeks, months) and several links/nodes. Examples of sections in case of transit systems are the entrance/exit of railway stations/bus terminals/airports, the get on/get off to/from the trains or buses.

The monitoring on (multi-modal) paths is today mainly based on data collected from smartphones, smartcards, Points-Of-Interest (POIs) and GPS that trace the travellers along their trip; for example, from the origin to the destination of the trip [26].

Smartphones are potentially capable to provide a great amount of data about travellers' trips for long periods at relative low costs. Nevertheless, the distribution and the shape of phone cells limit their quality. Smartphone data needs to be adequately elaborated and structured to obtain space-time trajectories of travellers.

Smartcards are generally used for Automated Fare Collection (AFC) in public transport systems. They provide space–time based trip data referred to the place where the transactions are executed. They generally record only travellers' boarding and are suitable for the estimation and/or updating of origin-destination matrices of passenger flows.

POIs data may be used to combine data about the locations where systematic trips from home to work originate and have their destination (e.g. provided from smartphones), with data about the locations where not-systematic trips originate/have their destination, such as leisure activities, shopping.

GPS are generally used from insurance companies to monitor private cars, commercial and bus fleets. The challenge of GPS data concerns the association of the discrete row data about vehicle time-space position with the link of the road network (e.g. mapmatching) especially in urban area.

The above ICT tools allow to obtain a great amount of data (big-data) that need to be adequately elaborated and structured before it can be used as input for travel demand models.

The data may be classified into two main groups: land use and level-of-service data (attributes) and flows data of users (and/or vehicles).

Land Use. The land use data concern census data about the population and economic activities inside the study area. The data about the population includes, for instance, the number of residents, employees, students. The data about the economic activities may include the number of workplaces in different economic sectors, the number of shops in urban areas, and schools. The census data are collected during periodic surveys (e.g. every 5 years) form national statistic institutes (e.g. Istituto Nazionale di Statistica-ISTAT in Italy) due to their high costs.

Level-of-Service. The level-of-service data concerns the performance of the transport network. The most common attribute belonging to this class is the travel time. The link travel time may be referred to a road section or to a section of transit line between two stops, while the node travel time is the time necessary for crossing a road intersection or a transit terminal. The path travel time may be the time, let's say, from the origin of the trip to the destination of the trip and it presents several components associated with the phases of the trip (e.g. access, waiting time at the bus stop/station, on-board, egress). There are other level-of service attributes, such as the average speed on the link and nodes of the transport network, in the case of trips with private modes (e.g., car); the frequency of the transit lines, in the case of trips with transit modes (e.g. bus or train).

Flow Data. The flow data are generally related to a sample of links/nodes or paths of the transport network. The flows on links/nodes sections are obtained as the ratio between the observed people that cross the section and the reference time period (e.g. hour, day) and they do not contain any information about the origin/destination of the trip. The flows on the (multi-modal) paths contain several information about the origin/destination of the trip; the portions of the path undertaken with each mode, such as (e.g. car, train, …), if the path is multimodal.

3.2 Disaggregate Survey

The aim of disaggregate surveys is to obtain data about the choice behavior of each individual traveler, which belongs to a sample in a specific study area.

The setting of the survey concerns the definition of the location of interviewers and the sampling of the travelers.

Location. The location of interviewers may be different: at the origin or the destination of the trip, at home, at workplace, by phone and along the trip and performed by operators in different ways: for instance, at a railway stations, airports, bus terminals, on-board of transport vehicles. The location influences the questionnaire design, in terms of specific questions to be submitted to the travelers. An example is in the medium-long haul services. In the case of railway, different configurations of the question are necessary according to the questionnaire is submitted on-board or at the railway terminal, as some information (e.g. run, departure and arrival time, …) are implicitly known by the operator when she/he is on-board.

Sampling. It is necessary to define the sampling unit, the procedure for the extraction of the sample and the size of the sample. The individual traveler is generally considered as the sampling unit, but in some cases the family may be also considered. The literature proposes several methods for the extraction of the sample, for instance the simple random sampling, the stratified random sampling, the cluster sampling. The relevance of the latter element is given by the necessity, for instance, to include inside the sample travelers belonging to different socio-economic classes, or to different geographic areas, in order to capture the choice behavior of travelers that may be conditioned by different values of attributes. This consideration is held in the choice of the fare, where two main class of users' behavior may be defined. The time-based user, that chooses the run/flight on the basis of the desired departure/arrival time and the day of trip, regardless to the fare;

and the price-based user, which chooses the run/flight with the lowest fare available, independently of the departure/arrival time or the day of trip (see, among the others [27]). As an example, the students that travel for leisure purposes behave as a price-based users; whereas autonomous workers that travel for business purposes behave as a time-based users.

In addition, the days of observation (or surveying) result to be dependent to the sampling method, to the variable to be estimated and to the statistical significance expected.

Questionnaire. The design of the questionnaire consists, mainly, in the formulation of the questions in order to collect data related to the socio-economic characteristics of the respondents and their trip choices. Two classes of preferences may be asked to the respondents:

- the preferences about the trip they have already undertaken given the current real conditions of the transport system; in this case we talk about a Revealed Preference (RP) approach;
- the preferences about the trip they could undertake given one, or more scenarios, where the conditions of the transport system are realistic but not real; in this case it is intended a Stated Preference (SP) approach.

The Revealed Preference (RP) survey refers to the investigation of the user choice behavior in a real context; while the Stated Preference (SP) survey refers to the investigation of users' choice behavior stated by the user in a hypothetical scenario proposed in the scenario. It is possible to submit one of the latter two (RP/SP) surveys to the user, otherwise there is the possibility to design a questionnaire with a combination of RP and SP questionnaires.

The data obtained from the disaggregate surveys may be classified into: socio-economic data and data about the choice behavior of each individual travelers.

Socio-economic Attributes. The socio-economic attributes of the respondents may concern the gender, the age, the level of education, the working condition, the residence and domicile, the number of family components.

Level-of-Service Attributes. The attributes are generally related to costs (e.g., monetary cost, travel time, …) and attributes concerning service satisfaction. Among these attributes, the fares play a key role in the users' choices. In the literature, the structure of fares are classified into two main approaches, such as static and dynamic. The static approach results to be used mainly for local public transport, whereas the dynamic approach means that the fares are characterized by variations over time, depending on several factors, in particular between the day of travel and the day of ticket purchasing (day of the week).

Trip Choice Behavior. The dimensions of choices of the users are various, thus from the choice to make a trip to the choice of the destination, the choice of the departure time, the choice of the transport mode and the service, and to the choice of the path or the run. Moreover, another dimension of choice results to be the ticket choice, especially in the public transport sector.

4 Survey Design: Italian Case Study

A survey based on the RP approach has been planned to obtain data about the trip choices of users in the dimension of the run and fare. A questionnaire has been submitted to users travelling along the relationship Rome-Milan (Italy) with HSR mode-services.

4.1 Experimental Test Site

The HSR line between Rome and Milan (Italy) was selected as it is the main Italian relationship in terms of volume of passengers and of services. The relationship includes besides the alternative of air services; however, this work does not investigate the mode choice level.

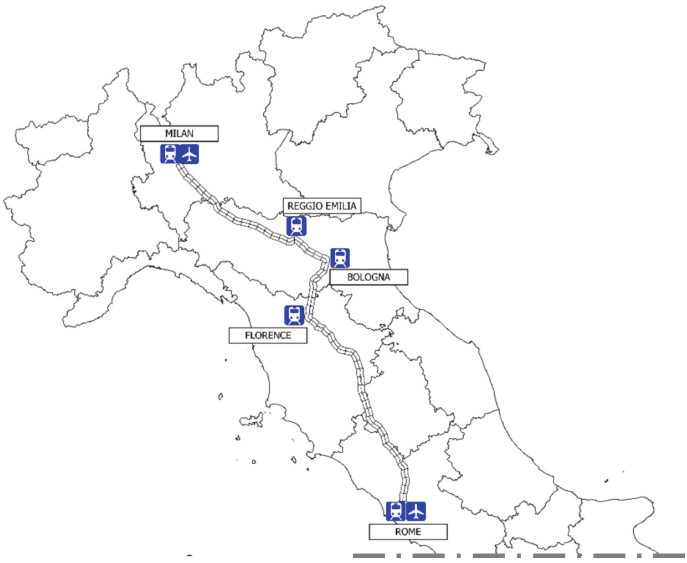

Fig. 2. Rome-Milan relationship (Italy)

The HSR line between Rome and Milan has been operating since 2009. Therefore, it began to generate intra-modal and inter-model competition, causing the diversion of travel demand from air and conventional rail services. Moreover, new travel demand was induced as a result of several factors, such as the increased level of service offered by HSR (e.g. reduction of on-board travel time).

The observation of available traffic before-after the HSR opening [28] shows that the passenger flows in the year 2008 were about 2,4 millions/year by the air mode and 1,0 millions/year by conventional rail mode. The passenger flows in the year 2018 were 1,2 millions/year by air mode and 3,6 millions/year by HSR mode-service.

Two HSR companies operate along this relationship. Trenitalia supplies HSR services and also conventional and local rail services; while Italo Nuovo Trasporto Viaggiatori (Italo NTV) supplies only HSR services. The two companies compete each other at

service and run choice levels, hence they both compete at mode choice level with some airline companies.

The frequency of HSR services is about, respectively, 45 runs/day (per direction) for the Trenitalia company, and 32 runs/day for the NTV company, during the year 2024. The scheduled runs are characterized by several elements such as the typology of service, for instance the shuttle runs (with at least one stop), the in-vehicle travel time, and the organization of the fares offered to the travelers. Each HSR company supplies services with higher performances, for instance in terms of minimum number of intermediate stops, in the peak-hours of the day (e.g., 06:00–09:00 am on the working days).

Concerning the fare choice level, both companies operating in Italy organizes and propose the ticket fares into two main categories, which are business and economy, each declined in one or more classes. In particular, Trenitalia company offers a wider set of fares than Italo NTV, thus characterized by numerous combination of services, however both companies offer flexible tickets (e.g., possibility to change day/hour of travel, possibility of refund, …), defined as Classes (e.g., "Super Economy" for Trenitalia and "Low Cost" for Italo NTV) and accommodation offered (e.g., wider seat, faster wi-fi connection, welcome service,..), defined as Quality of service (e.g., "Standard" for Trenitalia and "Smart" for Italo NTV). Each fare is the result of the combination of the latter two elements (class and quality of service), as well as the possibility of adding further services (e.g., seat selection, partial or total refund in case of trip cancellation,…). Consequently, there are lots of variables composing the fare, called dimensions, that determine a multi-dimension structure of the fares [29].

4.2 Questionnaire Design

The questionnaire is organized into 5 sections, described in the following (Fig. 2).

- Section 0 is dedicated to the operator who must fill the fields with specific information related to the location of the interview and about the chosen service;
- Section 1 is composed of 9 questions of a socio-economic nature concerning gender, age, level of education and working status, residence and domicile, number of household members and children under 18 years old, number of cars in the family;
- Section 2 concerns information about the trip from Milan to Rome and from Rome to Milan. It consists of four questions: the purpose of the trip, the purpose for staying in the area of origin of the trip, the frequency with which the same trip takes place and the period of staying in the area of origin/destination of the trip.
- Section 3 regards questions about the company chosen for the trip by the user. It is composed by fifteen questions, questions 1 and 2 concern the choice between the two Italian HSR transport companies and the purpose, while the subsequent questions concern the satisfaction of the chosen service.
- Section 4a and 4b concern the choice of the route and fare for Trenitalia and Italo NTV, respectively. Questions concern the reason for choosing the run, the desired departure time from the origin and desired arrival at the destination, the type of ticket and the services chosen. In addition, the price of the ticket, how many days before departure, as well as on which platform it was purchased (Fig. 3).

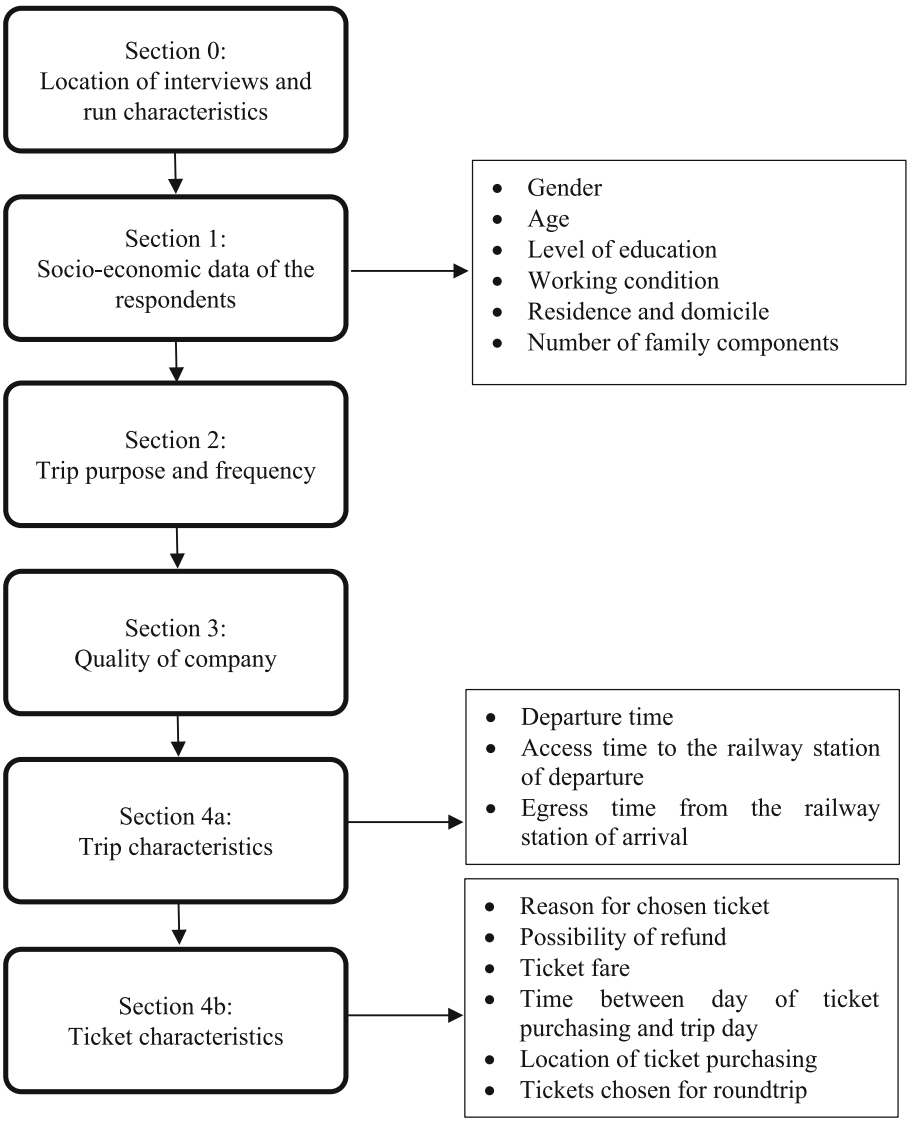

Fig. 3. Sections of the questionnaire organization

The survey has been carried out by submitting questionnaires to users in both directions of the relationship: Rome-Milan and Milan-Rome. Moreover, the sample has been designed in order to interview: at least 40% of workers, at least 40% of males and females, and at least about 40% of people travelling for business purpose. The composition of the sample is useful to better analyze the choices of several types of users. In addition, the questionnaires were submitted during different days of week, to capture the behavior of the users among the working days, weekend days and holydays.

Furthermore, the schedule of the services has been considered among the days of the week, hence the survey has been distributed not among all the scheduled runs, however, between the runs considered as a reference in the time slots of the day (e.g., the runs with at least one intermediate stop).

The submission of the questionnaire was performed onboard; hence the users has been interviewed during the trip. Therefore, a few information results ot be fixed: e.g., number of the run (e.g., also departure time to the railway stations), company, the number of the carriages.

5 Conclusions

The paper presents a RP survey aimed to build a dataset of users' trip behaviour for the specification and calibration of run choice models. The survey aims to investigate the users' choice behavior in an intercity context in which HSR services operate and different companies compete each other. The designed survey was submitted to users which travel among the main Italian route, thus the Rome-Milan relationship, in terms of service and flows, in terms of representativity of the sample.

The obtained data could reveal important information about the behavior of different typology of users in the dimension choice of run and fare that travels with HSR mode-service along this important Italian relationship.

Future research directions of the presented work concerns the use of available data for the specification, calibration and validation of discrete choice models in the dimensions of run choice and fare.

Acknowledgements. This study was carried out within the MOST – Sustainable Mobility National Research Center (CUP C33C22000240001) and received funding from the European Union Next-Generation EU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1033 17/06/2022, CN00000023). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

References

1. High Speed Lines In The World (Summary), Updated 1st October 2023. https://uic.org/passenger/highspeed/article/high-speed-data-and-atlas. Accessed 26 Feb 2025
2. Russo, F.: Which high-speed rail? LARG approach between plan and design. Future Transport. **1**(2), 202–226 (2021). https://doi.org/10.3390/futuretransp1020013
3. Massimo di Gangi, Francesco Russo. Potentiality of rail networks: integrated services on conventional and high-speed lines. WIT Trans. Built Environ. **213**, 101–112 (2022). https://doi.org/10.2495/CR220091
4. Massimo di Gangi, Francesco Russo, Design of hybrid rail services on conventional and high-speed lines. Int. J. Transp. Develop. Integrat. https://www.iieta.org/journals/ijtdi/paper/https://doi.org/10.18280/ijtdi.070206
5. Corrado Rindone, Antonio Russo. A network analysis for High Speed Rail services in the South of Italy. In: Conference proceedings of the international Conference on Computational Science and ITS Applications ICCSA 2024 July 1–4, 2024, HANOI, Vietnam. https://link.springer.com/chapter/https://doi.org/10.1007/978-3-031-65318-6_15

6. Ben-Akiva, M., Cascetta, E., Coppola, P., Papola, A., Velardi, V.: High Speed Rail demand forecasting in a competitive market: the Italian case study. In: Proceedings of the World Conference of Transportation Research (WCTR). Lisbon, Portugal (2010)
7. Cascetta, E., Coppola, P.: High speed rail (HSR) induced demand models. Procedia-Soc. Behav. Sci. **111**, 147–156 (2014)
8. Russo, F., Sgro, D., Musolino, G.: Sustainable development of railway corridors: methods and models for High Speed Rail (HSR) demand analysis. In: Gervasi, O., et al. (eds.) Computational Science and Its Applications – ICCSA 2023 Workshops. ICCSA 2023. LNCS, vol. 14110. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-37123-3_36
9. Ben-Akiva, M., Bergman, M.J., Daly, A.J., Ramaswamy, R.: Modelling interurban route choice behaviour. In: Proceedings of the 9th International Symposium on Transportation and Traffic Theory, pp. 299–330. VNU Science Press (1984)
10. Ortúzar, J.D.D., Willumsen, L.G.: Modelling transport, 3rd edn. John Wiley, Chichester, NY, USA (2001)
11. Cascetta, E.: Transportation systems analysis: models and applications. Springer (2009)
12. Manski, C.F.: The structure of random utility models. Theor. Decis. **8**, 229–254 (1977)
13. Quattrone, A.; Vitetta, A. Random and Fuzzy Utility Models for Road Route Choice. Transp. Res. Part E Logist. Transp. Rev. 2011, 47, 1126–1139
14. Vitetta, A.: Quantum utility model for route choice in transport systems. Travel Behav. Soc. **3**, 29–37 (2016)
15. Russo, F., Moschella, M., Musolino, G.: Railway demand evaluation: HSR induced component. In: Gervasi, O., Murgante, B., Garau, C., Taniar, D.C., Rocha, A.M.A., Faginas Lago, M.N. (eds.) Computational Science and Its Applications – ICCSA 2024 Workshops. ICCSA 2024. LNCS, vol. 14822. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-65318-6_12
16. Russo, F., Musolino, G.: A unifying modelling framework to simulate the spatial economic transport interaction process at urban and national scales. J. Transp. Geogr. **24**, 9–22 (2012). https://doi.org/10.1016/j.jtrangeo.2012.02.003
17. Yao, E., Morikawa, T.: A study of an integrated intercity travel demand model. Transp. Res. Part A **39**, 367–381 (2005)
18. Cascetta, E., Papola, A., Pagliara, F., Marzano, V.: Analysis of mobility impacts of the high-speed Rome-Naples rail link using within-day dynamic mode service choice models. J. Transp. Geogr. **19**(3), 423–432 (2011). https://doi.org/10.1016/j.jtrangeo.2010.07.001
19. Cascetta, E., Coppola, P.: An elastic demand schedule-based multimodal assignment model for the simulation of high-speed rai(HSR) systems. Assoc. Euro. Oper. Res. Soc. **2012**(1), 3–27 (2012)
20. Román, C., Martín, J.C.: Integration of HSR and air transport: Understanding passengers' preferences. J. Transp. Geogr. **41**, 77–85 (2014). https://doi.org/10.1016/j.jtrangeo.2014.01.001
21. Cascetta, E., Russo, F., Viola, F.A., Vitetta, A.: A model of route perception in urban road networks. Transport. Res. Part B: Methodol. **36**(7), 577–592 (2002)
22. Vitetta, A.: Path choice in transport systems: comparing random, quantum, and fuzzy utility models in a small network. Front. Future Transp. **6**, 1544947 (2025). https://doi.org/10.3389/ffutr.2025.1544947
23. Ben-Akiva, M., Lerman, S.R.: Discrete choice analysis: theory and application to travel demand. MIT Press, Cambridge, MA (1985)
24. McFadden, D.: The measurement of urban travel demand. J. Public Econ. **3**(4), 303–328 (1974). https://doi.org/10.1016/0047-2727(74)90001-7
25. Italian Government. Ministry of Transport and Infrastructures: Sistemi di monitoraggio deltraffico linee guida per la progettazione (2000)

26. Croce, A.I., Musolino, G., Rindone, C., Vitetta, A.: Estimation of travel demand models with limited information: floating car data for parameters' Calibration. Sustainability **13**(16), 8838 (2021). https://doi.org/10.3390/su13168838
27. Xiao, Y.-B., Chen, J., Liu, X.-L.: Joint dynamic pricing for two parallel flights based on passenger choice behavior. Xitong Gongcheng Lilun yu Shijian/Syst. Eng. Theory Pract. **28**(1), 46–55 (2008)
28. Ferrovie dello Stato Italiane. Nota stampa, Fs Italiane: Dieci anni di alta velocità, cambiato il paese e la vita delle persone. FS-Italiane (2019). https://www.fsitaliane.it/content/dam/fsitaliane/Documents/fsnews/comunicati-stam-pa/2019/dicembre/2019_12_05_NS_2_FS_Italiane_10_anni_AV_cambiato_Paese_e_vita_persone.pdf. Accessed 2 Feb 2024
29. Russo, F., Sgro, D., Musolino, G.: dynamic structure of fares for high speed rail services. In: Gervasi, O., Murgante, B., Garau, C., Taniar, D., C. Rocha, A.M.A., Faginas Lago, M.N. (eds.) Computational Science and Its Applications – ICCSA 2024 Workshops. ICCSA 2024. LNCS, vol. 14822. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-65318-6_13