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Development of an integrated set of indicators to measure the quality of the whole traveller experience

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Abstract

The EU project METPEX is developing a measurement tool for the perceived quality of the whole journey experience. Special emphasis is given on the contribution to the overall quality perception from different phases of such experience, from pre-trip information acquisition to the eventual joint use of different services, especially for multimodal trips. Differences among travel means and user groups are investigated as well. Rather than exclusively focusing on public transport, the project also investigates quality issues dealing with other modes, especially walk and bike. Within such framework, the paper presents some sets of indicators distilled through Principal Component Analysis that could be used in different assessment exercises, shortly discusses how such indicators are showing us the different facets of the "quality of transport" concept and identifies future research directions for the project.

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1. Introduction

The measurement of the quality of transport services has been the object of an intensive research activity in the last decades. Several different factors influencing service quality have been considered: objective measures of performance and related subjective perceptions, satisfaction for a whole trip and for specific aspects along with their relative importance, impacts of sociodemographic and lifestyle variables, personality traits and situational factors such as trip purpose or traveller mood, just to mention some of them.

The EU project METPEX (A MEasurement Tool to determine the quality of the Passenger Experience, www.metpex.eu) seeks to give a contribution in this field by focusing on some aspects that are less investigated in most of the existing studies. The first aspect is related to the fact that perceived quality is measured throughout the whole traveller experience, therefore not simply considering the trip made by using a specific service. All phases of the journey experience are then considered, ranging from the pre-trip information acquisition process to the final movement to arrive at destination. Analyses on a preliminary dataset during the earlier phases of METPEX have already confirmed that overall trip satisfaction is only loosely related to satisfaction for the main leg in multimodal trips (Susilo and Cats, 2014). Additionally, the project mainly considers also non-motorised transport means (walk, bike), while other researches in this field often exclusively focus on public transport. Finally, specific viewpoints of particular groups of travellers, such as commuters, women and physically challenged individuals are explicitly considered.

The body of knowledge that has been accumulated over the years on the measurement of quality in public transport systems is very large (see e.g. Diana and Daraio, 2014 and de Oña and de Oña, 2015 for recent surveys) and somewhat reflected in the development of quality monitoring methods for practitioners, such as those recommended in the U.S. Transit Capacity and Quality of Service Manual (TCRP, 2013). Within METPEX, about 70 papers were collected and analysed to reconstruct the state of the art (METPEX, 2015a). This review confirmed that many of these researches have a different focus from that of the project: they just consider public transport and often rely on objective quality measures, such as minutes of delay, rather than subjective ones. On the other hand, the European Standard EN-13816 considers a "quality loop" where both the provider and user viewpoints are considered, even if only guidelines to develop quality indicators are provided.

Focusing more specifically on the research gaps that METPEX is aiming to cover, some researchers have tried to evaluate the whole journey rather than the travel on-board only (Tyrinopoulos and Antoniou, 2008; Lu et al., 2009; Carreira et al., 2013 and 2014). However, some limits about the concept of 'whole journey' could arise when, for example, the surveys used for the analysis concentrates on more general users' opinion about public transport and not on a specific journey. This is especially troubling in case of multimodal journeys. Concerning the other identified research gaps, we could not find papers specifically dealing with the development of indicators to measure the perceived quality of bikers and walkers, or analysing the viewpoint of special user groups. The needs of passengers with disabilities are in fact often investigated through qualitative methods such as focus groups, while only limited evidence is available concerning the effect of some sociodemographic variables on perceived quality (Rojo Arce et al., 2011; Bordagaray et al., 2014), without an attempt to differentiate among different kinds of travellers.

On a methodological point of view, a survey in eight different European cities has been first carried out to elicit satisfaction ratings of a very large set of items related to the passenger experience: this activity is shortly described in section 2. In the following phase of the research, quality indicators have been proposed to summarise the information gathered through such satisfaction ratings, mainly using principal component analysis. The derivation process of such indicators is presented in section 3, whereas section 4 describes the indicators that were found. The last section summarises the main findings from this research activity.

2. Data collection activities

The aforementioned goals of the project required a tailored data gathering activity, since we are not aware of an available dataset with all the needed information. The basic idea was to collect information on satisfaction ratings

regarding the whole journey experience of individuals using different travel means and belonging to different social groups. Questions were therefore in the form “Please indicate your level of satisfaction with the following aspect”, with five possible answers, ranging from “Not at all satisfied” to “Completely satisfied”. The following ten travel means have been considered: private vehicles, buses, tram, trains, underground, pedestrian, bikes, waterborne, demand responsive transit and mobility vehicles. Motorised private means were then considered all together, since they are not the focus of the project. Furtherly, travellers were assigned to one of the following partially overlapping eleven user groups, with an unequal probability sampling design to over-represent less common categories: women, commuters, low income, aged over 65, aged under 24, travelling with children, travelling with dependents, communication impaired, mobility restricted, rural dwellers and visitors.

The questionnaire was formed of the following five main parts:

- Baseline questions (BL): socio-demographic characteristics of the traveller, attributes of the last journey done, general opinions and mood.
- Tier 1 quality questions (T1): satisfaction ratings of 21 quality components related to the overall journey.
- Mode-specific questions (TM): 10 bins of satisfaction ratings questions specific for the above listed travel means.
- User group-specific questions (UG): 11 bins of satisfaction ratings questions specific for the above listed user groups.
- Tier 2 quality questions (T2): 21 bins of satisfaction rating questions, each corresponding to one T1 question, for an in-depth assessment of each T1 quality component.

All individuals answered the same questions in sections BL and T1, while they answered to only one bin of questions for sections TM and UG, according to their travelling activities and their assignment to a group. On the basis of the answers to the first four sections, they were then assigned to one of the 21 T2 bin.

The structure of the questionnaire is presented in Figure 1. The figure shows, for every section of the questionnaire, the number of questions and variables available in the dataset beyond the baseline questions. It can be noticed that there are less variables than questions, given the fact that some variables have been asked in different parts of the questionnaire. For example, some aspects typically related to the quality of rail public transport might have been asked both to those that travelled by train and to those that travelled by tram. In other cases, questions have been repeated for example both in the UG (user group) and T2 (Tier-2) sections, therefore potentially leading to multiple answers for the same satisfaction aspect. Beyond the baseline section of the survey, 417 satisfaction variables are overall available in the dataset, of which 342 are unique and 75 are repeated in two or more questions.

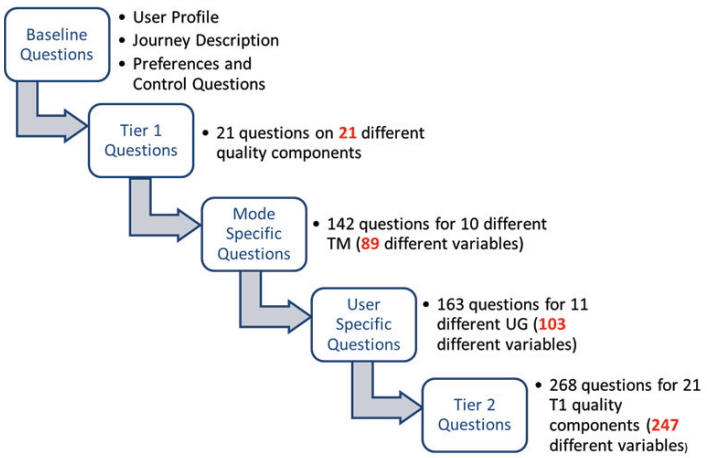

Fig. 1. General structure of the survey questionnaire.

The survey went on field in September-October 2014 in eight METPEX test sites: Bucharest (Romania), Coventry (UK), Dublin (Ireland), Grevena (Greece), Rome (Italy), Valencia (Spain), Vilnius (Lithuania) and Stockholm (Sweden). Additionally, the questionnaire was distributed by FIA (Fédération Internationale de l'Automobile) through their national networks of motorists. More than 6300 observations have been gathered through several different protocols, ranging from traditional face to face or self-administered surveys to gaming apps and tracking through a crowd-sourcing interactive navigator. Additional details on the survey planning and implementation are provided in METPEX (2013) and descriptive statistics of the sample can be found in METPEX (2014).

In the present paper we are not looking at the differences among cities, therefore all data have been jointly considered. This makes the analysis more difficult, since city-specific factors influencing quality are not controlled; however, the resulting indicators are likely to have more general validity since they were built on observations from quite heterogeneous cities. On the other hand, the influence of the surveying protocol on the provided answers is analysed in Susilo et al. (2015): in the following, we will pool together all observations from different sources.

3. Methodology to build the indicators

3.1. General framework

From the description in the preceding chapter, it follows that the dataset originating from the survey contains an initial set of variables stemming from the baseline questions and therefore of rather heterogeneous kind, ranging from metric (age) to categorical (travel mode) and from objective (travel time) to subjective assessments (mood). On the other hand, the last four additional sets of variables (T1, TM, UG and T2) all contain five-points satisfaction ratings, ranging from "Not at all satisfied" to "Completely satisfied". Quality indicators presented in this work were developed from such four latter sets, while in subsequent phases of the research we will study how indicators values are affected by sociodemographic characteristics of the travellers and by trip attributes that were recorded in the baseline section.

In our framework, indicators are thus representing latent variables that can summarise the information provided by the satisfaction ratings. Therefore, Principal Component Analyses (PCA) have been conducted on selected subsets of variables. PCA is a multivariate statistical analysis technique, where an initial set of variables (in our case, the satisfaction ratings) are linearly combined to generate a smaller set of new latent variables, called components. Linear combinations are defined in such a way that the smallest number of such new variables can explain the maximum proportion of observed variance in the dataset. Following standard practice in the use of such methods, components with eigenvalues greater than 1 have been retained and cognitively interpreted to check if they could represent reasonably well a consistent latent factor, or concept. If this is the case, then the corresponding indicator I can be defined as a linear combination of the satisfaction ratings through the following expression:

$$I = \Sigma_i C_i * Z_i \quad (1)$$

where C_i are the component (or factor) score coefficients pertaining to the i variables that have a significant loading on the component under consideration and Z_i are the standardised scores of those i variables. It should be noted that factor score coefficients are something different from factor loadings. The former are the coefficients to be used to compute latent variables from the observed ones, while the latter must be considered to understand if an observed variable is significantly contributing to a latent factor. Details on the computational process can be found in any multivariate statistical analysis textbook (e.g. Hair et al., 1998).

3.2. Defining indicators on the basis of the structure of the survey

Given the large number of variables and the above described complex experimental design of the survey where different "stratifying variables" (user group, travel means and T1 quality components) are considered, it is clear that not all questions and respondents can be jointly considered. A strategy needs to be set up to run PCAs by focussing on subsets of both variables and observations, identified on the basis of the kind of indicator to be built. According

to common practice, considering more than 30 variables in a PCA makes in fact the interpretation of the results too complex and unduly increases sample size requirements (Hair et al., 1998). Beyond such constraint, a minimum number of observations must be considered to draw statistically sound results. Ideally, at least five observations for each variable included in the analysis should be available, with a minimum sample size of 100 (Hair et al., 1998).

At the outset, the most straightforward way to select subsets of variables to define indicators is to consider the structure of the questionnaire (shown in Figure 1). This leads to a first series of ten analyses, each one considering a set of mode-specific variables from the TM section of the questionnaire, and to a second series of eleven analyses based on the UG section. In each of these 21 analyses we also considered the T1 variables, in order to check how such quality components compound with the more specific TM and UG items. Indicators stemming from those two series of analyses will respectively be presented in the following subsections 4.1 and 4.2

It is however rather reductive to define indicators only from variables that were already grouped together in the survey design phase. For example, satisfaction questions that are relevant to a specific travel means might have been asked also in other parts of the questionnaire beyond the corresponding TM group. Moreover, the goal of METPEX is to study the whole journey experience, rather than the quality of specific mobility services. These two factors led us to explore the possibility of defining some classification schemes of the variables in the dataset, and then to extract indicators by jointly considering the variables that fall inside each one of these newly defined classes, irrespective of where the corresponding question was actually asked within the questionnaire. Several different classifications could be foreseen for our dataset: in the following subsection we describe three of them, and we show how these classifications informed the creation of additional indicators.

3.3. Classifications of the variables and resulting additional indicators

The variables of the dataset have been classified according to the following three different schemes: by relevance to the 10 travel means listed in section 2 (C1), by relevance to the 11 user groups again previously listed (C2) and by relevance to the different phases of the journey experience (C4). Two additional classifications C3 and C5, were worked out in METPEX (2015b) but they are not relevant here. Concerning C4, several alternatives were tested but the final considered phases are the following:

- *Pre-trip* (e.g. looking for timetables, buying tickets in advance, preparing to leave the origin).
- *Walking* from/to a point where a travel means is taken. We also consider here the variables that are relevant when "walking" was reported as a separate trip leg or stage, or even as the unique mode used for the whole journey.
- *Waiting* for a travel means before boarding it (excluding waiting on-board before the departure).
- *Travelling on-board* a given means (public or private, motorised or not).

4. Results of the principal component analyses

Following the above specified methodology, it has been possible to define 24 mode-specific quality indicators for 7 different travel means (TM section of the questionnaire) and 34 user group-specific indicators for 10 different traveller profiles (UG section). The available sample size did not allow defining indicators for three less commonly used travel means (waterborne, demand responsive and mobility vehicles) and for the "travelling with dependents" user groups. Space limitations do not allow us to give a complete account of all these indicators: in the following we will only list them respectively in subsections 4.1 (mode-specific) and 4.2 (user group-specific). The complete presentation of all indicators can be found in METPEX (2015b).

Additionally, 7 quality indicators for communication restricted and mobility impaired passengers using public transport were defined (jointly considering C1 and C2 classifications) along with 9 indicators focusing on some of the above specified phases of the journey experience, based on C4. These two groups of indicators are presented respectively in subsections 4.3 and 4.4. Again, the available sample size had an influence on the results that is later described.

4.1. Mode-specific indicators

Indicators specific for 7 different travel means are listed in Table 1. To save on space, only the indicator label and complete name is reported, along with the number of observed variables that significantly load on each indicator.

Some comments are possible on these results. The number of indicators changed across several means, due to the different number of factors with eigenvalue greater than 1. Indicators for the two "heavy rail" modes (trains and underground) are similar, while those for bus services show the increased concerns of passengers on reliability and comfort. Active means perceived quality is heavily relying on the quality of infrastructure and of design.

Table 1. Indicators for different travel means.

Travel mode	Indicator label and name	No. of variables*
Trains	RAIL1: On-trip performance	11
	RAIL2: Ticketing and performances before boarding	9
Underground	UNDER1: On-trip performance	11
	UNDER2: Ticketing and capillarity	7
Tramways	TRAM1: Service integration and reliability	13
	TRAM2: Comfort and staff helpfulness	10
	TRAM3: On-trip quality	6
	TRAM4: Tickets and timetabling	3
	TRAM5: Fares convenience	3
	TRAM6: Information quality	2
Bus services	BUS1: Reliability	10
	BUS2: Ticketing and other issues	8
	BUS3: Comfort on board	7
Walk trips	PED1: Information and safety	10
	PED2: Environmental aspects	7
	PED3: Sympathy of design	1
	PED4: Intermodal travel and barrier free accesses	2
	PED5: Pavements cleanliness	1
Bicycles	BIKE1: Cycling infrastructure	11
	BIKE2: Quality of information, availability and infrastructure	3
	BIKE3: Bikers' interests	9
	BIKE4: Public transport plus bike trip quality	8
	BIKE5: Easiness in carrying bicycles	4
Motorised private	PRIV: Traffic calming and parking	9

* See METPEX (2015b) for the list of variables in each indicator.

4.2. User group-specific indicators

Table 2 shows how the underlying dimensions of the perceived quality of the travelling experience change according to the kind of traveller. Reliability is important for the most active categories, while accessibility matters for elderly. Both ticketing and information issues are a consistent quality factor for a number of groups, while comfort is emerging for commuters (due to the intensity of use of means), low income (probably due to the use of cheaper and lower quality services), rural dwellers and communication impaired.

4.3. Indicators for special users groups riding public transport

Public transport quality indicators of two different groups of travellers with special needs were developed: mobility restricted (four indicators, Table 3) and communication impaired (three indicators, Table 4). The second column of each table lists the satisfaction rating items needed to compute each indicator through the formula presented in section 3.1, while the third column shows their respective component score coefficients C_i. The focus of the project on users with special needs is justified by the relevance of public transport services for these users and the levels of investment that have been attained to try to adequate existing services to their needs. Each table shows

the complete definition of the proposed indicators, including the list of the observed variables upon which the respondents expressed their ratings and, in the last column, the corresponding components coefficients C_i needed to compute the indicator itself. From the tables it can be seen that some of these indicators seem to overlap with those previously introduced. Yet the detailed definition of the indicator could be different, since for example CIMP6 and PT-CI2 encompass partly different items.

By comparing the indicators in the two tables one can appreciate their wide difference. This result points at the importance of looking at the individual needs of different categories, since a wide range of needs might be expressed by people with different health problems, while in some cases public transport services exclusively focus their improvement efforts on aspects that are relevant to specific subgroups of users.

Table 2. Indicators for different user groups.

User group	Indicator label and name	No. of variables*
Women	WOM1: Safety and security, comfort and staff helpfulness	12
	WOM2: Integrated tickets and range of fares	6
	WOM3: Reliability	5
Commuters	COMM1: Facilities and parking	12
	COMM2: Reliability	7
	COMM3: Ticketing issues	7
	COMM4: Comfort aspects	4
Aged over 65	OLD1: Information and accessibility	7
	OLD2: Performance issues for elders	12
	OLD3: Travel services	8
	OLD4: Infrastructural design	7
Aged under 24	YOUNG1: Service design and information	16
	YOUNG2: Reliability	17
	YOUNG3: Convenience issues	4
Low income	LOW1: Low cost services issues	7
	LOW2: Comfort	6
	LOW3: Convenience	6
Visitors	VISIT1: Information issues	10
	VISIT2: Barriers for foreigners	6
Rural dwellers	RURAL1: Service coverage and costs	10
	RURAL2: Ground aspects	7
	RURAL3: Comfort and availability	5
Travelling with children	CHILD1: Design and quality on-board	9
	CHILD2: Ground aspects	6
Mobility restricted	MOBR1: Quality issues specific for mobility restricted	14
	MOBR2: General quality issues	15
	MOBR3: Ability to meet individual needs	10
	MOBR4: Ground services	3
Communication impaired	CIMP1: Quality issues specific for communication impaired	7
	CIMP2: Information issues specific for communication impaired	9
	CIMP3: General quality issues	10
	CIMP4: On-board quality and information	10
	CIMP5: Comfort	2
	CIMP6: Information aspects	4

* See METPEX (2015b) for the list of variables in each indicator

4.4. Indicators for different phases of the journey experience

Mainly due to limitations in the number of available observations, walking and waiting phases were merged in the PCA and no specific indicator was distilled for the pre-trip phase, when jointly considering all relevant variables according to classification C4. Therefore, Table 5 reports the previously defined indicator RAIL2 since it is related to the pre-trip phase, while Table 6 lists indicators for travelling on-board public transport vehicles and Table 7 for both walking and waiting. Again due to the small sample size, some of the indicators in the latter two tables present

a smaller number of variables. This is due to the fact that the relevant questions in the T2 part of the survey are on average asked to less than 5% of the sample, according to the experimental design described in section 3. As discussed in our conclusions, re-running the analysis by excluding T2 questions could be an interesting avenue for future research.

Table 3. Indicators for mobility restricted individuals.

Indicator label and name	Variable definition	C_i
PT-MR1: Infrastructural design	Availability and accessibility of lifts and escalators	0.581
	Level of assistance available during journey	0.424
	Reliability at off peak times	0.119
	Provision of public toilets	0.067
	Shelter provided from weather	0.010
	Information about disabled friendly interchanges (main terminals)	0.169
	Location of disabled parking spaces	-0.004
PT-MR2: Relevant features for mobility restricted	The overall accessibility of my journey was adequate for travellers with additional needs	0.296
	Extent to which transport provision provides equal opportunities for mobility	0.273
	Overall accessibility of the vehicle you used for those with additional needs	0.245
	Availability and suitability of priority seating	0.193
	Electronic Information appliances within easy reach	0.167
	Availability of ramps/dropped kerbs	0.164
	Design of crossing spaces (e.g. road crossing facilities)	0.105
	My passenger rights (e.g. able to access all transport services) were respected	0.103
	Easiness of connections with other modes of transport	0.099
	Design of shared spaces with pedestrians/other modes of transport (on roads)	0.084
	Information about disabled friendly interchanges (main terminals)	0.061
	Benches/seating provision	0.030
	Information on accessibility of vehicle and station facilities	0.022
PT-MR3: Service operations	Punctuality	0.557
	Reliability at off peak times	0.379
	Reliability of services	0.326
	Range of fares offered	0.119
PT-MR4: Ticketing and other issues	Ticket purchasing process was easy to follow	0.604
	Vehicle design was suitable for my needs	0.327
	Comprehensibility of ticketing structure	0.249
	Provision of public transport only lanes	0.226

Table 4. Indicators for communication impaired individuals.

Indicator label and name	Variable definition	C_i
PT-CI1: Communication aspects	Levels of anti-social behaviour	0.527
	Accessibility of ticket offices for those with communication/language problems	0.271
	Staff communication skills	0.188
	Overall accessibility for those with sensory impairments	0.185
	Reliability of services	0.185
	Helpfulness of customer facing staff	0.103
	Provision of tactile information	0.058
PT-CI2: Information design	Clear provision of real time information in multiple formats	0.591
	Clearly marked routes	0.413
	Design of information which is comprehensive and easy to understand	0.289
	Clarity of travel information	0.248
PT-CI3: Punctuality and reliability	Punctuality	0.595
	Reliability of services	0.390

5. Discussion and conclusions

Data available from the survey campaign allowed us to define a preliminary set of indicators with a good coverage across several different travel means and user groups and could also offer some insights on more specific

issues, such as those measured through indicators in subsections 4.3 and 4.4. These indicators are not mutually excluding, therefore it is unlikely that they need to be all used in an evaluation exercise. The most appropriate set should rather be selected on the basis of the evaluation framework and objectives. Then, the corresponding items will define the set of questions to be included in the METPEX tool in that particular case.

Table 5. Indicators for the pre-trip phase.

Indicator label and name	Variable definition	C_i
RAIL2: Rail ticketing and performances before boarding	Ability to buy one ticket which covers different forms of transport	0.345
	Range of fares offered	0.257
	Comprehensibility of ticketing structure	0.262
	Accessibility of platforms	0.203
	Availability of ticket buying locations	0.202
	Value for money of services was good	0.254
	Accessibility of station facilities	0.165
	Ticket purchasing process was easy to follow	0.171
	Distance from Origin or Destination to closest station	0.093

Table 6. Indicators for travelling on-board a public transport means.

Indicator label and name	Variable definition	C_i
ON1: Staff behaviour	Respect shown by public transport staff	0.688
	Helpfulness of customer facing staff	0.657
	Public Transport Staff were receptive to my needs	0.535
ON2: Policy and planning aspects	The city supported my mobility needs	0.897
	The different modes of transport I used worked well together	0.769
ON3: Trip specific aspects	My safety and security while travelling was good	0.749
	The quality of my ride was good	0.777
	The quality of transport infrastructure (e.g. whole transport service) on my journey was good	0.658
ON4: Service operations characteristics	Provision of public transport only lanes	0.817
	Frequency of services	0.569
ON5: On-trip performance*	Level of noise	0.365
	Level of crowding	0.303
	Air temperature and ventilation inside vehicles	0.209
	Cleanliness of vehicles	0.200
	Speeding and driving behaviour	0.168
	Shelter provided from weather	0.142
	Helpfulness of customer facing staff	0.120

* This indicator was built for different public transport forms and results were similar: here it is reported the specific one for bus services.

Table 7. Indicators for waiting and walking to/from a public transport service point.

Indicator label and name	Variable definition	C_i
PT-WW1: Infrastructures design	Design of stations was adequate for my needs	0.712
	Design of transport interchanges (main terminals) was efficient	0.673
	Design of transport stops was adequate for my needs	0.575
PT-WW2: Trip-specific aspects	The quality of my ride was good	0.887
	The quality of transport infrastructure (e.g. whole transport service) on my journey was good	0.285
PT-WW3: Safety and security	Feeling of Security/Safety inside stations	0.826
	Safety and security at transport stops	0.643

By inspecting the above tables it can also easily be seen that the indicators are far from being perfect, and the judgment of an expert could easily amend them. Spurious variables sometimes are included in a given indicator, due to the observed correlation patters. For example, PT-MR1 mostly deals with infrastructural design issues but we read also a “Reliability at off-peak times” item in the third line of Table 3. On the other hand, other variables could be added to enrich other indicators. However, in this phase of the research we deliberately chose to adopt a purely empirical approach by “letting the data speak”, and therefore considering the indicators as they came out from our

PCA analysis. Further assessment activities would drive to more refined definitions for such indicators, by excluding variables that albeit sharing the same correlation pattern are not relevant to a given indicator, and perhaps including more consistent additional ones. Notwithstanding such limitations, we believe that these indicators represent a contribution in filling some of the research gaps that were identified in the introduction, namely the proper consideration of viewpoints of different users groups, travelling on different means and considering the whole journey experience.

The final phases of METPEX will involve the assessment of indicators here presented, in order to come up with a final list that will be made available through a manual (METPEX Deliverable 5.4). The manual will also contain tools and examples on the policy use of such indicators. Beyond the project end, future work will focus in completing the set of indicators, especially for different phases of the journey experience, by excluding T2 variables from the analysis. This will increase the number of available observations therefore presumably leading to a more complete (albeit with less nuances) set of indicators, especially for pre-trip, waiting and walking phases. Another interesting avenue for future research is to build a measurement model through structural equations models (e.g. de Oña et al., 2013), in order to check how the indicators there proposed compound in determining the whole traveller experience.

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