Key factors for defining an efficient urban transport interchange: users' perceptions

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ABSTRACT

The sustained increase in the urban population and the trend towards urban sprawl in European cities has led to a change in mobility patterns, and many public transport users now need to combine several modes or transport services at urban transport interchanges before they reach their final destination. Therefore, they have become an everyday experience for users where, in addition, users spend time inside. This paper aims to identify the key factors both from a functional and psychological perspective for defining an efficient transport interchange. Since the users' perceptions of their experience are particularly important for achieving the most appropriate policy measures for interchanges, an ad-hoc travellers' satisfaction survey was designed and carried out in three European transport interchanges. The assessment methodology used here –Principal Component Analysis– is proposed as a useful step-by-step procedure. The results of this research highlight the ambivalent nature of the urban transport interchanges. The key functional aspects identified contribute to make easier the transfer and reduce the waiting time, while the psychological factors make the stay more comfortable for users.

Key words: transport interchanges, urban mobility, users' perceptions, intermodal transfer, Principal Component Analysis

Highlights:

- Urban transport interchanges are vital elements for reducing transfer inconvenience
 - A travellers' satisfaction survey was done to capture users' perceptions
 - Principal Component Analysis is used to identify the main factors for users
 - Travellers make decisions based on perceived walking and waiting times
 - The overall interchange performance is directly linked to safety and security conditions
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1 Introduction

Cities worldwide are undergoing clear and continuous growth. More than half the world's population today lives in urban areas, and this trend is expected to continue rising. According to Heilig (2012), by 2050, 86% of the global population in developed regions will live in urban areas. Cities today are complex systems, with massive numbers of interconnected citizens, businesses, transport modes, services and utilities (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014).

This sustained increase in the urban population and the trend towards urban sprawl in European cities has led to a shift in mobility patterns. The challenge facing all major cities is how to increase mobility while at the same time reducing congestion, accidents and

pollution (COM, 2006). This rapid growth has gone hand in hand with greater demand for transportation facilities (Debnath, Chin, Haque, & Yuen, 2014). In urban areas –the scenario of most daily trips–, distances travelled and travel times have risen dramatically (Banister, 2011), forcing many public transport users to combine different transport modes to complete their trips and decreasing the attractiveness of public transport versus the private car. Reducing the inconvenience inherent in transferring between modes is a basic principle for achieving sustainable mobility.

The Committee on Intermodal Transfer Facilities, Transportation Research Board (1974), already pointed out that the total effectiveness of the transportation network is determined by intermodal transfer facilities. Iseki & Taylor (2009) noted that the attractiveness of Public Transport (PT) can be substantially increased by reducing the burden of walking, waiting and transferring. It is therefore crucial to establish the factors that optimize and determine the competitiveness of these terminals. At the urban level, transport interchanges are vital to ensuring smooth journeys for passengers and improving the overall efficiency of the public transport system (Abreu e Silva & Bazrafshan, 2013; Li, 2013). As defined by Edwards (2011), a transport interchange is a more complex transport facility than a conventional station, and allows travellers to transfer from one mode to another. Intermodal transfers are more onerous than intramodal transfers (Liu, Pendyala, & Polzin, 1997). Urban transport interchanges are located within cities and play a key role both as transport network nodes and as *'meeting places'*, thereby enhancing their function as a place and not as a barrier, and creating synergies unrelated to transport. Peek & van Hagen (2002) noted that this ambivalent nature creates opportunities for synergy between both functions: moving and staying. This dual approach can also be compared with the new concept of High Speed Rail stations within cities defined by Bertolini & Spit (1998).

As noted by Terzis & Last (2000), an efficient urban transport interchange must be competitive and, at the same time, be attractive for users given that their physical experiences and psychological reactions are significantly influenced by the design and operation of the interchange. Therefore, the main goal of this paper is to identify the key factors from the users' point of view that define an efficient urban transport interchange, i.e. seeking balance of this dual approach: functional and psychological. This was done by conducting a travellers' satisfaction survey in three European transport interchanges.

The paper is structured as follows. Section 2 presents the review of the literature into the key aspects and elements identified as important in the design, operation and management of multimodal passenger transport stations. Section 3 defines the main features of each case study. The data collection procedure and assessment methodology are described in sections 4.1 and 4.2 respectively. The analysis of the key factors obtained and the interpretation of the results are presented in section 5. Finally, section 6 summarizes the main conclusions and offers some essential principles for defining an efficient urban transport interchange.

2 Multimodal transport stations: review of previous studies

Transport interchanges today are a crucial element in sustainable urban transport policies (COM, 2007), and yet there are no standards or regulations specifying the form

these interchanges should take in Europe. In fact, the literature review reveals that most studies and research focus mainly on railway and underground stations. This section reviews the studies that identify the key aspects and elements for defining, operating and managing multimodal transport stations, and the most recent studies on the subject of urban transport interchanges.

A survey carried out in the United States and Canada identified *covered waiting areas* and *passenger information* as the most common amenities provided at transfer facilities (Stern, 1996). This study analysed these facilities as transport nodes within a network, but disregarded other aspects. Desiderio (2004) pointed out that in urban environments, multimodal transport stations also establish relationships between users and the territory, and should thus be considered as an element in urban development strategies, due to their role as “*city gates*”. They should generally be considered as multimodal facilities where travellers are not only passing through, but are also spending time (van Hagen, 2011). It is therefore crucial to take into consideration other aspects and elements that improve the users' experience.

The Station User Panel (2011) developed seven ‘*Railway Station Usability Principles*’ for the government of Victoria (Australia) in order to improve railway station effectiveness taking into consideration the users' experience of the rail system. These principles were: *accessibility, ease of navigation, comfort & amenities, information, safety, local area integration* and *community ownership & activity*. Peek & van Hagen (2002) also identified *safety* and *comfort* as important requisites in railway station operation. However, visual features such as *layout* and *visible presence of staff* were identified as key aspects for improving stations from the ‘*meeting place*’ perspective (Peek & van Hagen, 2002). Garmendia, Ribalaygua, & Ureña (2012) concluded that the ‘*station as a place*’ approach produced different outcomes, usually depending on the size of the city. Durmisevic & Sariyildiz (2001) focused their research on analysing various techniques for building underground stations and examined their efficiency, again taking into account the human factor. This study defined important ‘*functional aspects*’ for the operation of the station – *internal connections of the spaces* and *efficiency of movement*– and ‘*psychological aspects*’ – such as *public safety* and *comfort*– that are more closely related to the user's experience of a station as a space.

Terzis & Last (2000) carried out one of the first research works into the subject of urban transport interchanges. This study concluded that *accessibility, facilities, image* and *information provision* were the most relevant aspects in the design and operation of interchanges. Desiderio (2004) focused on analysing the factors that determine the quality of intermodal interchanges considering both users' and operators' requirements. These factors were classified into six different categories: *accessibility & external circulation, physical design, shops & amenities, security & psychological factors, information* and *ticketing*.

The latest research on urban transport interchanges found that these multimodal facilities also depend on other factors such as *the position in the network, the urban environment* and *the modes involved* (Harmer et al., 2014). Hernandez, Monzon, & De Oña (2015) proposed a methodological framework to identify the strengths and weaknesses of transport interchanges. The results showed *information, transfer conditions* and *safety & security* to be the most relevant aspects.

In summary, the literature review essentially reveals there are two types of aspects to take into consideration in the design, operation and management of passenger multimodal transport stations, and particularly in railway and underground stations. Most studies identify *information provision* and *accessibility* as the most relevant functional features, while *safety & security* and *comfort* as the most important psychological aspects. The other relevant aspects identified are listed below:

- Layout
- Internal connections
- Ease of movement
- Waiting areas
- Services and facilities

But, how should an existing or new urban transport interchange perform? Which fundamental functional and psychological aspects are fundamental from the users' point of view? This study aims to identify the key factors and provide essential principles for reducing the transfer inconvenience and thus, improving the user's experience at urban transport interchanges.

3 Description of the case studies

According to Pitsiava-Latinopoulou & Iordanopoulos (2012), the location, the transport modes involved and the passengers' characteristics are key variables for determining the category of a multimodal transport station. European case studies were therefore selected to provide a balance in terms of geography, seeking a heterogeneous range of transport modes, size and the role of the interchange within the city in order to evaluate different types of the interchanges. Additionally, the typology was selected following the classification criteria developed by PORTAL (2003) that defined the transport interchanges according to their location in the network: peripheral interchanges, sub-centre interchanges and city centre interchanges, respectively. The interchanges selected were Ilford Railway Station (London, UK), Moncloa (Madrid, Spain) and Kamppi (Helsinki, Finland). Table 1 provides a brief description of the main features of each interchange. Additionally, it shows the transport modes involved at each case study and indicates the daily demand of the main modes in each transport interchange.

Kamppi and Moncloa are fairly new urban interchanges, built and refurbished in 2006 and 2008 respectively. Conversely, Ilford was built in 1839 and rebuilt in 1980. The transport modes and services involved in the interchanges vary. Users travel mainly by metro and bus in Kamppi and Moncloa, and by rail in Ilford. The role of the Moncloa interchange is basically local and regional with only a few national services, while the Kamppi interchange also includes the main national bus station. There is also one international bus service (i.e. to St. Petersburg). The Ilford interchange is predominantly a railway station and focuses on local services, mainly for local commuter trips.

Table 1: Main characteristics of the case studies

Urban transport interchange	Year built	Modes of transport (1)	Passengers/day (2013)	Role/place	Description surrounding
Ilford Railway Station	1839	Rail	22,405	Local + Regional	Large suburban town in the London borough of Redbridge. Located in the town centre. Shopping centre opposite the station. <i>(Peripheral interchange)</i>
	Rebuilt in 1980 Planned for refurbishment	Bus Bike (with bike parking) Private car with drop off Car parking Taxi			
Moncloa	1995 Refurbishment in 2008	56 metropolitan bus lines	59,989	Local + Regional + National (2 lines)	Entrance gateway to Madrid , near city centre and area with historic monuments. Metro line 6 connects all central points in Madrid <i>(Sub-centre interchange)</i>
		3 urban bus lines 2 metro lines 2 long distance bus lines No private car parking	96,789 109,321		
Kamppi	2005 (Started operation) 2006 (Shopping centre)	21 local bus lines	19,360	Local + Regional + National + International (1 bus to St. Petersburg)	Central location in downtown Helsinki. Shopping centre. Railway station is 500 metres from the Kamppi interchange. <i>(City centre interchange)</i>
		40 regional bus lines 15 metropolitan bus lines 1 metro line 1 international bus line 2 tram lines on street network Bike centre (parking, rental, service) Car parking Taxis	8,500 7,500 21,700		

(1) The most relevant transport modes in each case study and their daily demand are indicated in bold

It is worth noting that all three interchanges play a key role in multimodal trips in their corresponding cities and cover a wide spectrum of interchange types and geographical distributions.

4 Methodological framework assessment

The above review highlights several points that are relevant to travellers' decision-making, and particularly that they find transfers to be stressful and/or time-consuming, thus discouraging PT use (Iseki & Taylor, 2009). It is therefore essential to determine which attributes and factors define an efficient urban transport interchange from the users' point of view. This section presents the data collected in each case study in order to capture the users' views, along with the targeted analytical methodology that was applied to obtain these factors, thus enabling its effective implementation by policy planners and operators.

4.1 Data collection through a travellers' satisfaction survey

Passenger multimodal transport facilities tend to be designed and operated by multiple stakeholders. However several authors conclude that an understanding of the users' views is essential for defining and developing an efficient urban transport interchange

(Durmisevic & Sariyildiz, 2001; Peek & van Hagen, 2002; Friman, 2010; Harmer et al., 2014)

A travellers' satisfaction survey was designed and implemented in the three case studies described above. This ad-hoc survey contained primarily 37 observed variables relating to different aspects and elements of an interchange (see Figure 1), based on the findings of the literature review and previous studies (PIRATE, 1999; Terzis & Last, 2000; Durmisevic & Sariyildiz, 2001; Iseki & Taylor, 2010; Abreu e Silva & Bazrafshan, 2013) and built to consider the following eight categories: 1) travel information, 2) way-finding information, 3) time & movement, 4) access, 5) comfort & convenience, 6) image & attractiveness, 7) safety & security, and 8) emergency situations. Each respondent was asked to rate the level of satisfaction with each of the 37 variables on a Likert scale from 1 (strongly dissatisfied) to 5 (strongly satisfied). The 5-point Likert scale was adopted because it is the most widely adopted in the traveller's satisfaction questionnaires (De Oña, 2013). Additionally, the survey also contained some questions related to socio-economic characteristics and trip habits in order to define user profiles and mobility patterns.

A new implementation method was applied to do the survey in urban transport interchanges combining computer-assisted methods (online surveys) with traditional techniques (face-to-face interviews). Firstly, a short face-to-face interview was conducted to travellers in order to explain them the main objectives of the survey and secondly, they were given a card which included a link to the survey website and a *survey number* to monitor the received surveys and avoid duplication of responses. They were carried out between May 2013 and October 2013. They were received 1,471 surveys ($N_{\text{Ilford}}=234$, $N_{\text{Moncloa}}=928$ and $N_{\text{Kamppi}}=309$) and by ruling out any incomplete or incorrectly answered surveys, there was a total sample of 1,389 valid surveys ($N_{\text{Ilford}}=226$, $N_{\text{Moncloa}}=865$ and $N_{\text{Kamppi}}=298$).

Figure 1: List of observed variables in the travellers' satisfaction survey

Table 2 presents the main characteristics of the user profiles and trip patterns obtained from the analysis of samples.

Table 2: Main characteristics of the user profiles and trip patterns for each case study

			Moncloa	Kamppi	Ilford Railway Station
USER PROFILE	Gender	Female	54.1 %	64.1%	39.3%
		Male	45.9 %	35.9%	60.7%
	Age	(18-25)	42.5 %	14.5 %	8.0 %
		(26-40)	26.1 %	33.8 %	42.4 %
		(41-65)	28.0 %	44.3 %	42.0 %
	Employment status	Employee	49.0 %	71.8 %	83.1 %
		Student	38.0 %	16.1 %	4.9 %
	Frequency of use of the interchange (1)	Habitual user*	84.7 %	62.4 %	80.5 %
	PT ticket	Monthly pass	84.5 %	61.7 %	65.5 %
TRIP PATTERNS	Driving license	Yes	70.9 %	75.8 %	66.8 %
		No	62.0 %	36.9 %	43.4 %
	Access to private vehicle	Yes	70.9 %	75.8 %	66.8 %
		No	62.0 %	36.9 %	43.4 %
	Journey stage	Starting	34.9 %	38.6 %	72.1 %
		Transfer	56.9 %	36.9 %	11.6 %
		Ending	8.2 %	24.5 %	16.0 %
	Number of transfers (mean)	---	2.0	1.0	2.0
	Main access mode	Train	---	---	28.4 %
		Metro	51.9 %	25.2 %	---
		Metropolitan bus	23.7 %	46.3 %	28.9 %
		Walking	10.4 %	18.5 %	37.8 %
	Main egress mode	Train	---	---	64.4 %
		Metro	17.5 %	21.5 %	---
		Metropolitan bus	58.8 %	50.3 %	8.0 %
		Walking	8.9 %	22.8 %	24.0 %
	Trip purpose	Work	48.6 %	55.4 %	81.4 %
		Study	34.5 %	10.7 %	3.1 %
		Leisure	11.1 %	30.5 %	12.4 %
	Total travel time (median)	---	50 min	45 min	45 min
	Time inside the interchange (median)	---	10 min	9 min	6 min
	Use of time (inside the interchange)	Transferring	18.2 %	17.6 %	39.1 %
		Queuing	58.3 %	39.4 %	38.5 %
		Shopping	6.8 %	25.2 %	4.6 %
		Other pursuits	16.7 %	17.8%	17.8%

(1) Habitual user: user who uses the interchange daily or 3-4 times a week

4.2 Principal Component Analysis: step-by-step procedure

The methodology applied in this study is based on a Principal Component Analysis (PCA) covering the set of 37 observed variables described in section 4.1. This analysis is a complex multi-step process that aims to identify groups or clusters of variables. These clusters help reduce a dataset to a more manageable size in order to understand and interpret the structure of the set of variables (Field, 2009). This statistical technique has been widely used and broadly applied in social sciences (Costello & Osborne, 2005).

Several aspects and conditions must be considered to ensure the correct application of this analytical technique. A step-by-step procedure is proposed in view of the nature of the data and the study objective, based on previous research on the urban built environment (Comendador, López-Lambas, & Monzon, 2014). The PCA were applied to the three samples obtained in each case study and performed using the SPSS®v20 software package

Step 1. Data consistency

A number of conditions must be checked previously to ensure the correct application of the PCA as shown in Table 3. Bartlett's test showed highly significant results in all cases, indicating that correlations among the 37 observed variables are sufficiently large to apply a PCA. Excellent results were also obtained for both the KMO index and the reliability of the sample.

Table 3: Statistical criteria to be met before a Principal Component Analysis

	Ilford Railway Station (N _{Ilford} = 226)	Moncloa ^a (N _{Moncloa} =865)	Kamppi (N _{Kamppi} = 298)
Sample size (1)	>200 <i>Fair</i>	>500 <i>Very good</i>	≈300 <i>Good</i>
Reliability (2)	0.967 <i>Excellent</i>	0.948 <i>Excellent</i>	0.953 <i>Excellent</i>
KMO index (3)	0.948 <i>Superb range</i>	0.950 <i>Superb range</i>	0.937 <i>Superb range</i>
Bartlett's test sphericity (Jackson, 1993)	p< 0.000 chi ² (630)=6,354.300	p< 0.000 chi ² (630)=15,995.266	p< 0.000 chi ² (666)=6,544.268

^a Item 12 in the Moncloa transport interchange was excluded from the PCA as it had a loading of less than 0.3 in all factors, and its communality was less than 0.4, meaning that this variable was not properly classified in any factor extracted. The PCA was re-applied to the 36 variables.

(1) There are many 'rules of thumb' about the proper sample size. The common rule is to have at least 10-15 participants per observed variable (Field, 2009). Nevertheless, Comrey & Lee (1992) defined the following ranges: 100 as poor, 200 as fair, 300 as good, 500 as very good, and 1000 or more excellent.

(2) Cronbach's alpha is the measure of internal consistency reliability and a value from 0.7 is generally considered to represent an acceptable scale (Wittwer, 2014).

(3) The index used to measure the sampling adequacy is Kaiser-Meyer-Olkin (KMO) index (Field, 2009). The KMO statistic varies between 0 and 1. Hutcheson & Sofroniou (1999) defined values between 0.5-0.7 as mediocre, values between 0.7-0.8 as good, values between 0.8-0.9 as great and values above 0.9 as superb.

Step 2. Factor extraction method.

The main aim of this step is to simplify the dataset structure into a reduced number of latent

factors or components. Based on the sample sizes and the convergence of the *Scree plot* (Cattell, 1966) and *Kaiser's criterion* (Yeomans & Golder, 1982), six factors were identified at the Ilford and Kamppi interchanges, and eight components were obtained from the analysis of the Moncloa interchange. The explained cumulative variance of the factors accounted for more than 60% in the three case studies, which means that the underlying structures can be considered correct in all cases.

Step 3. Rotational method

This step discriminates between factors in order to ensure a more reliable and correct interpretation of the loading of the variables on each one. There are two types of rotation: orthogonal rotation and oblique rotation. The main difference is that orthogonal rotation ensures that latent factors are uncorrelated while the oblique rotation assumes their correlation (Field, 2009). It should be stressed that orthogonal rotation reveals the order of importance of the extracted factors according to the percentage of variance, whereas oblique rotation does not.

Appendix A presents the detailed results and the factor loadings of each observed variable in all cases after rotation. Firstly, orthogonal rotation method was applied. However, the correlation matrices¹ indicated that the factors were interrelated to some degree in all case studies. As a result, orthogonal rotation method was dismissed and the oblique rotation was therefore selected as the appropriate method. Interestingly, it should be noting that the same underlying structures were obtained for both rotational methods in all cases studies (see Table A.1, Table A.2 and Table A.3), which highlights their robustness. Finally, the reliability of the internal consistency of each factor obtained from the oblique rotation was checked (the Cronbach's alpha of each factor was greater than 0.7 in all cases).

Step 4. Interpretation

The results of the PCA must reflect theoretical and conceptual assumptions. Loadings with an absolute value of over 0.3 can be considered important, although the sample size also has an influence (larger sample sizes imply statistically meaningful smaller loadings) (Field, 2009). The number of factors is considered correct in human sciences when the underlying structure explains at least 50-60% of the variance (Wittwer, 2014; Streiner, 1994).

5 Interpretation and discussion of results

The quality of both the infrastructure (building, facilities and so on) and services (information provided and so on) perceived by the users of a transport interchange usually depends on the context of the interchange (Hine & Scott, 2000; Redman, Friman, Gärling, & Hartig, 2013; Abreu e Silva & Bazrafshan, 2013; Harmer et al., 2014). Some of the issues that can directly influence the users' perception include the main modes of transport involved,

¹ The component correlation matrix and the theoretical and conceptual assumptions are a guide to whether it is reasonable to assume independence between factors. This matrix, the final output, contains the correlation coefficients between factors (Field, 2009).

location of the infrastructure, age of the building, and user profiles and travel patterns.

However, an analysis of the results of this research points to some fundamental elements in all case studies independently of the interchange context. Even though the three transport interchanges are significantly different, they share certain key factors and the observed variables that define each one (i.e. the variables with the highest factor loadings² –see Appendix A). The factors that define an urban transport interchange are '*Information*', '*Transfer conditions*', '*Safety & Security*', '*Emergency situations*', '*Design & Image*', '*Environmental quality*', '*Services & Facilities*' and '*Comfort of waiting time*'. Table 4 shows these factors and the main observed variables in each case study. It is also worth noting that some components or factors are influenced by different aspects according to the context of the urban interchange. '*Information*' and '*Transfer conditions*' are clustered in the case of the Ilford Railway Station and '*Environmental quality*' is clustered with the '*Safety & Security*' factor in the case of the Kamppi interchange (see Appendix A – Table A.1 and Table A.3).

Table 4: Key factors obtained from the oblique rotation and their main observed variables in each case study

Key factors	Main observed variables		
	Ilford Railway Station	Moncloa ^a	Kamppi
Information	Travel information	Signposting	Travel information (displays & at interchange)
		Travel information (at interchange)	
Transfer conditions	Transport operator coordination	Transfer distance	
		Transport operator coordination	Distance (facilities & transfer)
Safety & Security	Security in transfer & waiting areas (evening/night) Security surrounding area	Use of time (at interchange)	
		Security in transfer & waiting areas	Safety (inside interchange)
		Security surrounding area	Security in transfer & waiting areas Security surrounding area
Emergency situations	Emergency exits (Location & Signposting)	Emergency exits (Location & Signposting)	Escalators (case of fire)
			Emergency exits (Location)
Design & Image	Design (External & Internal)	Design (External & Internal)	Design (External & Internal)
Environmental quality	Noise	Air quality	Air quality
	Temperature	Noise	Temperature
Services & Facilities	Shops	Shops	Coffee-shops & restaurants
	Coffee-shops &	Coffee-shops &	

² Large factor loadings indicate a significant influence of the variable on the latent factor. Conversely, small factor loadings suggest that the variable is not substantially influenced by this factor (Tyrinopoulos & Antoniou, 2008).

	restaurants	restaurants	Shops
Comfort of waiting time	-----	Telephone signal & Wi-Fi Travel information displays	-----

Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization. Eigenvalue>1.

^a Factor 'Comfort of waiting time' was only identified in the Moncloa transport interchange

These factors define an efficient urban transport interchange from two different perspectives, functional and psychological, confirming the previous theoretical and conceptual assumptions based on the literature review. As a consequence, an urban transport interchange should be conceived both as 'a transport node' and 'a place' (see Figure 2). Factors such as 'Information' provision –travel information and signposting– and 'Transfer conditions' –distances and coordination between transport operators– facilitate the use of the interchange 'as a node of transport'. Iseki & Taylor (2009) concluded that physical conditions such as transfer distances and adequate information can reduce perceived walking times. Conversely, 'Design & Image', 'Environmental quality' –air quality, noise and temperature– and 'Services & Facilities' –number and variety of shops and coffee-shops– are more closely related to the users' experience inside an interchange 'as a place'. Iseki & Taylor (2009) concluded that these factors affect travellers' perceptions of comfort and convenience and thus how they perceive waiting time. Comfort at a transfer terminal is identified as a determining factor in PT users' perceived ease of making a transfer (Guo & Wilson, 2011). Availability of telephone signal, Wi-Fi and travel information displays can also be oriented to improving the quality of waiting time.

'Safety & Security' –both inside the interchange and in the surrounding area– are crucial in both approaches, and is directly linked to the overall performance of the interchange. Several authors have noted that personal security at terminals is the most important factor in travellers' decision to use PT (Atkins, 1990).

Finally, 'Safety & Security', 'Information' and 'Transfer conditions' are identified as the most important factors³ in all case studies.

³ The variance considered for each factor determines its importance in an orthogonal rotation; that is, when there is not a high correlation between factors or it is not taken into account.

Figure 2: Key factors in a transport interchange

6 Conclusions and policy recommendations

Many PT users today need to combine several transport modes or services to reach their final destination, and the inconvenience caused by these transfers has led to a decline in the attractiveness of PT (Guo & Wilson, 2011). Urban transport interchanges are an everyday experience for users and have become fundamental elements in reducing transfer inconvenience and improving user experience.

This research has identified the key factors from the users' point of view that define an efficient transport interchange –considering them not only *'as nodes'* within the transport network, but also *'as places'*–, and the most relevant elements and aspects in both approaches.

The results highlight common key factors and attributes in all the case studies, despite significant differences in the features and context of each interchange. General guidelines can be extracted in order to improve the design, operation and management of an urban transport interchange. Since travellers make decisions based on perceived walking and waiting times, it is crucial to reduce the inconvenience of transfers in order to increase the attractiveness of PT. An efficient urban transport interchange should fulfil four essential principles under the dual approach described above:

'As a transport node'

- *Reducing waiting time.* Transfer distances and co-ordination between operators are crucial.

- *Making it easier to use the interchange and reducing the users' stress levels.* Travel information and signposting are the most important aspects here.

'As a place'

- *Making the stay more comfortable.* Fundamental aspects are external and internal design, air quality, temperature and noise, information displays.
- *Improving the use of time in the interchange.* Services & facilities and the availability of a telephone signal and Wi-Fi could help achieve this purpose.

Finally, Safety & Security are psychological features that are indispensable to users and are directly linked to the overall performance of the interchange. It is particularly important to pay special attention to security aspects in transfer and waiting areas and in the surroundings, and the emergency exits should be clearly located and signposted, and perfectly identified.

In conclusion, current urban transport interchanges can host other type of activities and act not only as transport nodes, but also as meeting places within cities. As noted by Scott (2003), urban transport interchanges are therefore key features for the future development of cities.

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APPENDIX A. Results of the PCA: factor loadings

Rotation Method		Orthogonal		Oblique	
Factor	Observed variables	Factor loadings	Variance explained (%)	Factor loadings	Cronbach's alpha
Information & Transfer conditions	Travel information before trip	0.812	19.354	0.878	0.938
	Travel information displays	0.750		0.764	
	Travel information at interchange	0.747		0.762	
	Co-ordination transport operators	0.721		0.703	
	Transfer distance	0.718		0.678	
	Use of time at interchange	0.673		0.641	
	Signposting to transfer	0.644		0.613	
	Signposting facilities and services	0.638		0.565	
	Ticket purchase	0.618		0.550	
	Information provided by staff	0.621		0.546	
	Distance between facilities	0.510		0.424	
	Accessibility	0.641		0.409	
	Design & Image	External design		0.724	
Internal design		0.728	0.628		
Number of elevators, escalators		0.630	0.576		
Surrounding area is pleasant		0.654	0.560		
Movement (crowding)		0.536	0.428		
Safety & Security	Security in transfer and waiting areas (evening/night)	0.752	12.316	0.814	0.911
	Security surrounding area	0.747		0.812	
	Safety (inside interchange)	0.738		0.771	
	Security in transfer and waiting areas (day)	0.713		0.750	
	Safety getting on / off the transport mode	0.692		0.700	
	Lighting	0.587		0.555	
Emergency situations	Signposting to emergency exits	0.787	7.410	0.851	0.940
	Location of emergency exits (emergency event)	0.773		0.834	
	Real time information to improve sense of security	0.737		0.788	
Services & Facilities	Shops	0.798	9.473	0.846	0.855
	Coffee-shops and restaurants	0.791		0.833	
	Cash machines	0.745		0.783	
	Telephone signal and WI-FI	0.479		0.447	
	Comfort (information screens)	0.418		0.342	
Environmental quality	Noise	0.780	9.585	0.867	0.864
	Temperature	0.679		0.727	
	Cleaning (generally)	0.655		0.700	
	Air quality	0.624		0.665	
	Seating	0.402		0.355	
Explained cumulative variance (%)		68.625			

Table A.1: Summary of the exploratory PCA of the travellers' satisfaction survey at Ilford

Extraction Method: Principal Component Analysis. Rotation Methods: Varimax & Oblimin with Kaiser Normalization. Eigenvalue > 1.

Table A.2: Summary of exploratory PCA of the travellers' satisfaction survey at Moncloa

Rotation Method		Orthogonal		Oblique	
Factor	Observed variables	Factor loadings	Variance explained (%)	Factor loadings	Cronbach's alpha
Information	Signposting facilities and services	0.692	10.038	0.671	0.814
	Signposting to transfer	0.694		0.656	
	Travel information at interchange	0.634		0.577	
	Ticket purchase	0.550		0.510	
	Information provided by staff	0.501		0.419	
	Travel information before trip	0.485		0.411	
	Accessibility	0.447		0.351	
Transfer conditions	Transfer distance	0.736	7.790	0.798	0.797
	Co-ordination transport operators	0.718		0.755	
	Use of time at interchange	0.701		0.741	
	Distance between facilities	0.592		0.602	
	Movement (crowding)	0.438		0.412	
Design & Image	External design	0.724	6.831	0.723	0.835
	Surrounding area is pleasant	0.697		0.700	
	Internal design	0.709		0.688	
Safety & Security	Security in transfer and waiting areas (evening/night)	0.794	11.013	0.831	0.881
	Security in transfer and waiting areas (day)	0.790		0.826	
	Security surrounding area	0.740		0.784	
	Lighting	0.667		0.669	
	Safety (inside interchange)	0.618		0.638	
	Safety getting on and off the transport mode	0.641		0.607	
Emergency situations	Location of emergency exits (emergency event)	0.806	8.583	0.891	0.903
	Signposting to emergency exits	0.783		0.862	
	Location of escalators in the event of an emergency	0.756		0.831	
	Real time information to improve sense of security	0.660		0.683	
Services & Facilities	Shops	0.798	6.003	0.822	0.757
	Coffee-shops and restaurants	0.792		0.814	
	Cash machines	0.502		0.488	
Environmental quality	Air quality	0.740	7.464	0.789	0.793
	Noise	0.709		0.750	
	Temperature	0.668		0.684	
	Cleaning (generally)	0.565		0.548	
Comfort of waiting time	Telephone signal and WI-FI	0.630	5.843	0.603	0.707
	Travel information displays	0.564		0.539	
	Comfort (information screens)	0.566		0.496	
	Seating	0.498		0.436	
Explained cumulative variance (%)		63.566			

Extraction Method: Principal Component Analysis. Rotation Methods: Varimax & Oblimin with Kaiser Normalization. Eigenvalue>1

Table A.3: Summary of exploratory PCA of the travellers' satisfaction survey at Kamppi transport

Rotation Method		Orthogonal		Oblique	
Factor	Observed variables	Factor loadings	Variance explained (%)	Factor loadings	Cronbach's alpha
Information	Travel information displays	0.739	10.319	0.801	0.768
	Travel information at interchange	0.745		0.784	
	Travel information before trip	0.743		0.778	
	Co-ordination transport operators	0.364		0.297	
Transfer conditions	Distance between facilities	0.679	17.165	0.747	0.877
	Use of time at interchange	0.621		0.638	
	Transfer distance	0.602		0.626	
	Movement (crowding)	0.552		0.550	
	Signposting to transfer	0.556		0.531	
	Signposting facilities and services	0.521		0.502	
	Number of elevators, escalators	0.454		0.425	
	Ticket purchase	0.466		0.404	
	Accessibility	0.421		0.369	
	Information provided by staff	0.405		0.338	
	Design & Image	External design		0.818	
Internal design		0.806	0.837		
Surrounding area is pleasant		0.663	0.669		
Seating		0.346	0.308		
Safety & Security and Environmental quality	Safety (inside interchange)	0.814	10.144	0.829	0.918
	Security in transfer and waiting areas (evening/night)	0.728		0.745	
	Security in transfer and waiting areas (day)	0.748		0.729	
	Security surrounding area	0.684		0.707	
	Safety getting on and off the transport mode	0.680		0.636	
	Lighting	0.656		0.625	
	Air quality	0.618		0.568	
	Temperature	0.616		0.557	
	Cleaning (generally)	0.602		0.541	
	Noise	0.598		0.539	
	Comfort (information screens)	0.496		0.412	
Emergency situations	Location of escalators in the event of an emergency	0.782	7.456	0.767	0.908
	Location of emergency exits (emergency event)	0.789		0.761	
	Signposting to emergency exits	0.751		0.715	
	Real time information to improve sense of security	0.622		0.548	
Services & Facilities	Coffee-shops and restaurants	0.816	8.217	0.816	0.747
	Shops	0.807		0.807	
	Cash machines	0.545		0.509	
	Telephone signal and WI-FI	0.369		0.334	
Explained cumulative variance (%)		61.006			

Extraction Method: Principal Component Analysis. Rotation Methods: Varimax & Oblimin with Kaiser Normalization. Eigenvalue>1

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