DESIGN OF PASSENGER INTERCHANGES

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Abstract: Three projects focussing on intermodality and interchanges are currently in progress, promoted by the European Commission: GUIDE, MIMIC and PIRATE. After a short description of each project, the paper concentrates on the MIMIC project. The MIMIC approach consists in a structured evaluation of the necessary and desirable conditions to improve interchanges and intermodality. In particular, the project's aim is to identify passengers' needs and priorities in order to help decision makers to choose among the many investment projects competing for the same pot of money. MIMIC uses the notion of barriers to intermodality as a way of throwing light on and evaluating problems relating to interchanges in six sample cities (Bilbao, Copenhagen, London, Rome, Tampere and Warsaw). The tools used to assess and scale users' needs are presented and commented. These include both surveying and modelling tools. The modelling tools (logit model, micro-simulation model and GIS tool) are described in detail. Finally, the most important 'barriers' to intermodality are summarised and commented.

1 Interchange-based projects promoted by the European Commission

There are three projects promoted by the European Commission which have looked at interchanges and intermodality. All are complementary, looking primarily at the role of interchanges in encouraging intermodality, but take different approaches to the issue.

– **PIRATE** ('Promoting Interchange Rationale, Accessibility and Transfer Efficiency') is concerned with developing a specific technique to solve problems at interchanges, based on discussion with users, non-users, professionals involved in the interchange and employees in the interchange. It works by scaling the perceived importance of various characteristics of the interchange, and scaling the perceived performance of the interchange in those characteristics. By comparing importance against perceived reality an indication of where action should be taken is possible. The project has taken the technique which was piloted in earlier research, and has applied it to various types of interchange.

– **GUIDE** ('Group for Urban Interchanges Development and Evaluation') is concerned with taking an objective view of interchange with a view to understanding in more general terms what makes for a successful interchange, and improving current practice by providing guidance on better practice. It involves a review of literature, expert evaluations of a large number of interchanges, and the furtherance of theory regarding the characteristics of interchange. As examples of this it differentiates between interchange as an *activity* and as a *location*, and looks at physical, network, operational, institutional and organisational characteristics.

– **MIMIC** ('Mobility, InterModality and InterChanges') is concerned with barriers to intermodality. It starts from the standpoint that, in an ideal world, people would make decisions regarding travel which would often involve mixing and changing modes, but that barriers of various types inhibit people into habitually using single modes and, most commonly, the car. The project uses a number of different surveying and modelling tools to identify the existence and relative

importance of such barriers, in an attempt to ascertain what users ask for and what actions may be appropriate in different interchanges to allow cost-effective action to be taken to encourage intermodality.

2 The MIMIC approach

The MIMIC approach is based on the notion of 'barriers to intermodality'. Taking as a premise the idea that with a 'level playing field' people would make travel and modal decisions incorporating intermodal options, MIMIC defines the factors which encourage people to make single-mode and car-based options as 'barriers' to what would be the norm of intermodal transport options. The research plan is developed according to the following four study areas:

1. **Door-to-door factors and demand responses**. Study of the importance of different factors which affect travellers' choices relating to intermodal trips including all the door-to-door trip components, and in particular the weight of barriers at interchanges in modal choices.
2. **Catchment area**. The catchment area of the interchange and the relationships with the interchange multi-modal access network, the individual and land use characteristics.
3. **Types of barriers**. The barriers which inhibit modal interchange, identifying those which are absolute, which are relative, and those which are specific to particular modes or user categories. Barriers such as funding and management are also studied.
4. **Implementing cost-effective local solutions**. Using the notion of barriers to intermodality cost-effective solutions for selected sites can be identified which may reduce barriers to intermodality and improve the attractiveness of the interchange, at different levels (planning, designing, funding and managing).

The above-mentioned study areas have been analysed in a series of test sites in Europe. This in-depth investigation of selected interchanges occurred in six cities: Bilbao, Copenhagen, London, Rome, Tampere and Warsaw. The list of investigated interchanges is given in Table 1.

Table 1. Main test sites studied by MIMIC

City (country code)	Interchanges	Status
London (GB)	1. Stratford	Under redevelopment
Rome (IT)	1. Ponte Mammolo	Existing
Tampere (FI)	1. Tampere Intermodal Passenger Terminal	Existing and under development
Copenhagen (DK)	1. Valby	Recently opened
Bilbao (ES)	1. Termibús	Under construction
	2. Abando	Under construction
Warsaw (PL)	1. Wilanowska/Pulawska	Existing but planned to be developed

It can be seen that the MIMIC methodology can be applied both to existing and planned interchanges.

The analysis of the main test sites is complemented by an investigation of other issues identified in significant and recent case studies in Europe. The investigation of other significant and recent case studies aims at integrating examples of good practice that cannot be deducted from the selected case studies in the six MIMIC cities.

The final project output is recommendations valid at the European level for improving intermodality and the attractiveness of interchanges, including:

- Key issues, i.e. the identification and assessment from relevant actors' perspectives of barriers and related key issues to improve intermodality.
- Success stories from case studies where barriers have been successfully dealt with.
- Recommendations, i.e. good practice guidelines, in the following areas:
  - planning of interchanges and door-to-door solutions,
  - funding of the interchange,
  - physical and operational design of the interchange,
  - management of the interchange.

3 The MIMIC tools

The MIMIC approach includes the development of a number of survey and modelling tools in order to analyse the four study areas mentioned in section 2. The relevance of both surveying and modelling tools for the analysis of each study area is synthesised in Table 2. The complete list of MIMIC tools is the following:

Surveying tools

- *Interchange deconstruction*, to break down the various factors which represent a barrier to effective and efficient intermodality that exist between the various modes of transport at the interchange site.
- *'Types of barriers' questionnaires*, to capture data on the most significant barriers and attractive features for a broad sample of users/non-users of a particular interchange site.
- *'Catchment area' questionnaire*, to identify catchment areas by access modes.
- *Door-to-door factors' questionnaires*, to identify the most significant door-to-door factors affecting individuals' choices to make intermodal trips.
- *'Revealed/Stated preferences' questionnaire*, to capture data on present behaviour (RP) and stated preferences (SP) of users/non-users of a particular interchange site. The mixed SP and RP information collected is then used to calibrate a logit choice model.

'Table 2. Relevance of surveying and modelling tools to study areas

		Study areas			
		Door-to-door factors and demand responses	Catchment area	Types of barriers	Implementing cost-effective local solutions
Tools used for assessment	Interchange deconstruction			X	X
	'Types of barriers' questionnaires			X	X
	'Catchment area' questionnaire		X		
	'Door-to-door factors' questionnaires	X			X
	'Revealed/Stated Preferences' questionnaire	X			
	Key Actor interviews			X	X
	Focus Group discussions			X	X
	On-site investigation of the surrounding area		X		
	Video observation			X	X
	Gap analysis				X
	Logit model	X			X
	GIS tool		X		X
	Micro-simulation model			X	X

- *Focus Group discussions*, to identify objectives and expectations according to the needs of specific user groups, including students, disabled, cyclists, business community, etc.
- *Key Actor interviews*, to enable problems and good practice to be contextualised within each interchange site from a number of different perspectives, including regulators, operators, planners, local authority, passenger pressure groups, etc.
- *On-site investigation of the surrounding area*, to identify and evaluate the main relevant characteristics (both transport modes and land use characteristics) of the area surrounding a specified interchange (population, employees, transport modes feeding the interchange, etc.).
- *Video observation*, to actively observe travellers' behaviour at a case study site and record difficulties with barriers experienced by the different types of users.
- *Gap analysis*, to identify gaps at the main test sites in order to complement the database developed in the six MIMIC test cities with knowledge from other European case studies.

Modelling tools

- *Discrete choice logit model*, to quantify demand responses to changes in door-to-door factors relating to supply of transport and other services along the whole trip from origin to destination.
- *Micro-simulation model*, to find out the time it takes the passengers to pass from one means of transport to another and the energy consumed to cross the terminal.

– *GIS tool*, to represent population density, work ratio, road network and public transport network in the area surrounding an interchange site.

Links and relations among MIMIC tools are shown in Figure 1 as a flow chart.

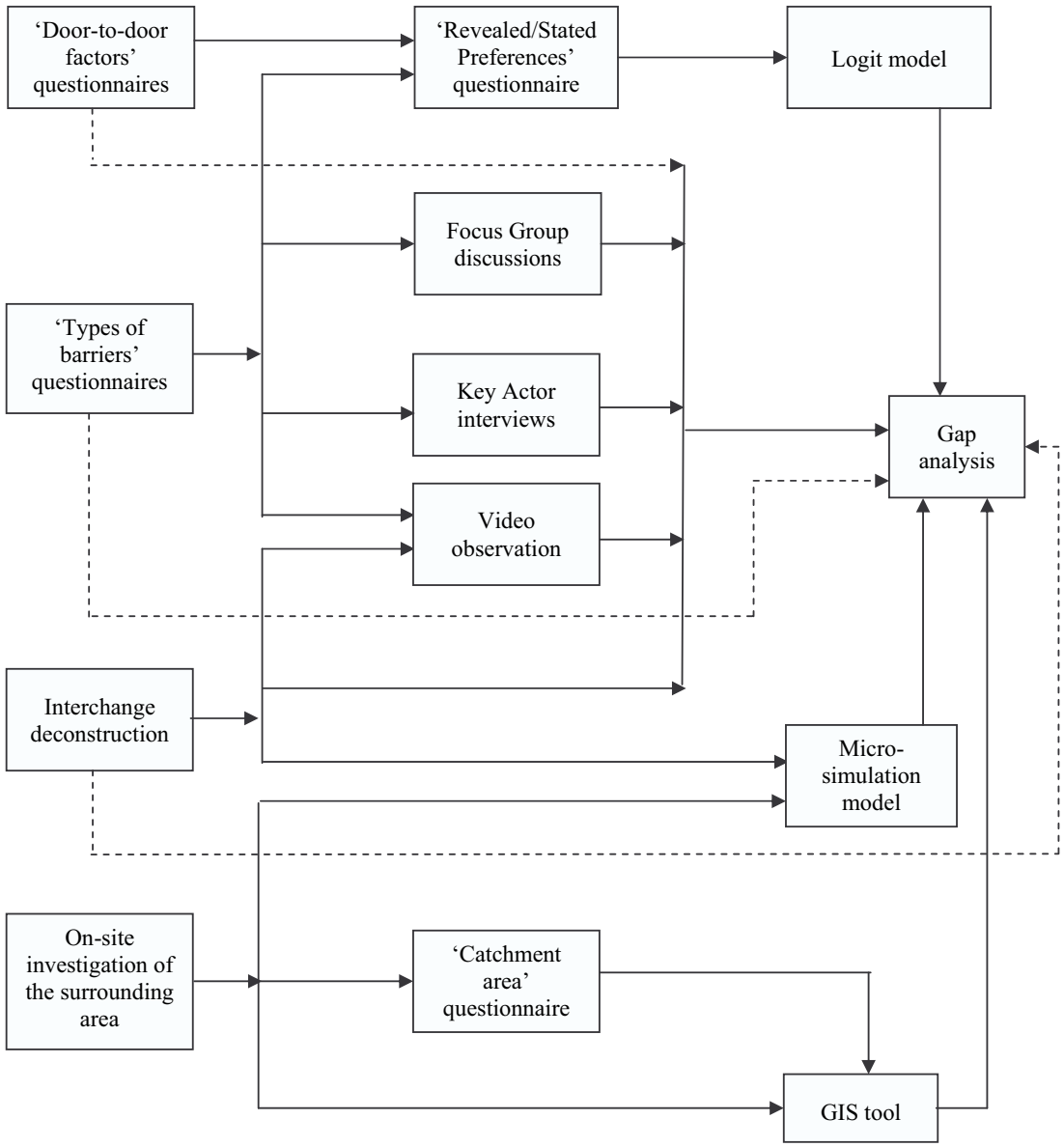

Figure 1. Links and relations among MIMIC tools

Only the MIMIC modelling tools are described in this paper (see section 4), since the authors believe they represent the most interesting tecniques of analysis developed by the MIMIC team as a whole.

4 The MIMIC modelling tools

4.1 Logit model

Two logit models have been calibrated by the MIMIC team, one in Copenhagen, the other in Rome. The Danish model focuses mainly on public transport users (trains and buses), while the Italian one considers car users and Park-and-Ride users.

Both the models use a joint RP/SP estimation technique. The theoretical framework for combining data sources and the specification of the model and the likelihood function are not discussed here.[1] The joint use of RP/SP data requires a special method. If data were simply mixed to estimate choice models, an error would show up in both the measured components and in the unmeasured components (variance) captured in the models themselves. This must be explicitly taken into account in the specification of the model structure and the utility functions.

As for the Italian model, the utility functions are listed below.

$$U_{Car}^{SP} = \eta TAATTA + \iota TRBTTB$$

$$U_{Park\ \&\ ride}^{RP} = Cost3 + \alpha COSTO + \beta COSTPA$$

$$U_{Car}^{RP} = \eta TAATTA + \iota TRBTTB$$

where:

- COSTO is the cost of the trip with the means of transport used;
- COSTOPA is the cost of the trip with the alternative means (Park-and-Ride for car users and vice versa) divided for the number of persons on board;
- COSTOB is the cost of the trip with the bus;
- LENGTH is the walking distance between parking and underground station;
- TT is the travel time on the means of transport used;
- TAATTA is the access travel time of the alternative means (Park-and-Ride for car users and vice versa) divided for the total travel time of the alternative means;
- TRBTTB is the egress travel time of the bus divided by the total travel time by bus.

The estimated coefficients and their t-stat values, together with values of θ and ρ^2, are presented in Table 3.

[1] See M. A. Bradley and A. J. Daly. *Estimation of Logit choice models using mixed stated preference and revealed preference information.* Hague Consulting Group, The Netherlands, 1992.

Table 3. Coefficients estimated by the model

Variables	Variables Coefficient	Estimated coefficient value	t-values
CONSTANT	Cost1	6.823	3.6
COSTO	α	$-0.2213*10^{-3}$	-2.9
COSTPA	β	$0.1274*10^{-3}$	2.6
FEE	χ	$-0.9035*10^{-4}$	-2.2
CONSTANT	Cost2	6.795	2.7
COSTOB	δ	$-0.947*10^{-3}$	-2.6
TT	ε	-0.04824	-2.9
SHOPS	ϕ	0.3133	0.5
SAFETY	φ	0.1457	0.2
LENGTH	γ	$0.5049*10^{-3}$	0.2
TAATTA	η	64.45	3.7
TRBTTB	ι	6.221	2.8
CONSTANT	Cost3	5.404	3.7
	θ	0.5474	3.6
	ρ^2	0.37	

4.2 Micro-simulation model

The simulation consists of a computer elaboration of a model able to represent the real system to be studied. The simulation permits knowing how a system will react (output) when the external conditions (input) change and what parameters will make the system behave optimally. A simulation model permits not only reproducing the actions of a real system, but also some forecasting. It is a powerful planning tool.

A simulation model representing the Ponte Mammolo Interchange in Rome has been developed and tested by the local MIMIC team. The interchange is represented as a collection of objects, members of different classes: cars, local and regional buses, metro trains and different types of pedestrians. Each object can move on different paths and has its own properties. The car, bus and metro movement has been implemented by choosing, as an analysis zone, a large enough area comprising the terminal and all the streets connected to it; this zone is represented in Figure 2.

The specific objective is to find out the time it takes the passengers to pass from one means of transport to another and the energy consumed to cross the terminal, once the distributions of the arrivals and departures of buses and trains and the distributions of passengers alighting from each means are given.

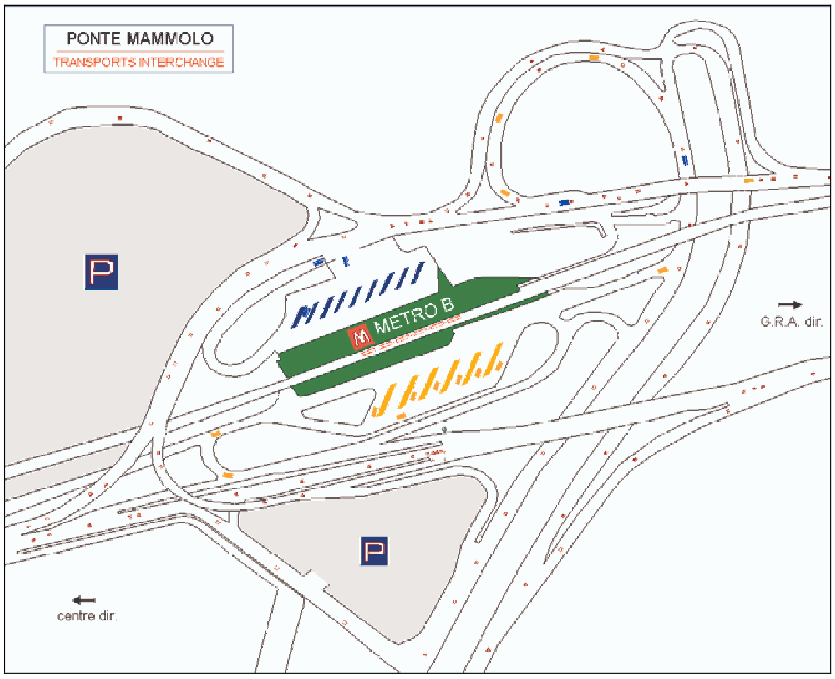

Figure 2. Car, bus and metro movement at the Ponte Mammolo Interchange in Rome

The average value of the means' arrivals and departures, the car flows and the passenger flows are known and the distribution around this value that it wants to be assumed (uniform, Poisson, normal, exponential, binomial, random, etc.) can be chosen. The capacity and speed of the transport means, the passengers' speed, and some others parameters can be changed as well.

An animation of the discrete event simulations has been made in Rome, using a post-processing animator. An animation is useful in both the inspection and the presentation phase. It is the most immediate tool for analysing the system response because it is reproduced and visualised step by step.

4.3 GIS tool

A GIS tool has been used in all the six MIMIC test cities to represent the most important characteristics of the area surrounding each interchange site. Four different coloured maps have been developed for each MIMIC city. The list of coloured maps is as follows:

1. Map A: road network of the surrounding area;
2. Map B: public transport network of the surrounding area;
3. Map C: population density by annulus;
4. Map D: work ratio by annulus.

Maps C and D consider four annuli, or concentric circular areas, lying 0–0.5, 0.5–1, 1–2, and 2–3 from the interchange, which represents the centre of the circle.

Population density and work ratio are defined as follows:

- Population density: ratio of population living in the surrounding area to the area itself (in Km^2);
- Work ratio: ratio of employees (i.e. jobs) in the surrounding area to the population living in the same area (in Km^2).

5 MIMIC main results

In this section are synthesised the most significant barriers identified by the MIMIC research. Barriers have been assessed on the basis of two parameters:

1. *Number of sites* where the barrier proved to be a significant one;
2. *Categories of interviewees* (i.e. users, focus groups and key actors) who cited the barrier in one of the MIMIC test sites.

Table 4 presents results achieved on the basis of this criterion. Users and focus groups are presented in a single column, since each focus group represents a subset of users. As for the column titled '**Cities**', the meaning of symbols is as follows:

\+ if the barrier was cited in 3 sites or less;
++ if the barrier was cited in 4 or 5 sites;
+++ if the barrier was cited in 6 or 7 sites.

As for the column titled '**Key Actors**', the symbol '+' means that the barrier has been cited at least by a key actor in one of the MIMIC test sites. The same symbolism has been adopted for the column titled '**Users & Focus Groups**'.

On the basis of this criterion, the most significant barriers are those given five '+' symbols (three in the column '**Cities**', one each in the other two columns). This means that the barrier is important for both users and key actors in a large number of MIMIC test sites. In the following seven subsection (one for each of the seven MIMIC barrier headings) results synthesised in Table 4 are presented in more detail.

Logistical and operational

The MIMIC research has identified a number of logistical and operational barriers due to lack of co-ordination between different bodies and key players at the interchange, as follows:

- Poor/lack of time synchronisation between services. Lack of knowledge of actual running times of connecting services can be a major barrier to interchange and limits the potential for greater patronage.
- Poor/lack of a common and coherent information system. In many cases information on routes, times and delays is available only for some transport modes.

- Poor/lack of integrated fares and through ticketing. Queues at ticket offices and complex ticketing systems were found to be common barriers, especially among those having low levels of knowledge about a transport system. Moreover, where serial ticketing is the rule, there are often different ticket offices and machines for different transport operators.

Difficult access by foot, cycle, bus or private car can also be a serious barrier to intermodality. The MIMIC research found that:

- Pedestrian access to interchanges often involves difficult access over busy roads or through unpleasant (often unsafe) areas.
- Cyclists often face significant problems when accessing interchanges by cycle and handling a cycle in interchanges. Moreover, secure and covered cycle parking is often missing.
- Public transport services feeding the interchange are often very poor. In particular, density and proximity of bus pick up points are often very scarce, leading to a small patronage in the local catchment area. Moreover, public transport vehicles are generally crowded, old and in poor condition.
- Problems of dropping off and picking up passengers are common, with no provision in many cases.
- In Park-and-Ride interchanges there are often long and poorly maintained distances to walk. Capacity of parking areas is often inadequate and in some cases parking areas are missing.

Psychological

Personal security in the interchange and on access routes proved to be a significant issue for a very wide range of travellers. Women and elderly people are the most affected, but all groups interviewed express concern. Personal security was found to be a major barrier even where cities had maintained at the start of the project that it was not an issue.

The type of fear and the people experiencing fear vary greatly between interchanges surveyed. The MIMIC research has identified four main types of fear, as follows:

- Physical attach and sexual violence
- Thefts of cars, car parts and car radios
- Thefts of cycles and cycle parts
- Vandalism to vehicles and buildings

The feeling of being unsafe is increased when the interchange is located in ‘dangerous’ areas. The constant presence of vagrants, beggars and drug addicts in the surrounding area makes the interchange appear dangerous.

In many cases the rumours and news stories about assault and non-availability of staff create a fear which can be more 'real' than reports about newspaper exaggeration and about diminishing numbers in the criminal statistics. Many female users mentioned that their tendency to choose public transport is absolutely dependent on the hour of day.

Another psychological barrier is created by general safety, mainly due to poor lighting and slippery floors and stairs. General safety and fear of crime proved to be two of the most serious barriers to intermodality, since they were cited in most of the MIMIC test sites by all categories of interviewees (see Table 4: both the barriers have been given five '+' symbols).

Institutional and organisational

Evidence from the MIMIC survey shows that a large number of key players and bodies makes the planning process of interchanges more complex, protracted and costly. Moreover, a large number of key players and bodies responsible for different areas and/or modes leads to a poorly integrated interchange management, which can be a serious barrier to use. As a consequence of this, 'fragmented staff' (i.e. each transport operator has its own staff) are not able to handle enquiries from travellers and to answer to their questions. Where transport staff give a poor image in terms of being helpful, this is perceived by users as a barrier to intermodality.

The MIMIC research has also shown that in many cases private and deregulated transport modes (especially the long-distance ones) can see each other as rivals, leading to competition on passengers and double services.

Physical design

A prime concern of users and potential users is to have good 'basic' services: good ticket offices and ticket machines (to avoid long queues for tickets), clean toilets (possibly with baby changing facilities), comfortable waiting areas. In particular, seating is important to travellers and people meeting at interchanges; consequently, the importance of comfortable and clean waiting areas was stressed both by users and key actors. MIMIC found out also that facilities (mainly reserved areas) for working staff are often very poor (or even lacking).

It should be noted that in some cases users complained about general level of cleanliness of the interchange site.

The MIMIC research proved that the needs of special groups (e.g. disabled, elderly, cyclists, etc.) are often not well thought out. In particular, special access routes, ramps and lifts for wheelchairs are often missing or are poorly maintained. This proved to be a serious barrier to intermodality, as shown in Table 4 with five '+'.

Interchange deconstruction showed that many of the most important linkages in interchanges have very complex routes and barriers. In many cases distances to be walked between services are more than 200 m, and often no protection from rain or sun is available.

The MIMIC team identified a conflict between the view that interchange should be as fast and short as possible (the 'seamless interchange') and the view that those waiting need good and comfortable facilities and lots of space.

Local planning and land use

Interchanges without people or facilities in the immediate surrounding area are perceived as a barrier to local use. As mentioned above, the feeling of being unsafe is increased by an isolated location and psychological barriers can significantly reduce the potential patronage of an interchange.

The fear of crime is increased if the interchange is also located in a 'dangerous' area (e.g. night-club/prostitution district).

Moreover, the location of an interchange can be a barrier to local access because of busy roads or other physical barriers (e.g. a river).

Last but not least, interchanges can become focal points in people's mental maps of a city. If they are badly spaced around the city, it may lessen the chances of people including public transport facilities in their mental maps.

Another significant barrier to intermodality and interchanges is created by lack of consultation. In many cases the problem is that people feel they have not received feedback on their contribution, have no way of knowing if their contribution has been listened to and have subsequently lost touch with the planning and design process. In other MIMIC case studies, public consultation was not carried out at all.

Economic and social

The MIMIC team has clearly identified a conflict between travellers' needs and traders' needs. While travellers ask for shops and facilities inside interchanges (also for security reasons: a busy and lively environment is also a safer one), interchanges with short waiting times often find it harder to attract shops and business since traders feel people will not be shopping while they wait (or only be there for a short period).

Cost of travel can be also perceived as a serious barrier to intermodality. Even if public transport fares vary significantly among MIMIC countries (e.g. the cost of a yearly travel card in London is more then ten times the cost of a similar card in Rome), affordability excludes a significant part of lower-income groups from being able to choose public transport services. In particular, students, disabled and elderly people should be given special thought.

Information

Information was often found to be lacking or of poor quality. The MIMIC research identified two basic needs travellers ask for:

1. *Real-time information on timetables and service delays*. This kind of information is mainly asked by regular or frequent users. In many MIMIC interchanges real-time information is lacking or is available only for some transport modes.
2. *Information on routes and services.* This kind of information is needed by occasional users (e.g. tourists), and the lack of it proved to be a significant barrier to use (many potential users are intimidated by the 'unknown' or complexity of journeys). Information is often not available in the right places and many users and potential users find great difficulty using existing timetables and information (one does not have to be dyslexic to have difficulty reading a timetable).

Moreover, in many interchanges staff are often not found to be on hand to help passengers with information, but also with personal security and safety.

Last but not least the MIMIC research found out that the needs of special groups (e.g. disabled, ethnic minorities, tourists, etc.) are often not well thought out. Lack of staff knowing to deal with people with hearing, speech or learning difficulties, and lack of acoustic signals or brochures in Braille make access to information difficult to many. Signing, in particular, was often found to be lacking or of poor quality. It was often not usable by several groups (especially partially sited and those not speaking the local language).

Table 4 summarises the main barriers identified by the MIMIC research. Barriers are described in short sentences under the seven MIMIC barrier headings.

Table 4. Main barriers identified by the MIMIC research

Typology of barriers	**Main barriers**	**Cities**	**Users & Focus Groups**	**Key Actors**
Logistical and operational	Poor/lack of time synchronisation between services.	+	+	+
	Poor/lack of a common and coherent information system.	+		+
	Poor/lack of integrated fares and through ticketing.	+	+	
	Pedestrian access to interchanges often involves difficult access over busy roads or through unpleasant (often unsafe) areas.	+	+	+
	Cyclists often face significant problems when accessing interchanges by cycle and handling a cycle in interchanges.	++	+	+
	Secure and covered cycle parking is often missing.	++	+	+
	Public transport services feeding the interchange are often very poor.	++	+	+

	Poor conditions of public transport vehicles.	+	+	+
	Problems of dropping off and picking up passengers are common, with no provision in many cases.	+	+	+
	In park-and-ride interchanges there are often long and poorly maintained distances to walk.	+	+	
	Lack of parking areas.	++	+	+
Psychological	Fear of crime.	+++	+	+
	General safety.	+++	+	+
Institutional and organisational	Private and deregulated transport modes can see each other as rivals, leading to competition on passengers and double services.	+		+
	A large number of key players and bodies responsible for different areas and/or modes leads to poorly integrated interchange management.	+++	+	+
	A large number of key players and bodies makes the planning process of interchanges more complex, protracted and costly.	+		+
Physical design	Lack of ticket machines.	+	+	
	Toilets not properly maintained.	+	+	
	Poor cleanliness.	+	+	
	Waiting areas uncomfortable or unclean.	+	+	+
	Queuing for tickets.	+	+	
	Steps and staircases.	+	+	
	Lack of services for people working at the interchange.	+		+
	Needs of mobility-impaired and wheelchair users are often not well thought out.	+++	+	+
	Many of the most important linkages in interchanges have very long routes.	+	+	
Local planning and land use	Interchanges without people or facilities in the immediate surrounding area are perceived as a barrier to local use.	+	+	
	Lack of consultation.	+	+	+
Economic and social	While travellers ask for shops and facilities inside interchanges, interchanges with short waiting times often find it harder to attract shops and business since traders feel people will not be shopping while they wait (or only be there for a short period).	+	+	
	Cost of public transport services.	+	+	
Information	Real-time information lacking or available only for some transport modes.	++	+	+
	Lack of information on routes and services.	++	+	+
	Staff are often not found to be on hand to help passengers with information and personal security and safety.	++	+	
	Lack of staff knowing to deal with people with hearing, speech or learning difficulties.	+	+	+
	Lack of acoustic signals or brochures in Braille.	++	+	+
	Signing is often lacking or of poor quality. It is often not usable by several groups.	+	+	+