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REAL TIME PASSENGER INFORMATION SYSTEMS AND QUALITY OF BUS SERVICES

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One of the main problems in urban areas is the steady growth in car ownership and traffic levels. Therefore, the challenge of sustainability is focused on a shift of the demand for mobility from cars to collective means of transport. For this end, buses are a key element of the public transport systems. In this respect Real Time Passenger Information (RTPI) systems help citizens change their travel behaviour towards more sustainable transport modes. This paper provides an assessment methodology which evaluates how RTPI systems improve the quality of bus services in two European cities, Madrid and Bremerhaven. In the case of Madrid, bus punctuality has increased by 3%. Regarding the travellers perception, Madrid raised its quality of service by 6% while Bremerhaven increased by 13%. On the other hand, the users´ perception of Public Transport (PT) image increased by 14%.

Keywords: Real Time Information, bus reliability, perceived quality of service

1. Introduction

Nowadays, negative externalities of mobility play a key role in transport policy. Current trends in transport indicate that the system is moving away from sustainability and the major changes are necessary to make the transport system more compatible with environmental sustainability (Banister et al., 2000). Therefore, there is a need of new tools to achieve sustainable mobility in an efficient way.

The shape of the city and its transportation network set the mobility guidelines for a region (Monzon & de la Hoz, 2009). As a result of decentralization of the activities within the cities, one of the main problems in the urban areas is the steady growth in car ownership and traffic levels (Monzón et al., 2007). This situation affects the everyday life of European citizens, while people need to move more rapidly between different places. The challenge of sustainability is facing calls for a shift of the demand for mobility from cars to collective means of transport. Hence, public transport performance has become a key issue, above all in urban areas. Particularly, bus systems are recognised as essential component of efficient urban transport, providing a flexible and sustainable mode of transport (Hounsell et al., 2009).

Taking these circumstances into consideration, it is vital to increase attractiveness of bus systems for all groups of stakeholders. The Intelligent Transport Systems (ITS) offer substantial potential for improving bus operations in urban areas, (Hounsell et al., 2009). In the last years, the use of ITS in public transport has been widely extended. It includes systems which are installed in public transport vehicles as well as at terminals, stops and interchanges. An important part of these systems for public transport is to provide real time information to travellers with updated multimodal information about routes, departure times, possible disturbances and connecting services.

From passengers' point of view, these measures are very useful for reducing the uncertainty of waiting time, which is very negatively weighted by PT users, and also for allowing an accessibility to all kind of information (fare, timetable, route, travel time, connections, etc.) for planning their journey, (Daskalakis & Stathopoulos, 2008). From the operator's standpoint, these new technologies are very important for managing bus schedules, routes, incidents…, thus improving the reliability and punctuality of the bus services.

This research study is based on the results of the European project "European Bus System of the Future", (EBSF) from the Seventh Framework Programme. The aim of this project is to develop a high quality bus system which combines, in an integrated way, innovations regarding vehicles, infrastructure and operation domains in order to create synergies, so that the value of the overall solution might be much higher than the simple addition of the value of each part. This project has tested some innovations in 7 European cities.

This paper tries to evaluate the impacts of new technologies on bus services performance and how Real Time Passenger Information (RTPI) systems could improve the perceived quality of services from the user´s point of view. The methodology will be applied in two European cities, Madrid and Bremerhaven.

2. *Real Time Passenger Information* Systems Applied to Bus Service Performance

Many global (Bristow et al., 1997) and domestic (Tyrinopoulos & Antoniou, 2008) studies highlight the importance of ITS applications for Public Transport (PT) attractiveness and their contribution towards improving the quality of services. There exist several ITS applied to PT, depending on the desired purpose, e.g. Automatic Vehicle Location (AVL), Real Time Passenger Information (RTPI) both at bus stops and on board, Urban Traffic Control (UTC) and so on. From the passengers´ point of view, provision of information is definitely the most important service ITS can offer (Politis et al., 2010).

It is widely accepted that RTPI offers significant benefits to PT users, present and potential, by providing a wide spectrum of information. In this respect RTPI systems improve PT services and help trip makers change their travel behaviour towards more sustainable transport modes, i.e., the reduction of car use contributing to road decongestion and, in general, to a more efficient transportation system. Therefore, the RTPI systems have been mainly developed to ease the use of PT through both perceived and actual reductions in passenger waiting time and increase passengers’ satisfaction. Access to this information before the trip can assist in decreasing the actual waiting time, when information is available to the passenger on route; it can help to reduce the perceived waiting time (Daskalakis & Stathopoulos, 2008).

Other likely benefits of the RTPI systems are as follows: increased willingness to pay; more efficient travelling through better use of waiting time; positive psychological effects (reduced uncertainty, increased feeling of personal security, creation of a general sense of trust in the PT system, increased easiness of use); better overall image of the system; and greater passenger satisfaction. Several studies have dealt with these issues coming to similar conclusions that RTPI systems offer several benefits to PT users and that the majority of users are quite satisfied with them (Lappin, 2002). Researches in this field have examined the potential effect of the introduction of RTPI systems on the perceived quality of service and bus services performance. Politis et al. (2010) evaluated a bus passenger information system from the users’ point of view in the city of Thessaloniki, Greece. The analysis performed on the data collected from the survey of both regular and circumstantial PT users in the city showed that the existing RTPI system is generally evaluated positively. Satisfaction levels were quite high, over 80% for both – the content and the reliability of the information given (Politis et al., 2010). But although extensive studies have been conducted on travel behaviour changes as a result of Information and Communications Technology (ICT), in general, studies of the nature in the case of real-time transit information systems are relatively few (Tang & Thakuriah, 2012).

This study aims to show the results of the applications of innovative RTPI systems in two European cities. The analysis is focused on the user’s perception and performance of advanced transport systems. The two cases highlight the importance of ITS tools to enhance the link among travellers, operators and regulators.

3. Case Studies: Madrid and Bremerhaven

As it has been mentioned before, the two case studies selected for evaluating the impacts of innovative RTPI systems are Madrid and Bremerhaven

3.1. Madrid

The Madrid case study is related to the metropolitan buses lines between the Majadahonda municipality and Madrid City, within Madrid Region. The demand of bus services in the corridor, in a labour day, is 30,000 passengers (more than 50% of the total users for the Majadahonda network).

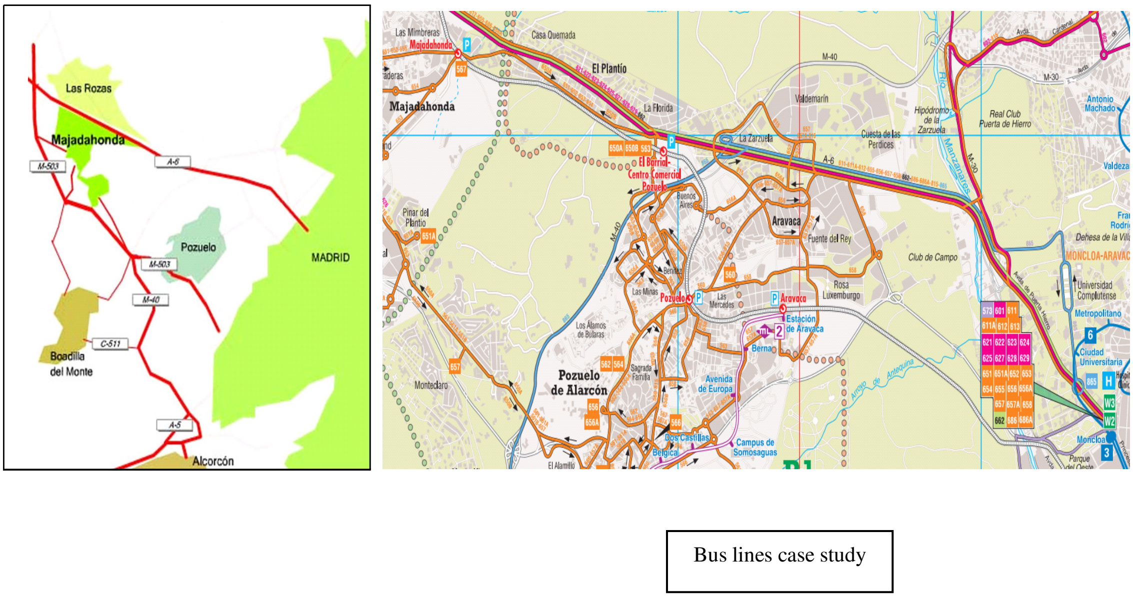

Figure 1. Majadahonda location and bus lines case study

Majadahonda is a town located in Madrid west, 18 km away from the centre of the capital. The municipality has an extension of 38.5 km^2 and it has 70,000 inhabitants. The urban structure is summarized in a compact and small centre – the traditional city centre –, to which are adhered many developments of single-family and multi-family residences of low density that extend across a large part of the municipality. There are only enclaves in which are tertiary activities concentrated, commercial and large equipments.

The public transport network in Majadahonda is composed of 18 intercity bus lines, 2 urban lines and suburban rail station. The main intercity bus offer is channelled to Madrid, mean the corridor A-6, reaching to the Moncloa interchange, in the capital.

In order to improve the quality of public transport services, encourage its use and provide the best mobility alternative has been needed to develop and test architecture for a highly modular AVMS system. Such an integrator system in Madrid is called CITRAM *(CRTM Integrated PT Management Centre).*

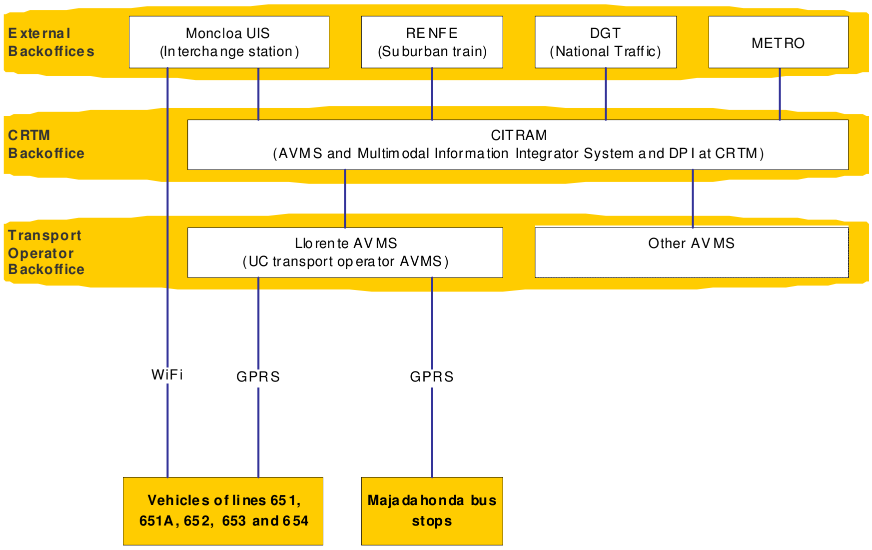

Figure 2. Madrid Use Case ITS system architecture

An advanced AVMS system has been implemented in 40 buses in 6 bus lines (651, 651A, 652, 653, 654 and 655) connecting Majadahonda and Moncloa interchange station, from September 2011 to February 2012. These buses have been equipped with such AVMS systems, including screens on board and audio information system. Four time information displays (with audio system) on bus stops in Majadahonda, plus one more with a Bluetooth device to download the information on next bus arrivals have been implemented. One more screen has been installed in Moncloa interchange to give next departures and breakdowns or delays.

In addition a specific webpage has been developed to provide real time information to the users. A SMS system has been also deployed to get information about the next bus arrivals and incidents/ breakdowns on the whole transport network.

3.2. Bremerhaven

Bremerhaven is a city at the Weser delta at the German North Sea cost. It has about 114,000 inhabitants and is an exclave of the city state of Bremen. Bremerhaven has a thin, long geography (about 15 km long and 8 km wide, see Figure 3). There is a small city centre and the further inland fades out into less populated residential areas followed by rural areas for agriculture.

Public transportation consists only of buses, a fleet of 74 busses along 17 lines with a total of 253 stations. In total the public transportation system serves 14.5 million passengers a year of which about two third are regular users (monthly tickets) and one fourth are students of the University and schools.

The bus line 502 was selected as test field to encourage linkages between transfer points and surrounding areas and to extend the level of information to other means of transport and information sources. Line 502 runs through the whole city from north to south and covering about 65% of the entire city population.

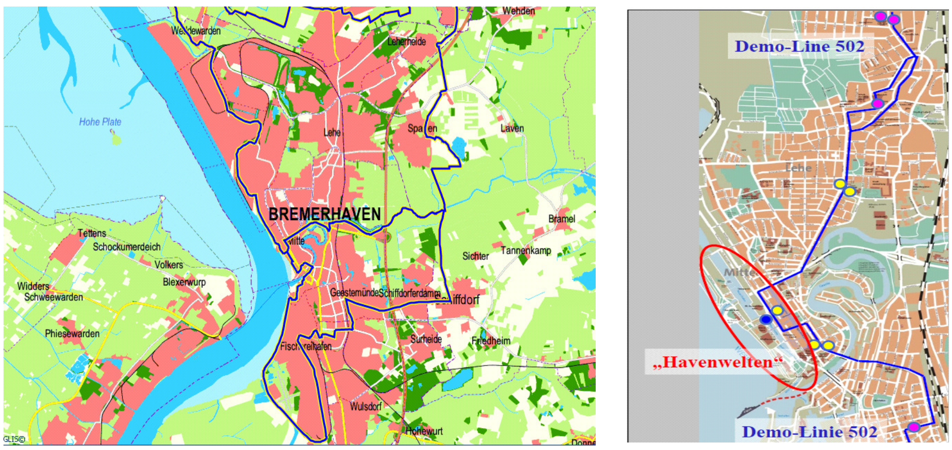

Figure 3. Map of Bremerhaven and surroundings

One vehicle of the type "EvoBus demonstrator" was equipped with a Driver Terminal and On-Board AVMS computer with integrated IP-Gateway functionality as well as announcement systems and TFT passenger information screens. The demo bus communicates with the central application via UMTS/GPRS, WLAN or LAN. All other busses serving line 502 were retrofitted with equal equipment. This system provided passengers with travel information during their trip.

4. The Impacts of *ITS* Measures on Bus Performance

The main objective of this study is to appraise the impacts of new technologies on buses operation. In order to achieve this purpose, an evaluation methodology has been developed built on a previous research study about the evaluation of economic, social and environmental effects of urban transport projects (Cascajo, 2004). The evaluation methodology aims to indicate to what extent the implemented measures in the cases studies improve the following aspects of the bus systems:

- Customer satisfaction
- Technical reliability
- Cost-effectiveness
- Externalities (environmental and social benefits).

For this end, four evaluation categories have been defined, which are divided in 8 areas of investigation. The relationship between objectives and categories are shown in Figure 4:

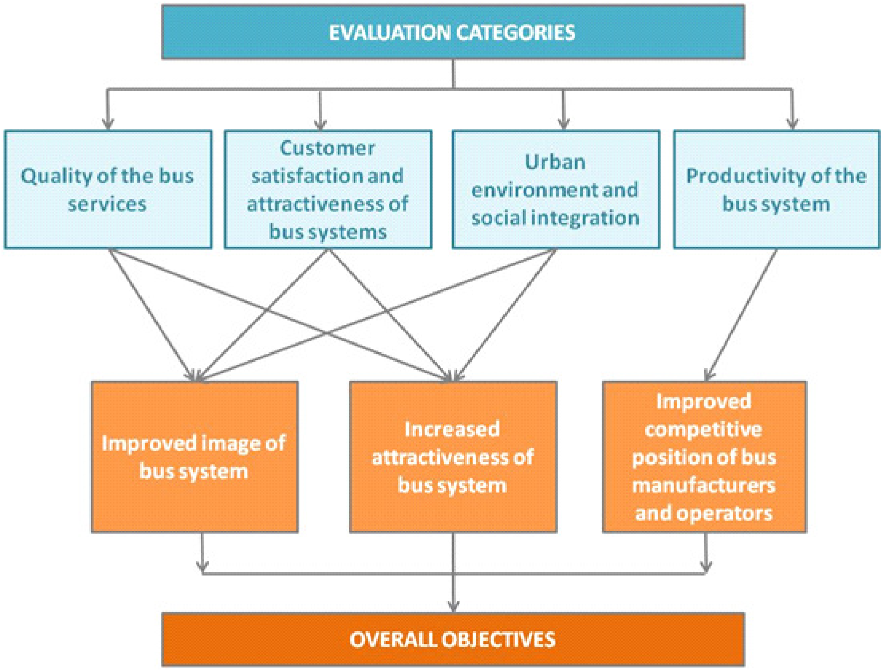

Figure 4. Direct and indirect relationship between the evaluation categories and the overall objectives

For each evaluation category and each area of investigation, a set of Key Performance Indicators (KPIs) has been selected (EBSF, 2012).

To carry out the assessment of the performance two different scenarios are defined: "*ex-ante*" scenario (before the starting of the testing phase of each use case without any measure implemented) and "*during*" the testing phase (once the measures have been implemented). The analysis of the effects produced by a transport investment is based on the comparison between both scenarios. For certain KPIs, such as accessibility to real-time information or data on the number of stops equipped with real-time information, data collection was done before and after implementation. For the evaluation of the effectiveness and the public perception of the innovation, passengers had the opportunity to evaluate various categories with questionnaires during the two phases of inquiry: "Before" and "During". This procedure allows assessing the effect the innovation had on the performance of the existing bus service.

Table 1. Key Performance Indicators for the overall assessment

Evaluation categories	Areas of investigation	KPIs	Units	Mad	Brem
Quality of the bus services	Modal integration and additional/ flexible services	Level of modal integration services	%	X	
	Service performance	Bus punctuality	%	X	
Customer satisfaction and attractiveness of bus systems	Comfort, cleanness and quality feeling/ perception	Perceived quality of services		X	X
		Customer perception of image			X
	Information to passengers, relational and behavioural issues	Accessibility of real time passenger information	%	X	X
		Availability of information for connecting with other PT services		X	X

The continuation of Table 1

Evaluation categories	Areas of investigation	KPIs	Units	Mad	Brem
Urban environment and social integration	Environmental issues	Energy consumption	Litres/ pass-km		X
	Urban development and quality of life	Mobility of inhabitants	Trips/ inhabitants	X	
Productivity of the system	Economic and operation issues	Operating costs	Euro/km		X
		Passenger demand	Passenger/ month	X	X
	Pricing and commercial policies	Service efficiency	%	X	X

5. Site Specific Evaluation

The site specific evaluation is a part of the overall assessment of the performance of the different measures implemented in the two cities: Madrid and Bremerhaven. This evaluation considers local conditions or particularities of each city.

5.1. Madrid

The evaluation has been performed considering a set of 9 KPIs which allowed a comparison between the "before" and "during" test phases. The period of data collection was February 2011 for "ex-ante" data and February 2012 for "during" data. Information coming from the questionnaires, submitted to both Operator and Passengers, was collected between February and April 2011 ("ex-ante" data) and February 2012 ("during" data). The number of respondents on board was 2,122 in "ex-ante phase and 2,234 in "during" phase, of which most of the passengers surveyed were female, 69% against 32% male. The results obtained are shown in Table 2.

Table 2. Madrid, KPIs values

Name KPI	Units/ Source	Value "ex-ante"	Value "during"	Variation (%)
Level of modal integration services	%	74.5	72.7	-2
Bus punctuality	%	93.0	96.0	3
Perceived quality of service	Passengers questionnaire	6.9	7.3	6
Accessibility of Real Time Passenger Information	%	0	23.0	100
Availability of information for connecting with other PT services	Operators questionnaire	5.90	7.10	20
Mobility of inhabitants	trips/ inhabitant	3.6	3.8	6
Passenger demand	Passengers/month	507,000	457,000	-10
Service efficiency	%	47.5	47.0	-1

Level of modal integration services has decreased by 2% between scenarios. Although it isn't a very significant variation, one reason for this has been the decline in the monthly tickets sales, as general trend in the whole public transport system in the Region, as consequence of the decrease in demand due to the crisis and high rates of unemployment. This is proved in the KPI of passenger demand, which shows a decrease in the UC lines by 10%. However, due to the availability of Real Time Passenger Information systems, a large number of aspects have improved in the bus operation. Bus punctuality has increased by 3% with very high values of services in the line in punctuality, 93% and 96% respectively. Perceived quality of service by passengers has risen by 6% respect to ex-ante situation. The results obtained from the surveys to the operator show a 20% increase in the availability of information for connecting with other public transport services and mobility of inhabitants, in terms of number of trips per inhabitant, has increased by 6%. The increase in the number of trips per inhabitant has been 3.61 to 3.82 trips.

Concerning the perceived quality of service, passengers give more value to punctuality, waiting time at bus stops and easiness of payment than to the possibility of getting information while travelling. The results can be seen on Figure 5:

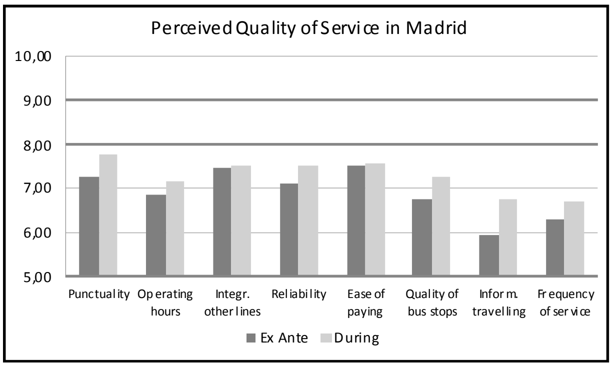

Figure 5. KPIs perceived quality of service in Madrid

5.2. Bremerhaven

For the evaluation of Bremerhaven case study, a set of 8 KPIs has been defined. The period set for data collection was from July to September 2010 ("ex-ante") and same months 2011 ("during"). Information coming from the questionnaires, submitted to both operator and passengers, was collected within this period. For the passenger survey 440 persons participated in the "ex ante" phase and 400 in the "during" phase. About 40% participants were male and 60% female. The results obtained are shown in Table 3.

Table 3. Bremerhaven, KPIs values

Name KPI	Units/ Source	Value "ex-ante"	Value "during"	Variation (%)
Perceived quality of service	Passengers questionnaire	7.9	9.0	13
Customer perception of image	Passengers questionnaire	7.5	8.7	14
Accessibility of real time passenger information	%	47	52	11
Availability of information for connecting to other PT services	Passengers questionnaire	8.0	8.3	2
Energy consumption	Litres / pass-km	0.0933	0.0958	-3
Operating costs	€/km	4.91	4.91	0
Passenger demand	Pass./month	248,692	239,715	-4
Service efficiency	%	79	79	0

In line with the general drop of the passenger demand between 2010 and 2011 on all lines in Bremerhaven, the passenger demand has also decreased by 4% in line 502. On the other hand, a small increase in fuel consumption (3%) has obtained. It can primarily be attributed to higher use of air conditioning systems and electronic equipment (according to the operator). Nevertheless, several aspects have improved thanks to the availability of Real Time Information Systems. Accessibility of real time information has risen by 11% due to the installation of info-terminals in some stops as well as the availability of information for connecting to other PT services (2%). Concerning the passenger evaluation, it has significantly increased in all relevant aspects in the "during" phase with respect to the "ex ante" phase. The perceived quality of service has increased by 13% and the customer perception of image has risen by 14%.

Regarding the perceived quality of service, the ease of paying and the available information while travelling improve the passenger's perception of the service. On the other hand, the image of the bus system was improved through all aspects covered in the passenger survey. Particularly, the innovation was valued with 89% of possible score. This result indicates that the innovations were recognized and appreciated as an improvement of quality of service.

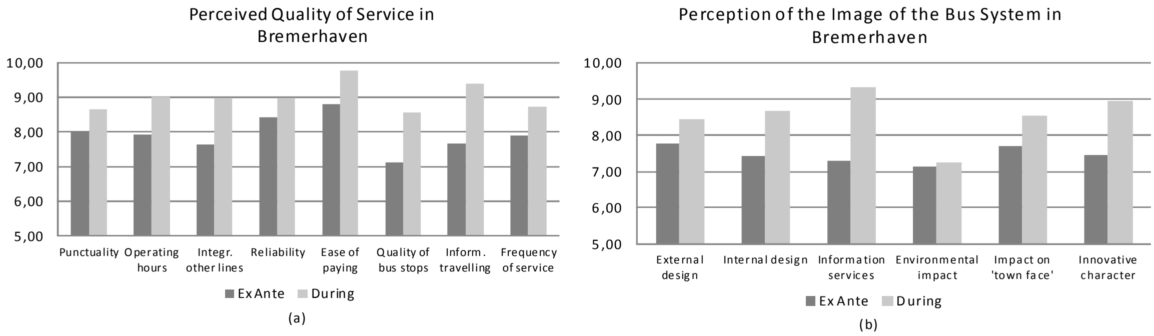

Figure 6. (a) KPI perceived quality of services and (b) KPI perception of the image of the bus system in Bremerhaven

6. Cross-Site Evaluation

A cross-site evaluation has been carried out in order to identify the most relevant factors in both cities and to see to what extent they contribute to the development of an innovative high quality bus system. For this evaluation, a Multicriteria Analysis (MCA) approach has been applied. Within this methodology the benefits are calculated by the variation between the "ex-ante" scenario and the "during" scenario, for each KPI category. This variation has been considered relative, in order to compare the case studies more precisely. Once we have obtained the values of all the indicators, it has converted the range of variation between scenarios of each indicator to a homogeneous one, in such manner that social utility of the measures implemented in each city is obtained.

The measures developed both in Madrid and Bremerhaven are based on the Real Time Passenger Information systems implementation. Madrid presents higher social utility 0.41 against 0.25 in Bremerhaven. In both cases, it is observed that the ITS measures implemented have an impact mainly in the category "*Customer satisfaction and attractiveness of bus systems*".

Regarding "*comfort, cleanness and quality feeling*", passengers in Bremerhaven have perceived an important increase in both, quality of service and image of the bus system. However, the improvement of this area of investigation in Madrid is due to the perception that passengers have experimented in punctuality, reliability, information while travelling and frequency.

Figure 7 shows the comparative results between the ex-ante and during scenarios for both cities. The user perception about all indicators improved with the implementation of RTPI systems. It is noticeable that some KPIs increase their score even when their real values remain the same. That means that the smartest the bus the most favourable perception of the users.

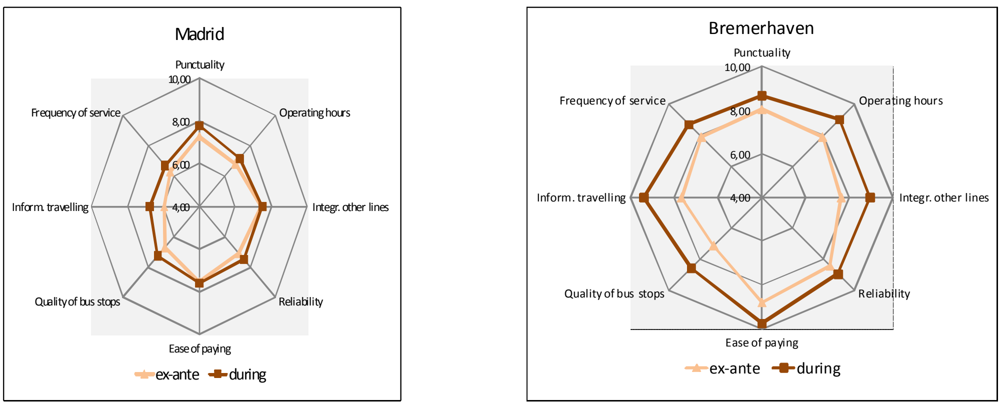

Figure 7. Cross-site evaluation of KPIs perceived quality of services

On the other hand, both cities present an impact in the area "*information to passengers, relational and behavioural issues*". Madrid has improved the availability of information through different means (web, SMS, displays, Bluetooth, etc.); it is a multimodal information, providing the state of others modes of transport. In Bremerhaven, the equipment introduced in the retrofitted buses and the bus stops have caused an increase in the quantity and quality of the real time information for passengers.

7. Conclusions and Policy Recommendation

The research results indicate the importance of providing bus services of high quality. For this end the use of RTPI systems appear to be a key factor. In both cases of study the surveyed passengers show a higher perceived quality of service when stops and buses are equipped with information devices.

In the case of Madrid, punctuality and reliability are two operational variables that have been improved thanks to the use of RTPI systems. Then users are more willing to use buses than before. The new information provided for connecting bus with other PT services clearly improve the seamless mobility in the corridor. These results can produce a transfer of trips from car to buses in the medium-long term.

The new prototype bus of Bremerhaven presents a high level of performance, which has been very positively perceived by their users. It is remarkable that the perceived quality of service and the image has increased by more than 13%. Again this improvement of the level of service will attract passengers out of cars.

The methodology developed for assessing the customer satisfaction has proved efficient to measure changes in the quality of bus services. Therefore, the proposed multi-criteria analysis could be valid for testing the impacts of new technologies in PT networks.

The overall results indicate the goodness of having a high level bus system. Most of the deterrent factors such as waiting time at stops, delays, uncertainty, payment time and lack of information for connecting with other services are clearly reduced. Hence, the image of PT became more competitive in relation with other modes, particularly cars. It produces environmental benefits because level of occupancy of buses is raised and the number of car trips reduced. In conclusion, it is very advisable to invest in a better bus fleet equipped with RTPI systems both on-board and at bus stops and terminals.

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