EVALUATION METHODOLOGY OF THE IMPACTS OF BUS RAPID TRANSIT CORRIDORS (BRT) IN LIVORNO NETWORK

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ABSTRACT

The objective of the European project TIPS&Info4BRT was to study, analyze and evaluate the impacts and benefits of BRT corridor realization (Bus with High Level of service-BHLS in Europe). The BHLS can be seen as flexible concept able to be introduced in different contexts (urban, sub-urban area, etc.) with different service schemes and realization levels. This document faces different aspects which have to be studied and evaluated in order to realize a BHLS corridor. The first part focuses on both the characteristics and the interventions on the neighbouring areas supporting the implementation of the Corridor. Whereas, in the second part, each step of the proposed methodology is described in order to evaluate the impacts on the private traffic and the benefits for the Public Transport. The proposed methodology is suitable to be adapted in any kind of city.

Keywords: BRT/BHLS, traffic light priority, assessment of traffic impacts

1. INTRODUCTION

TiPS&Info4BRT -"Traffic lights Priority System and Information work-flow for Bus Rapid Transit Corridors" project is a European project financed by fifth EraSME program of 7FP involving Italian and German partners promoting the cooperation within SME and Research Institutes at transnational level. The project will involve 5 partners (3 SME and 2 Research Organizations) geographically distributed in Tuscany (Italy) and North Rhein Westphalia (Germany). Study cities involved into the project are Livorno and Aachen, in particular Italian consortium worked for the design, testing and validation of prioritization measures for the corridor in Livorno (1) and the German consortium worked for the design, testing and evaluation of road work event management modules (2).

The project started on December 2009 and lasts 18 months.

TiPS&Info4BRT project focuses on the evaluation of the impacts of the introduction of BHLS corridors in medium size cities by using simulation tool. In order to reach this objective, the overall assessment process deals with two different phases and supporting measures involved in BHLS implementation:

1. evaluation of impacts and validation for priority management measures at traffic lights to be activated on a BHLS corridor proposed for Livorno network. In this pilot site the study of the performances that public transport can reach adopting a good mix of physical and technological priority measures has been demonstrated;
2. evaluation and validation of the benefits of the use of a sw tool for the management and the distribution of road work event information. This tool will be integrated with simulation environment in order to assess the impacts of traffic flow redirecting measures.

To reach the above objectives, the activities carried out by the project are the following:

- Analysis of the state of art of current trend for the implementation and operation of BHLS corridor (adopted technologies, priority measures, etc.);
- Contribution to increase the awareness of the methodological steps required for the planning of BHLS corridor, evaluation of benefits and impacts, etc. through the local dissemination activities and the organization of workshop/seminars at regional level;
- Elaborate guidelines for the planning study of BHLS and the feasibility design of the whole transport system as a package (supporting measures, ITS systems, etc.);
- Evaluation of both the impacts on the private traffic flow and benefits for PT service through the use of simulation tools and results assessments;
- Synergies with running initiatives at EU level (COST).

2. BHLS CONCEPTS

The BHLS name was firstly launched in France and then largely adopted due to the relevant role carried out by French organizations (i.e. CERTU) and experiences in pushing up the promotion of such public transport systems and in consolidating the awareness of its role, benefits and potentials.

The above mentioned increasing interest fostered:

- the discussion on the role and the potentials of such kind of transport scheme in different scale of EU cities/urban/metropolitan area;
- the benchmarking and cross-related evaluation of the various experiences grew up in EU, sometimes born without a strong coordination action of National Authority (except France and few others countries);
- the funding of EU level initiatives able to analyze the trend under progress in the different EU countries and to enhance the national initiatives by promoting the identification of best practices, recommendations and supporting measures for the adoption of BHLS (i.e. COST action TU603: "Buses with a High Level of Service (BHLS) - Fundamental characteristics and recommendations for decision-making and research", involving 14 EU countries);
- the involvement and contribution of EU stakeholders and representatives to the think-thanks which are taking place at world level (i.e.: ITDP Institute for Transportation and Development Policy BRT World Congress, Guangzhou, 27 September – 1st October 2010, 90th TRB Transportation Research Board Annual Meeting, 23-27 January 2011, Washington, etc.). These events highlight that an EU approach to BHLS is emerging: it takes the fundamental from the consolidated experiences operated in North America even if it quite far from these and from the large mass transport system adopted in Asia and other emerging countries where BHLS role in wide conurbation is comparable to the role of train transport offer in our countries.

Some differences are possible to be identified between the European experiences and world context will. However this paper focuses on the European level.

BHLS can be seen as a flexible concept able to be introduced in different context (size of the urban area, operated transport services, service scheme, infrastructure implementation, etc.). The differences in the reference context to lead the identification of different objectives for BHLS implementations: this involve various options for the realization of the corridors and the operation of service.

Generally speaking, some common issues can be identified for BHLS:

- higher reliability compared to bus transport services;
- high performances in terms of quality and comfort (bus stops, platform, vehicles, etc.);
- strong appeal of the service and increase of its marketing potential (name, logo, colour of vehicles and stops, etc.).

Analyzing the European experience it is possible to point out the difference service scheme and dimensions, investment costs, etc, on the basis of the reference context,. The difference of BHLS approach between metropolitan areas and medium size cities will be detailed including the different role BHLS can act: feeder of tramway services in large metropolitan areas, main urban axis for mass transit in large/medium size cities integrated with other public and mobility public transport services: bus feeder services, bike sharing, etc.);

In order to reach the above mentioned objectives, it is required to act at three different level:

- Infrastructures: dedicated right of way, bus lanes and other traffic engineering measures that protect the bus services from delays in traffic;
- Priority for buses at traffic signals (at crossing points, etc.) which can be divided into two typologies (also mixed system can be adopted);
  - Physical ones: lay-byes and passing lanes at bus-stops, so that buses do not delay each other, etc.;
  - Prioritizations at cross points;
- ITS systems to assist operations management and problem-solving (fleet monitoring, electronic payment system, etc).

The presentation will give an outlook of EU running implementation: the classification will be carried out in terms of performances, adopted ITS solutions, measures for priority, etc.

3. BHLS CORRIDOR COMPONENTS

The objective of a BHLS corridor realization is to provide a service with an high level of service, preserving the right balance between interventions on the road infrastructures and available resources.

Concerning each one of the possible selection for the different elements interested by the BHLS corridor have been pointed out both the vantages and the disadvantages.

The main characteristic of the BHLS service is the dedicated corridor in order to guarantee the high system performances.

The corridor level protection is to evaluate on the basis of the existing road infrastructures and on the basis of the users behaviour. A consequence of the BHLS corridor realization is a new organization of the public areas; i.e. the realization of new cycle lanes, pedestrian areas, etc.

So, on the basis of the previous considerations, it is important to increase the PT services use, in order to obtain the traffic flow reduction in line with the capacity road decrease, as consequence of the required private traffic number lanes reduction .

Furthermore it is important to evaluate the exclusivity level of the corridor, the location of the corridor in respect of the axis road, etc.

3.1. Road Infrastructure characteristics

The road infrastructures could present different conformation on the basis of several characteristics: i.e. the exclusivity level of the corridor, the level of protection in relation of the other vehicular class traffic flow, etc.

The BHLS corridor could be realize on a new or existing road infrastructure and this is one more aspect to take in consideration.

Furthermore it is possible to use different level protection in the same corridor, on the basis of the road (and others) characteristics.

3.2. BHLS Corridor Location

The BHLS corridor realization entails several interventions which have to be carried out on the adjacent areas. The interventions could be present different characteristics on the basis of BHLS corridor location (in the road centre or at the road sides).

3.3. Bus Stop

One more element which affects the level of service and safety for the users is the location of the bus-stops along the BHLS corridor. The main characteristics to be consider are:

- Distance between two next bus-stops;
- Placement;
- Platform and bus-stop structure characteristics;

3.4. ITS System

The ITS systems help and are indispensable to achieve an high performance level of the BHLS service. The main and important system which have to be used in order to guarantee a reliable public transport service for the users and a manageable system by the operators point of view have been included in the following list:

- SAE/AVM System;
- UTC system;
- Traffic Light Priority system;
- Automatic Fare system;
- Security – Video surveillance system,

3.5. Bus Line Logo (brand the service)

Usually a BHLS service is developed on the earth surface, so it required to be easily detected by the users with an exclusive brand of the bus line.

It is very important to associate a good and exclusive image to the service, in order to give the idea of reliability of the services and in order to permit to the users to detect the BHLS line on the urban area.

4. METHODOLOGY FOR THE PLANNING OF THE CORRIDOR

During the project a methodology to be adopted for the planning study of the corridor was defined. The methodology can be generalized accordingly to the study of corridors in other context/cities. The main steps of the defined have been the following ones:

- Creation of the model:
  - Traffic data collection (or alternately the analysis of available data and its updating to generate the O/D matrix);
  - Generation of the road network associating the road and other characteristics to each network element (lanes number, traffic light periods, etc.);
- Calibration of the network model concerning the current state;
- Identification of the simulation scenarios;
- Evaluation of the private traffic impacts (means delay time at the junctions approach, means queue length at the junctions approach);
- Evaluation of the PT benefits in terms of travel time and delay time (comparison of the performance between a conventional bus line and the BHLS corridor). The comparison has been made under two scenarios:
  - Dedicated lanes;
  - Mixed traffic conditions.

The simulation results have been assessed from the point of view of traffic impacts and benefits for Public transport service (comparing, among the other factors, the travel time and the delay time between the current BUS Line 1 and the designed BHLS).

4.1. Traffic Data Collection

The O/D matrix of the City object of the study can be obtained using the data collected through the last available Census. Afterwards it could be updated using the gathered data using, i.e., data traffic measures campaigns.

4.2. Road Network

The generation of the road Network requires several kind of data: road geometrics characteristics, traffic light periods, lanes number, etc.

Each one of these fundamental information can be find through different way, i.e., it is possible to find the lanes width and similar information using satellite photos or DWG files (and similar) of the City in object.

The traffic light period could be gathered through hand measures campaign or with the cooperation of the society in charge of traffic lights system management.

4.3. Network Model Calibration

In order to carry out the calibration process it has been made a comparison between the values collected through the running simulation and the values obtained using the forms defined and included in the HCM 2000 manual. In this way it has been possible to verify the correlation between the "simulated" values and the "real" values in order to show their similarity.

The considered parameters which have been considered are the delay time and the mean queue length.

The HCM 2000 defines the methodologies both in case of a un-signalized junctions and of a signalized junctions.

The calibration will be considered positive if the linear correlation factor and the Root Mean Square Error (RMSE) provide satisfactory results.

4.4. Identification of the simulation scenarios

After that the calibration process provides the expected results it is possible to proceed with the generation of the simulation scenarios. There are different fields where it is possible to intervene in order to obtain different situation and traffic flow condition, i.e. it is possible to change the road geometrics characteristics, to hypothesize different BHLS corridor, to change traffic light characteristic (cycle length, periods, etc.), and so on.

4.5. Evaluation of the private traffic impacts

The running simulation of the generated network model of the City provides indications concerning the impacts on the private traffic flow caused by BHLS corridor realization. In this way it is possible to evaluate the better solution between the different simulation scenarios identified. Also in this case it have to been considered the two parameters just seen at point 2.1.3. : delay time and mean queue length at the junctions approach. They have to be compared with the limit values defined in the HCM 2000 manual in order to have at least an acceptable Level of Service.

4.6. Evaluation of the PT benefits

The evaluation of the PT benefits can be carried out through the comparison of the travel and delay time of different public transport service (conventional buses system and BHLS system) along a shared part of the bus line. It is possible to deep the study up to find the commercial speed of both the kind of service (in this case it is required to hypothesized more parameters of the services, i.e. "Stop&Go" situation along the bus journey, time stop at the bus station, etc.).

5. THE CASE STUDY OF LIVORNO CITY

In this section the application of the above mentioned methodology to Livorno context has been described. In particular the results of the simulation work point out the relevance to join the physical measures (like dedicated corridor) and the control commands (like the demand coordinated responsive traffic light plan).

Currently several corridors are supposed to be restructured as BHLS service. One of these started from railways station to the business district; this has been the object of simulation study carried out within Tips&Info4BRT project. The corridor is introduced on one of the most important axis of Livorno public transport network in terms of passengers and headways of currently operated lines. The routing of the corridor is currently operated partially by Line 1 and partially by Line 2.

5.1. Planned BHLS Corridor in Livorno

The main mobility axis in the City of Livorno are:

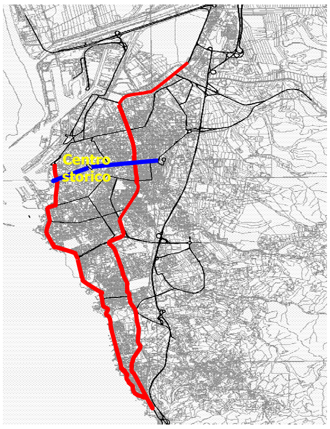

Figure 1 – Main Transport Axis of the City of Livorno

- East – West
- North – South

The Line 1 covers these two main axis, starting from Piazza Dante (Railway Station) to Miramare Ardenza.

The Line 1 service characteristics are:

- Frequency: two Buses every 15 minutes (7 minutes + 8 minutes);
- Buses Capacity: about 80 passengers;
- Path Length (From Piazza Dante to Miramare): about 7 Km.

The partial renewal of Line 1 as BHLS and the implementation of a prioritized corridor aim to increase the performances of public transport service on a main axis thus increasing the number of users and improving the mobility conditions, the overall accessibility to the city and the quality of life. The BHLS corridor is represented in the next figure.

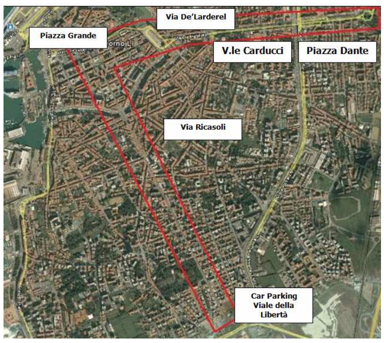

Figure 2 – Livorno City & BHLS Corridor (© 2010 Google Earth)

The BHLS Corridor is characterized by several important intersections placed along the Line which have been required a in-depth study and analysis.

5.2. Model calibration

The model calibration has been carried out using the HCM 2000 manual.

The manual present the methodologies how to calculate the values of the parameters to be compared with the values collected through the running simulation. In this way it has been possible to verify the correlation between the "real" values and the "simulated" values in order to show their similarity.

The first parameter which has been considered is the delay time.

The HCM 2000 defines the methodologies to calculate the delay time in the case of a un-signalized junction and of a signalized junction

In order to have more details it is possible to consult the HCM 2000 manual in the suitable section (section 16 for the signalized junction and section 17 for the un-signalized junction).

The correlation between the calculated values and the values collected with the running simulation is showed in the following graph:

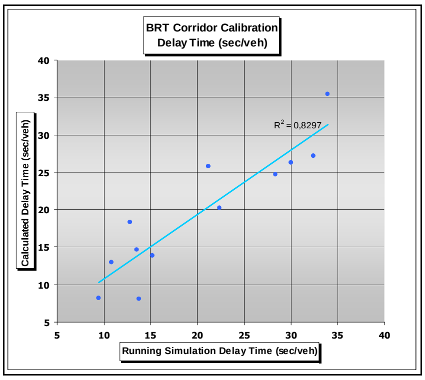

Figure 3 – Delay time Linear Correlation

As it is possible to see, the $R^2 = 0.83$. This means that there is a good linear correlation between the results above mentioned. Furthermore also the RMSE value has been calculated to verify the line inclination (a result equal to 0 means that the line inclination is 45°). The RMSE is calculated in function of the difference between the values of the first group and the values of the second group: RMSE = 3.60 sec/veh. This value confirms the good correlation and then the Network Model reliability.

After the delay time the queue length correlation is also considered. The methodologies used is based on two different formulas concerning the case of signalized junctions approach and the case of un-signalized

The correlation between the calculated values and the collected values through the running simulation is included in the following graph:

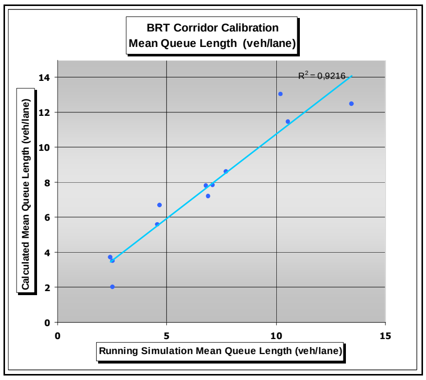

Figure 4 – Mean Queue Length Linear Correlation

The $R^2 = 0.92$. This means that there is a good linear correlation between the results above mentioned. Also in this case the RMSE value has been calculated to verify the line inclination (a result equal to 0 means that the line inclination is 45°). The RMSE = 1.30 veh/lane. This value confirms the good correlation and then the Network Model reliability.

On the basis of the collected results it is possible to conclude that the generated network model is an appropriate model of the current state.

5.2.1. Simulation Scenarios

The Future scenario has been defined including new reserved lanes building the BHLS Corridor. It is possible to point out the main change along the BHLS Line: the first one is the change of the route from Via De'Larderel to the parallel minor street of Viale Giosuè Carducci (direction: from West to East).

This is an important change for the viability and the general traffic flows, because it has required also an in-depth analysis of the traffic light time cycle length and its phases.

Furthermore the hypothesized BHLS presents the following characteristics:

- Frequency: 6'00'';
- Number of Buses: 7 vehicles operating the line (BHLS Corridor) at the same time 1 used as reserve.

The comparison between approach delay time concerning the Current State and the Future State has highlighted an important increase of the private traffic delay time. The reasons can be grouped as following:

- Viale Carducci: going on from Piazza Dante to Piazza della Repubblica there are several sections which present the same lanes number of the current state network, but one of these is reserved for the Public Transport, so the private traffic lane available get a lower capacity (this will bring more constraints for private traffic flow and higher delay time);
- The Bus line prioritization entails that during a cycle one or more phases miss their turn. So it is required that, after the prioritization end, the

traffic light controller (or the UTC system if it is present as in this case) defines the starting point of the new cycle or the strategy selected to divide the green time to the various phases. This event entails a disadvantage for the private traffic flow which must be considered in the total costs/benefits ratio together with the evaluation of the advantages for Public Transport.

In order to implement a suitable cycle time of the traffic light and the phases duration the Black Box optimization system has been used; this procedure has been developed by Engineering University of Florence, partner of the project (use for the most critical junction of the corridor).

Through the use of the available tools (simulation software, optimization procedure, etc.) it has been possible to hypothesized the necessary interventions on the road network of Livorno City (and each one of its components) so that the approach private traffic delay time at the junctions were acceptable and better than the critical limits defined in the HCM 2000 manual.

6. CONCLUSIONS

The Travel/Delay Time of the Current main Bus Line and the BHLS service has to be compared in order to evaluate the improvement of the performances of Public Transport service obtained with the BHLS corridor realization. Delay Time for Public Transport system has to be considered as "the delay time that the public vehicle accumulates compared to the optimal routing"

The main Bus Lines to analyze are the Line 1 and the Line 2. Their routing are different compared to the BHLS corridor, so the comparison between the relative Travel/Delay time is possible only in some part of the corridor (shared routing with the current lines)..

The Bus Line 1 routing starts from Central Railway Station (Piazza Dante) and arrives to "Ardenza Mare/Miramare" (and vice versa), so the routing trunk which overlaps the corridor starts from Piazza Dante and it ends in Piazza Grande.

The characteristics of the Bus Line 1 service are the following:

- Frequency of the service: 7'00'';
- The operating Buses are 8.

The Bus Line 2 trip starts from "Chioma" and arrives to the Central Railway station (Piazza Dante). In this case the routing trunk which overlaps the corridor is from "Viale della Libertà" to Piazza Grande (and vice versa).

The characteristics of the Bus Line 2 service are the following:

- Frequency of the service: 10'00'';
- The operating Buses are 6.

The BHLS Corridor entails Public Transport travel/delay time lower than the current Bus Service. As mentioned above the comparison has been made on the shared part of Line 1 and Line 2 with the hypothesized BHLS Corridor.

Table 1: BHLS – Bus Line 1 comparison

From Piazza Dante to Piazza Grande			
	Bus Line 1	BHLS	Difference
Travel Time	753	364	-389
Delay time	70.81	22.03	-48.78

Table 2: BHLS – Bus Line 1 comparison

From Piazza Grande to Piazza Dante			
	Bus Line 1	BHLS	Difference
Travel Time	674	400	-274
Delay time	57.90	24.99	-32.91

Table 3: BHLS – Bus Line 2 comparison

From Viale della Libertà to Piazza Grande			
	Bus Line 2	BHLS	Difference
Travel Time	451	427	-24
Delay time	21.88	15.28	-6.60

Table 4: BHLS – Bus Line 2 comparison

From Piazza Grande to Viale della Libertà			
	Bus Line 2	BHLS	Difference
Travel Time	474	379	-95
Delay time	26.44	14.59	-11.85

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The authors work at MemEx, an independent engineering consultancy supporting Public Entities (Transport Company, Municipalities, etc.) in purchasing (tendering), implementing and operating ITS systems. In particular their activities deal with the definition of functional specifications of ITS systems for PT and traffic regulation and in the management of tendering processes. They were involved also in the management of TIPS&Info4BRT project, where the simulation activity described in this paper has been carried out.