Available online at www.sciencedirect.com
ScienceDirect
Transportation Research Procedia 14 (2016) 2640 – 2648
Transportation Research Procedia
www.elsevier.com/locate/procedia
6th Transport Research Arena April 18-21, 2016

A European initiative for more efficient and attractive bus systems: the EBSF_2 project

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Abstract

In spite of genuine innovations in the field of bus manufacturing over the recent years, user acceptance of bus transport has not duly changed. Moreover, the economic situation today calls for further research development to make bus systems more attractive for passengers and, at the same time, more efficient and economical to operate. The European Bus System of the Future 2, coordinated by UITP, combines the efforts of 42 partners to tackle this challenge. The project is committed to complete the development and testing in real operational scenarios of a set of technological solutions to evaluate to which extent such innovations can contribute to improving the attractiveness and the efficiency of bus systems mostly in terms of operational costs and energy consumption. Demonstrations in real service in 12 cities address the following key areas for innovations: energy strategy and auxiliaries, green driver assistance systems, IT standards introduction in existing fleet, vehicle design (capacity, accessibility, and modularity), intelligent garage and predictive maintenance, interface between the bus and urban infrastructure. Key solutions that still require more steps for a wide acceptance in the market are also evaluated in the project through the use of prototypes and simulation tools. The paper presents the rationale of the project as well as its positioning and ambition with respect to the state-of-the-art scenario. It also describes the methodology developed to achieve the EBSF_2 mission and the scenarios and technological innovations addressed by the Gothenburg test site as an example of the approach implemented in all the demonstrations.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

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Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.421

Keywords: bus system; attractiveness; efficiency; demonstrations; EBSF_2

1. Introduction

The European Bus Systems of the Future 2 (EBSF_2) is an Innovation Action co-funded by the European Union within the Horizon 2020 Research and Innovation programme and coordinated by UITP – the International Association of Public Transport. The project (May 2015 – April 2018) capitalizes on the results of the previous EBSF project (September 2008 – April 2013) and, as the former, is aimed at developing a new generation of urban bus systems by means of new vehicle technologies and infrastructures in combination with operational best practices, and testing them in operating scenarios within several European bus networks. The distinctive factor of EBSF_2 is the consortium's ambition to raise the image of the bus through solutions for increased efficiency of the system, mainly in terms of energy consumption and operational costs, as required by today's economic situation.

The need for more cost-effective and energy efficient bus systems has led to the identification of a set of technological innovations and strategies with a strong potential to optimize mainly energy and thermal management of buses (in particular auxiliaries such as climate systems), green driver assistance systems, intelligent garage and maintenance processes, IT standard equipment and services. Moreover, to effectively address the need to move quickly from laboratory research to actual innovation of the bus fleets in operation in Europe, the technologies to be tested have been selected according to their technological maturity (and not only because of their potentiality) in order to ensure a short step for commercialisation after the end of the project. The use of simulators and prototypes has been conceived as a preliminary step for the validation of the innovations in real operational scenarios, performed within the project as well, or as a necessary task to prove the potential of more futuristic solutions currently implemented at early stage of development (e.g. modular bus).

1.1. Project rationale

The need for further research projects to reshape urban bus systems is due to current mobility problems: urban sprawl, re-location of activities to the suburbs and new mobility habits have resulted in chronic congestion throughout European cities, with the average of 29 minutes delay for one-hour journey driven in peak periods (TomTom International 2013). Car dependency, especially in terms of high motorization rates, space consumption and unsuitability to accommodate passenger flows in a sustainable way are at the root of the problem (Corazza et al., 2015). In contrast, public transport (including bus) is accredited for greatly contributing towards cities with high quality of life and promoting a resource-efficient and low-carbon mobility. A good example is the city of Vienna, where the use of alternatively-fuelled buses (mainly liquid petroleum gas and fully electric with batteries) in combination with policies that encourage the use of collective modes raised the modal share of public transport from 29% in 1993 to 39% in 2012, while it causes only 6% of the city's transport related CO_2 emissions (3iBS Project, 2015).

In this context, urban and regional buses have a major role to play since they remain the most widespread public transport mode with around half of all public transport passengers (30 billion per year) in the EU, reaching 100% in smaller towns and medium-sized cities (UITP, 2011). Moreover, within transit, the most recent generations of buses are a very appropriate mode to meet sustainability constraints in terms of energy efficiency, emissions and space occupancy, as well as operational effectiveness, since they can be more easily adapted to different requirements of passengers and do not require heavy infrastructures. Safety is yet another point of strength for buses, the related accident rates being very low if compared to other passenger transport modes (Corazza et al., 2015).

However, bus systems must make significant qualitative improvements in order to become more attractive. Customers expect the same kind of services and connectivity from vehicles and PT (public transport) terminals as they already have in their own living space. Such services build on basic requirements including comfort, security, cleanliness as well as operational excellence, which calls for enhanced frequency, punctuality and reliability of the transport services thanks to optimised network design and service performances (UITP, 2015). Moreover, the full potential of buses is exploited only when all the elements of the bus system (vehicle, infrastructure and operations) are deployed, i.e. when buses operate on reserved lanes with priority traffic lights and benefit from an accessible design of both vehicle and physical environment (bus stops, stations and intermodal hubs) as well as an easy access to ticketing and information systems. To reach this goal, a research and development strategy adequately supported by the European institutions is needed which implies a deep involvement of all bus stakeholders in order to achieve close collaboration between industries, public transport authorities and operators (3iBS Project, 2015).

Taking the above into consideration, EBSF_2 has been conceived as an open platform for dialogue that includes key representatives of all stakeholders involved in urban bus services. Over 40 partners of international relevance are involved in the projects, covering all areas of expertise (from manufacturing, to operations and research) and geographical regions in Europe. Their mutual collaboration, not limited by commercial relations, allows the development of solutions that represent the best technological answer to real operational requirements. In more detail (Table 1), the project consortium involves four leader European bus manufacturers, together with many others as associated members. Together they represent about the 70% of the European bus market and are therefore able to boost the introduction of key innovations on a large scale in Europe and beyond. In terms of Public Transport Authorities and Operators, consortium and associated members operate a fleet of more than 45,000 vehicles and transport more than 6 billion passengers per year. They are complemented by suppliers and research organizations as well as national and international associations that will ensure the highest dissemination and networking of the project results.

Table 1. EBSF_2 Consortium by stakeholder category.

Consortium Members						
Bus Manufacturers	*Suppliers*	*PT Authorities*	*PT Operators*	*Research entities*	*Knowledge providers*	*Associations*
EVOBUS	ACTIA	CRTM (Madrid)	DBUS (San Sebastian)	CEA	PE	UITP
IVECO	GROENEVELD	TFL (London)	RATP (Paris)	CHALMERS	DAPP	ASSTRA (Italy)
IRIZAR	DIGIGROUP	SYTRAL (Lyon)	KEOLIS	CEIT	DIGIMOBEE	UTP (France)
VOLVO	HUBNER	VTAB (Gothenburg)	START (Romagna)	UNIROMA	FIT	VDV (Germany)
	HOGIA		SSB (Stuttgart)	FRAUNHOFER	RINA	POLIS
	INIT		TMB (Barcelona)	VTT	RUPPRECHT CONSULTING TIS	
	INEO			UPM		
	PILOTFISH					
	PLUSERVICE					
	TEKIA					
	TRAPEZE					
Associated Members						
GOEPPEL BUS	DATIK	IETT (Istanbul)	DPP (Prague)		RTIG	ETF
SOLARIS	HISPACOLD	NMCU (Nantes)	RTAB (Bucharest)		Chalmers fastigheter	EUCAR/ACEA
BYD	IVU		MZA (Warsaw)		Yellow Window	FIA
MAN			TRANSDEV		Attoma	
EBUSCO						

1.2. Structure of the paper

After an initial outline of the relevance of EBSF_2 in the development of the bus as a more efficient and attractive travel option (already described in the previous section), the paper presents in section 2 the ambition of the project regarding the key research areas to be investigated through the demonstrations and, in section 3, the methodological approach developed to reach the respective objectives. An overview of the technological innovations to be tested in one demo site is reported in section 4. The paper concludes with a summary of the expected impacts.

2. Research logic and objectives

EBSF_2 aims to test, evaluate and validate innovative technological solutions or strategies for urban and sub urban bus systems through demonstrations in real service. The ultimate goal is to improve the efficiency of operations mainly in terms of costs and energy consumption but also to increase the modal share of bus services by improving the image of the bus for the users.

To produce breakthrough changes in the existing bus scenario, the project consortium has identified six key research areas with the highest potential to impact cost effectiveness as well as users' acceptance of buses, namely:

- Energy Strategy and Auxiliaries
- Green Driver Assistance Systems
- IT Standards introduction in existing fleet
- Vehicle Design (Capacity, Accessibility, Modularity)
- Intelligent Garage and predictive maintenance; and
- Interface between Bus and Urban infrastructure

The positioning and ambition of the project for each research area are explained in the following.

Today **auxiliaries** account for 15% to 25% of the total energy budget of an internal combustion engine (ICE) bus, but they can rise up to 50% in the case of electric propulsion with no excess heat energy to exploit. Thus, requirements for energy management for different propulsion technologies can vary, and so do the optimal solutions. Energy management strategies to be exploited within EBSF_2 are based on both real-time and anticipation of the near future operating profile and take into account auxiliary systems dealing with heating, ventilation, air conditioning, engine cooling systems, smart alternators, steering assistance etc. This predictive component is based on schedule, the vehicle's en-route position, street geometry and topography, and enables more adaptive and higher-level system control than traditional real-time but algorithm-based control. Solutions for new buses, especially electric buses, are considered very promising but many solutions can be adapted also for retrofitting of buses already in operation. It is therefore important to keep the additional hardware cost as low as possible.

Heating, ventilation and air conditioning (HVAC) are an important area for improvement in both ICE and battery-powered buses due to their high power needs. A combination of measures can increase the efficiency of air conditioning units as well as reduce heat loss via the interior and exterior design of buses. Effective circulation of air could also help maintain a comfortable temperature inside the bus with less energy input. Fresh air is required to control moisture/condensation on window surfaces which is imperative especially during snowy winter conditions. Solutions related to the bus stop events, such as controlled door openings for less heat exchange or a totally indoors bus stop, offer a major step-up from today's technology level. Improved HVAC systems that can use 20 to 30% less energy will be tested in different climate conditions.

A large number of **driver assistance systems**, including eco-driving systems, already exist for cars and trucks. However they do not take into account the public transport specifics where the driver needs to keep to a set schedule and starts/stops frequently. "After-market" eco-driving systems designed generically for vehicle fleets provide limited access to data other than vehicle accelerations and braking. Thus, they neither take into account several factors which influence energy consumption, nor differences between the driver's need for feedback in e.g. diesel compared to electric buses. Moreover, in eco-driving, like in other driver assistance systems, the efficiency of the feedback relies on the information transmitted to the driver but also on the design of the human machine interface (HMI). Present interfaces typically include displays showing the driver's eco-driving performance in terms of basic feedback which may suffice for the experienced driver but not for the less experienced. At the same time too much information will be difficult to perceive and may even distract the driver. EBSF_2 will develop insights into this aspect, focusing on hybrid and electric vehicles, by exploring eco-driving support systems adapted to a public transport context as well as information channels, required contents and appropriate choice of modality to inform drivers as well as enhance drivers' learning.

EBSF_2 will furthermore demonstrate the efficient introduction of **IT standards** (EN13149, SIRI, NeTEx) in an existing bus operational scenario based on results from the EBSF (EBSF, D2.3.2, 2012 and D3.2.2, 2012) and 3iBS projects (3iBS, 2014). The main innovation is to pass from vertical / proprietary solutions to fully interoperable ones both on board and back-office. It will permit to avoid IT supplier dependency for IT systems and to open up for competition. The introduction of these IT standards will take into account the co-existence of current IT systems to offer full interoperability. For public transport operators and authorities, the efficient introduction of such a standard IT architecture will offer a faster, easier and cost-effective interoperability of public transport systems at a regional level.

Applying new **design options for the exterior and interior layout of buses** may contribute to efficiency improvements by optimising accessibility and internal passenger flow, reducing dwell time at bus stops and, consequently, improving commercial speed of the vehicles and hence overall productivity. EBSF_2 activities concerning the layout of buses are a clear step beyond state-of-the-art solutions. The proposed solutions will capitalise on the EBSF project (EBSF, D2.1.1, 2010 and D2.1.3, 2011) by extending a vehicle interior layout simulator to also consider the interaction between bus and platform, the design opportunity provided by electric propulsion and accessibility for all requirements, including mobility impaired passengers. Selected designers of public transport systems from the UITP Platform for Design will develop entirely new concepts for electric bus design.

The **adaptable or modular bus approach** will also be progressed in EBSF_2 by testing a prototype that offers a completely new approach for the adaptation of the vehicle capacity to the actual demand, which will increase the efficiency of the bus system and minimise the environmental impact of operations, directly taking into account propulsion technologies as hybrid or fully electric. Contrary to the conventional bus-trailer-combination, the first segment of the bus must not be overpowered because other segments can be equipped with drive engines and/or additional energy storages.

Currently the **maintenance of buses** is managed using basic procedures. Applying standard IT architectures for collecting maintenance data in addition to the use of innovative systems based for instance on augmented reality and vehicle automation for intelligent garage can contribute to achieve a relevant saving (at least 10%) of the maintenance costs considering cost categories such as warehouse, labour, diagnostic vehicle immobilisation etc. The EBSF_2 tests on intelligent garage will focus on the definition of new algorithms for predictive maintenance, the use of innovative tools for bus depot and offers a new way to manage bus fleets with new maintenance procedures.

Regarding the **interface between bus and urban infrastructure**, it is proven that transforming bus terminals in urban places (rather than anonymous non-places) contributes to the creation of cities with a good quality of life. Passengers' experiences of bus stops and terminals could determine their perception and acceptance of the whole public transport system. The innovations that will be developed and tested in the project are expected to improve the passengers' satisfaction, remove accessibility constraints for all, ease the flow of passengers to and from the bus and hereby optimise dwell time, as well as implement new processes for proposing and discussing design of urban public transport infrastructure with relevant stakeholders. Moreover, electric buses (clean, high tech appearance, low noise, zero emissions) can "stay" closer to humans and provide a challenging and appealing opportunity to design concepts and new functionalities for bus stops as well as address interactions between passengers, vehicles and urban infrastructures. The highest innovation potential identified in EBSF_2 is the indoor stop for electric buses implemented in Gothenburg (described in section 4) which will be analysed in terms of users' perception and interplay between vehicle and infrastructure, such as the charging facilities, safety and technological issues.

3. The methodological approach

To facilitate the introduction of the selected technological solutions on vehicles and infrastructures beyond the specific project tests, EBSF_2 adopts a "system approach" which does not consider the vehicle in isolation, but as one of the elements integrated in the whole bus system together with infrastructural and mobility requirements. This concept reflects also the functional integration of the main bus system stakeholders who are represented in the consortium.

The assessment and validation of the EBSF_2 new concepts and solutions will be performed through a consolidated methodological approach characterised by three main activities.

3.1. Setting the scenarios

Firstly, the project will identify the functions and features, with respect to the six project research areas, that a bus system should include to meet the stakeholders' needs. Based on the extensive work done in EBSF (EBSF D1.3.4, 2012), the needs of all stakeholders of bus systems (regular and non-regular users, operators, authorities, industry and other users) will be analysed. These needs will help the consortium to consolidate a database of functional requirements for coherent system and subsystems (vehicle, infrastructure and operation), updating the definition of an "Innovative Bus System" developed in EBSF.

Therefore these functional requirements will facilitate defining a test scenario for each demo site, i.e. the test environment in which the selected technological innovations will take place, and identifying the validation objectives and performance targets to be met in the "EBSF_2 scenario" versus the "no EBSF_2 scenario". To measure the degree of achievement of the performance targets, appropriate Key Performance Indicators (KPI) are to be derived. These will include quantitative and qualitative KPIs suitable to measure both common system performances (e.g. attractiveness and cost-effectiveness) as well as performances specific to the demo sites and the technologies tested.

Finally, the evaluation framework will be completed by a measurement methodology and plan to guarantee comparability between the different sites and allow the transferability of the results.

3.2. Test innovations in real operation

The EBSF_2 technological innovations will be tested in 12 European cities: Barcelona, Dresden, Gothenburg, Helsinki, London, Lyon, Paris City and Paris area (Brunoy and Nanterre), Madrid, Ravenna, San Sebastian, and Stuttgart. The selection of the demo sites followed a three-step approach:

- screening of European bus stakeholders able to provide an added value in testing technological innovations in the EBSF_2 research areas;
- reduction of the initial set of candidates considering demo sites which allow covering all of main European climate areas (Continental, Mediterranean, Scandinavian), different environmental contexts (high/low population density, urban/suburban areas), transit networks and type of bus line. As a matter of fact, for several research areas (e.g. energy strategies, driver assistance or infrastructural interfaces) the physical environment where the buses run is a variable of utmost importance for the validation of the results and eventually their transferability in comparable contexts;
- prioritization of sites where the technical innovations will be tested in real operation.

Each city is committed to test a subset of innovations and several vehicles will be equipped with these solutions and run in operation for a period of between six months and one year. Overall, the 12 demonstrations deal with most current propulsion technologies (internal combustion, hybrid, electric) and address very different bus services (from Bus Rapid Transit to local lines) by involving in the tests more than 500 vehicles (operative buses or prototypes).

3.3. Evaluation and validation

The evaluation of the technical innovations will be performed to identify the whole impact of the measures when individually implemented, jointly implemented (to take into consideration the synergies that could arise from the combination of the solutions themselves) and when introduced in the whole network. Such an evaluation will not only assess the efficiency of the different innovations in terms of costs and energy consumption but also how they can increase the attractiveness of the bus systems to the user and the easiness of operation. To do so, the evaluation will be performed at four levels:

- Site-topic level, focusing the assessment on the impacts in each site (including perceptions from users/drivers). When possible, an upscaling of the successful technological innovations to the whole bus network will be simulated in the assessment;

- Horizontal Assessment, by priority topic, to evaluate which influential factors (congestion level, climate conditions, network characteristics, etc.) affect the results obtained in the different demo sites;
- Vertical Assessment, by demo site, to investigate the existence of synergies among the various technological innovations implemented in each demo site;
- Strategic Assessment that combines the contribution of several technological innovations when applied together to reach the global strategic targets set by the expected impacts.

4. The Gothenburg demonstration

Gothenburg is one of the 12 demo sites. The Gothenburg demonstration addresses three of the aforementioned key research areas for innovation, namely (i) energy strategies and auxiliaries, (ii) vehicle design, and (iii) interface between bus and urban infrastructure.

4.1. Scenarios and innovations

The demonstration is closely related to the ElectriCity initiative (www.goteborgelectricity.se/en) and a new electric bus line, line 55, running between two university campus (Gibraltar and Lindholmen) every weekday between 0600 and 1800. In the demonstration field trial, new vehicle designs will be tested and evaluated from different perspectives including attractiveness and efficiency. This includes three full electric buses and seven plug-in hybrid buses (for comparison) that operate the new bus line. The electric buses have a total length of 10.5 m (compared to 12 m), low floor, two large double doors in the middle of the vehicle to facilitate access/exit, an open layout with an extended number of folding seats to increase flexibility during peak hours, a modern colour scheme and onboard WiFi. The bus line 55 passes altogether 16 bus stops of which five will have a new design. One of these is an indoor bus stop, located at Lindholmen university campus (Fig. 1). It forms an extension to an existing building in which is located e.g. a cafeteria and teaching facilities. The construction is situated in a context of university buildings, office buildings, a science park, and restaurants. Close by new apartment buildings are also found. The main goal of the demonstration is to investigate how the interface between the urban infrastructure and the bus can be improved from different perspectives. The redesign of bus stops and the new buses are to contribute to more efficient boarding/alighting but there are also more overriding goals related to satisfaction and in the long run, demand. The demonstration will for instance allow for a comparison between traditional bus stops and indoor bus stops, which provide improved shelter but more fundamentally the intention is to create a shared space for PT and other urban activities, reducing the distance between PT and e.g. school or work and hereby changing the perception of a bus stop: from “bus stop” (a place where the bus stops) to a space for activities including travel.

Fig. 1. The electric bus drives through the entrance to the indoor bus stop at Lindholmen.

Regarding energy strategies and auxiliaries the overall objective is to reduce energy use by 30%. The demonstration will include simulation, laboratory tests, and a field trial. The simulations and laboratory tests will deal with investigations of the impact of vehicle designs on energy use by taking into consideration the number and type of windows, insulation, heated surfaces rather than heated air in compartment, as well as the effects of the number of passengers on-board. Comparisons will be made between different solutions to assess the possibilities for storing and distributing heat, for combining heat and cold storage as well as testing solutions to achieve a distribution of temperature which is perceived as comfortable by passengers and drivers. A new heating system driven by electricity and biofuels (instead of diesel) will be tested (on one of the buses) in the field trial. It will consist of a new heat pump and integrated air conditioner on the roof of the vehicle. In addition the coolant liquid is to be heated with a heater combining 16 kW heating capacity from bio-fuel with 7 kW electrical heating while driving and 9.2kW electrical heating in depot. A key to the improved performance is that the bus is pre-heated while standing in depot, either by hot coolant water or by electric power.

4.2. The local evaluation

The local evaluation will be based on the common evaluation framework (see Section 3.3) but adapted to the specific local context. A comparison will be made between comparable traditional bus lines (with diesel fuelled buses) and new bus line (with electric buses) as well as between electric buses and hybrid buses on the new bus line.

Regarding heating and energy use the efficiency of the respective solutions and their effect on energy use will be measured (kW) and cost calculated.

The impact of silent electric vehicles on the urban sound-scape will be investigated by measurements of noise (at bus stops, in housing close to bus stops, in defined areas through which buses pass, and on board buses) as well as by surveys to individuals along the targeted bus routes. The attractiveness and use of the new bus line, including vehicles and bus stops, will be investigated by registering the number of passengers that will travel with the new line; in addition interviews with a sample of passengers at the different bus stops as well as on board the different buses will be done, at minimum at three occasions during the demonstration period (beginning, intermediate, end). The sample will include also passengers with special needs (e.g. elderly and passengers with limited mobility). In addition, the passengers' behaviour on board will be documented, e.g. choice of door for embarking/disembarking, choice of seat, and flow through the vehicle, according to the methodology developed in the EBSF project (Andersson et al., 2010).

The evaluation of efficiency of the system will be addressed by measurement of dwell times/number of passengers that embark/disembark the vehicles; and observations at different bus stops and on board the different buses. The interaction between vehicle design and bus stop design will be evaluated as well by carrying out studies of passenger flow contributing also to developing the earlier mentioned simulation software (see Section 2).

5. Conclusions

The commitment of the main European bus manufacturers, the presence of top-leading suppliers and large operators with world-wide experience gives the confidence that the results of the EBSF_2 project will greatly contribute to new product developments (e.g. new IT standard equipment with related certification process), developments in the city (redesign of urban furniture including bus terminals linked to the RATP "Bus 2025" operation), steps towards the introduction of breakthrough innovations (e.g. augmented reality and autonomous movements in bus garage) as well as the possible development of standard concepts (e.g. new HMI for electric bus driver assistance systems, and the IT standard modules and services EN13149 with related certification).

Overall, the expected main impact of the EBSF_2 demonstrations is an increase in the attractiveness of bus systems and economic benefits with regard to total operational costs. With regard to the individual priority research areas the project consortium has identified the following specific targets to be reached:

- 10% reduction of auxiliaries consumption;
- 5 to 8% reduction of energy/fuel;
- 8% increase in commercial speed;

- 10% reduction of garage/maintenance costs;
- 5% reduction of operation costs (modular bus).

Moreover, the comparison and analysis of the demo results by research area will complement the test validation of specific technical innovations and allow the development of guidelines and tools to facilitate their introduction on large scale, more specifically:

- guidelines for including energy efficiency in procurement material, to help procurement on how to address energy efficiency when tendering new vehicles or services, as well as how to assess and improve energy efficiency of the existing fleet;
- guidelines for ergonomic design of user interfaces for driver assistance systems, the first step towards a harmonised development of driver assistance HMI;
- guidelines for the use of adaptable buses, to be used by operators as basis for the introduction of such bus concepts;
- the Bus Passengers Simulation Tool, to help stakeholders in jointly designing vehicles interiors and platforms to allow better accessibility and reduction of dwell time;
- new decision-making methodologies for public transport infrastructure design, guidelines for the adoption of a new process for proposing and discussing design for urban public transport infrastructure with relevant stakeholders;
- the Design Charter for new electric buses, which focuses on the opportunities created by electric propulsion in making buses not only clean but also more attractive.

The aim is to derive, from the experience gained during the EBSF_2 tests, material that European bus stakeholders can adopt beyond the specific demonstrations context. Specific attention will be given in disseminating such outputs to the widest relevant audience

Acknowledgements

The authors wish to thank all the EBSF_2 partners who actively contributed to the results above reported and in particular the contributing partners of Work Package 2 “Setting the scenario” and Work Package 13 “Gothenburg demonstration”.

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