DCE 21

4th DOCTORAL CONGRESS IN ENGINEERING

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Book of Abstracts

Symposium on Transport Systems and Mobility

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UNIVERSIDADE DO PORTO

4th DOCTORAL CONGRESS IN ENGINEERING

Book of Abstracts

of the

2nd Symposium on Transport Systems and Mobility

Editors:
Jorge Pinho de Sousa
Marta Campos Ferreira
Thiago Sobral
Juliana Carvalho

Porto
June 2021

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Edited by Jorge Pinho de Sousa, Marta Campos Ferreira, Thiago Sobral and Juliana Carvalho

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WELCOME

The one-day symposium on “Transport Systems and Mobility” held in the scope of the 4rd Doctoral Congress in Engineering (DCE21) takes place at a time when extraordinary changes are happening in our society and in the mobility patterns and services of many people around the world.

The pandemic is surely responsible for many of those changes, with new working habits and social needs, but the enormous technological advances, with digitalization, the electrification and automation of vehicles, the increasing role of smooth and active modes, and higher levels of intermodality, create a completely new environment in the area. In particular, huge opportunities emerge for the development of innovative, more efficient, socially inclusive and sustainable mobility services and business models.

Moreover, these trends naturally generate new interdisciplinary and challenging applied research opportunities. Research and technological areas such as artificial intelligence, big data, knowledge extraction and management, the sharing economy, the internet of things, connected and autonomous vehicles, are changing the urban landscape and fostering new innovative mobility solutions.

In this context, the symposium is surely an excellent forum for doctoral students and young researchers to present and discuss their ongoing research. The presence of peers, faculty members and industrial partners will surely create the right environment for debating some relevant current research topics and trends.

The challenges are immense but we will all be ready to face them by developing high quality research, together with companies, public authorities and transport operators, in order to help solve some of the biggest societal problems of today. Doctoral students and young researchers will surely play an important role in this movement.

Porto, June 2021

Symposium Organizing Committee

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PROGRAMME

Symposium on Transport Systems and Mobility

Chair: Jorge Pinho de Sousa, Professor at Faculty of Engineering of University of Porto

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KEYNOTE SPEAKERS

Pedro Barradas

Chief Strategy Officer at Armis

Topic: Mobility Orchestration

Pedro Barradas is Chief Strategy Officer at the Portuguese company, ARMIS ITS. ARMIS ITS is committed to the digitalization and decarbonization of transport and Mobility, by bringing together IT knowledge and experience with research and deployment of advanced solutions to enhance mobility management in highly complex transport systems, and in accordance to European Commission ITS Regulations, in favour of safe, clean, efficient, inclusive, affordable and sustainable transport.

Over the past years Pedro Barradas has had the chance work for the European Commission, at DG MOVE as a Seconded National Expert, and to participate in European projects in support of ITS and C-ITS policies, involving Road Authorities and Operators, among other stakeholders of the Sector, with in the CEF framework. In 2017, he was Chair for the C-ITS Platform 2nd Phase Working Group on Enhanced Traffic Management, focusing on C-ITS and Automation. Pedro was desk officer for the Pilot Project ‘C-The Difference’ (Helmond and Bordeaux) for the deployment of C-ITS in Urban context. As desk officer he was coordinator for the DATEX PSA, actively involved in the definition of EU norms and standards, namely: DATEX2 which defines a standard for the exchange and support of traffic information in Europe and the National Access Points (NAPs).

Today, Pedro and the team are actively engaged in Advanced Traffic Management systems, by investing into the DRIVE platform 3.0, a third generation for Traffic Control Centers, enabling monitoring and road network supervision, Incident Management and adaptative traffic management, and developing Decision Support systems based on simulation and machine learning forecast. This forms the basis to support city’s mobility managers with the implementation of its Strategic Urban Mobility Plans.

Pedro is a Civil engineer with a Master’s degree, with a wide knowledge of the road sector, from territorial and transport planning in cities to road design, construction, operations and maintenance, traffic management, asset management, road safety, quality and performance, road innovation, road standardisation, Intelligent Transport Systems, European policy and deployment Projects.

Lake Sagaris

Associate Adjunct Professor
Pontificia Universidad Católica de Chile (UC Chile)

Topic: Transport and mobility justice: lessons from the global south

Professor Lake Sagaris is an internationally recognised expert in cycle-inclusive urban planning, civil society development and participatory planning theory and practice. Born in Canada and working as a freelance journalist after learning about urbanism as an active citizen in post Pinochet Chile, Lake earned a Master of Science (2006) and a PhD (University of Toronto, 2012) in urban and regional planning. She directs the Laboratory for Social Change, a community university participatory action research initiative and teaches several innovative planning courses, including one of the first university-level courses on cycle inclusion, civil society and governance. She uses participatory action research methods to develop citizen-government collaborations for advancing sustainable transport, with a strong focus on social justice, inclusion and resilience. She is particularly interested in walk-bike-bus combinations that can address gender and other social needs. She also served on the founding board of the World Cycling Alliance (2015-2017), as one of two Latin American representatives, and remains an active member and collaborator as part of Muévete, Chile's national citizen organization for cycling and sustainable transport. She is currently an Associate Adjunct Professor and Researcher, associated with the BRT+ Centre of Excellence and the Centre for Sustainable Urban Development (CEDEUS), from the Pontificia Universidad Católica de Chile (UC Chile).

ABSTRACTS

Model-based dynamic toll pricing scheme for a congested suburban freeway with multiple access locations

Claudio Lombardi[1,2], Anuradha M. Annaswamy[2], Luís Picado-Santos[1]

[1] CERIS, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
[2] Active Adaptive Control Laboratory, Department of Mechanical Engineering, MIT, Cambridge, MA, USA
{ claudio.lombardi@tecnico.ulisboa.pt; aanna@mit.edu; luispicadosantos@tecnico.ulisboa.pt}

Abstract

In this paper we propose a novel approach for alleviating traffic congestion in freeways with multiple access locations through the use of dynamic toll pricing. The pricing strategy is determined using model-based feedback control, with the underlying model derived using a combination of both traffic flow modeling and driver behavior. The traffic segment we focus on is a suburban freeway with multiple access locations. The proposed toll-pricing scheme is tested with traffic data from Portuguese freeway A5, showing a significant improvement of the overall traffic conditions. The algorithm presented here provides an opportunity to improve on existing toll policy by guaranteeing more stable traffic conditions for the freeway users and optimizing the overall traffic throughput.

Author Keywords: Congestion Management, Suburban Freeway, Dynamic Toll Pricing, Driver Behavior Model, Traffic Flow Model, State Feedback

1. Introduction

The environmental and inefficiency concerns generated by traffic congestion are pushing research to investigate new solutions to tackle the problem. During the last decades, the technique of dynamic pricing, which entails the variation of prices according to market conditions, in response to the demand-supply imbalance, has gained great success in the transportation field for congestion relief purposes.

During the last decade, the main scopes of dynamic toll pricing research have been managed lanes and large scale road networks, while few studies have been dedicated to dynamic tolls for entire freeway segments (Lombardi, Picado-Santos, and Annaswamy 2021). Recently, (Pandey, Wang, and Boyles 2020) also stressed that many of the managed lanes dynamic pricing algorithms explored in literature make the assumption of single access location to the managed lane(s) and proposed a possibility of dealing with multiple-access cases through the division of the considered facility in links and the computation of a link toll. For a more complete review of dynamic toll pricing we refer the reader to (Lombardi, Picado-Santos, and Annaswamy 2021).

As a new solution for the multiple-access freeway dynamic toll definition problem, in this paper we propose a dynamic toll pricing scheme based on feedback control theory, similar to the approach described in (Phan et al. 2016) and (Annaswamy et al. 2018), for a freeway segment with multiple access locations. Our case study is A5 freeway, in Lisbon metropolitan area. We chose this freeway due to the severe congestion conditions that originate along its central segment, but the scheme could be adapted to fit to other freeways.

2. Materials and Methods

The goal of the proposed dynamic toll pricing scheme is to influence drivers' choices whether to enter the freeway or to follow an alternative route with the aim of guaranteeing free flow traffic conditions along the freeway segment, even during the congestion peaks.

According to (Phan et al. 2016), "viewing the real-time traffic information data as a sensor, and the price based on this data as a control input, the underlying traffic congestion problem is posed as a control problem". The control input, given by the toll price, is presented to drivers, who are viewed as actuators and affect traffic flow, as a result of their decision to enter or not the freeway.

The approach we propose consists in the real-time closed-loop strategy illustrated in Figure 1. The procedure starts with the selection of a desired state for the traffic flow, indicated by Z_{ref}. Any departure of the actual state from its reference value, indicated as error E, is fed into our price controller which determines toll prices Π. These prices, which need to be paid when accessing the freeway from one of the on-ramps, enter as inputs into the socio-technical model. The latter in turn consists of both the driver behavior model, which represents the driver's decision on whether to enter the freeway or not, and the traffic flow model that captures the dynamics between the incoming traffic flows from the on-ramps (Q) and traffic density at the counters' locations, defining the system state Z.

The details of the models adopted to build each block of both our price controller and socio-technical model are described in a paper of the authors currently under review for publication (Lombardi, Picado-Santos and Annaswamy, unpublished manuscript).

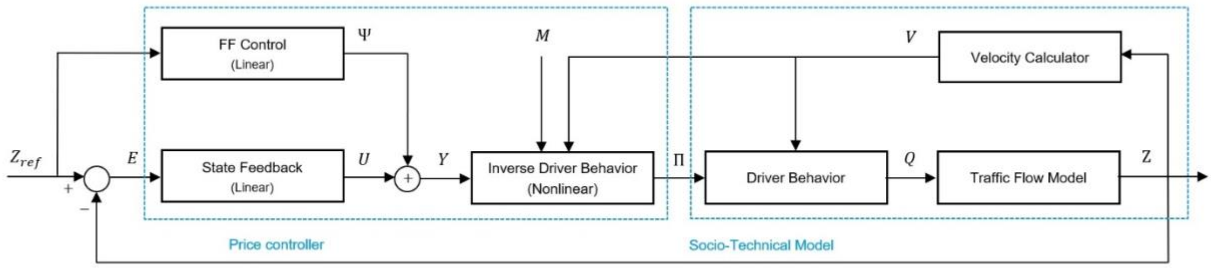

Figure 1: The inputs, subsystems, and variables of the entire system are shown in this representative block diagram. The inputs into the system are the vector of the desired state Z_{ref} and the demand vector M. The output is given by the actual system state Z.

3. Discussion

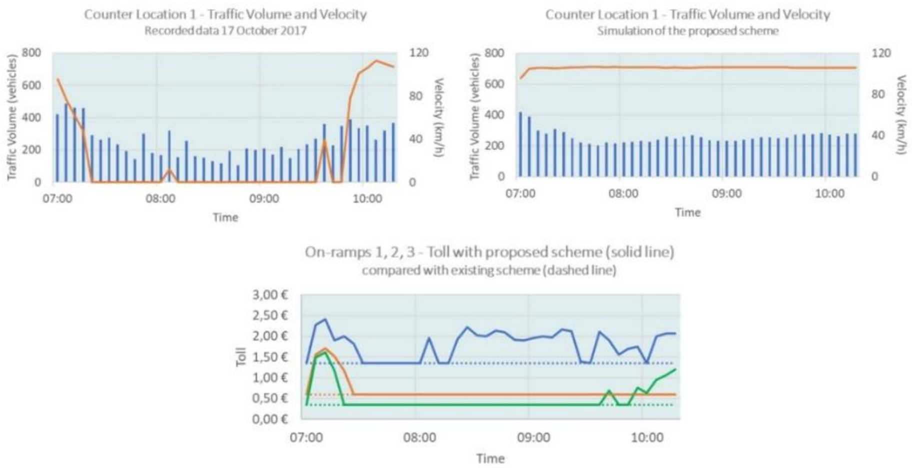

Figure 2: Results of the simulation of our model-based Pricing Controller compared with recorded data of October 17, 2017 between 7:00 A.M. and 10:15 A.M. Traffic Volumes are expressed in vehicles per interval of duration T=5 min, Velocities are in km/hour and tolls in €.
In the toll graphs, dashed lines indicate the current fixed toll prices.

The evolution of traffic volumes and velocities resulting from the simulation of our approach, is displayed in Figure 2 for the location of a traffic counter on A5 (Counter Location 1). The results are compared with the evolution of traffic volumes and velocities recorded at the same location during the morning of a day representing typical operation conditions of the freeway (Tuesday, October 17, 2017).

The recorded data show that traffic flows fluidly at the beginning of the analyzed period, conditions rapidly deteriorate between 7:00 and 7:30 A.M. and then they are poor for more than two hours; only at the end of the analyzed period, velocities increase determining the end of the morning peak period.

The plots resulting from the simulation of the proposed approach show a general improvement of traffic conditions due to the introduction of the dynamic tariff. The peak loads are reduced by an increase of the toll price. The initial peak load is eliminated by the rise of the toll corresponding to on-ramps 1, 2 and 3. Through the elimination of these peaks, our approach would be able to keep the freeway uncongested, with high and stable values of velocities, that allow higher flow rates. Therefore, while sometimes the traffic volume obtained through simulation is lower than the recorded one to reduce the peak loads, in some intervals our approach allows a higher traffic volume than the recorded one, as it happens between 8 A.M. and 9 A.M.

Calculated revenues for our simulation (28,785,28€) are around 164% higher than the manager's ones during the simulated time of October 17, 2017 (10,907.55€). This is mainly due to the fact that the access from most of the on-ramps is currently not tolled.

As displayed in Table 1, we estimated that the introduction of the proposed dynamic toll pricing scheme would lead to total travel time (TTT) savings amounting to 5,725.30 hours during the analyzed period compared to October 17, 2017, even though travel times on the alternative route are estimated to increase. The ratio between the increase in revenue and total travel time savings gives a value of 3.12€ of toll increase per hour of saved travel time.

		17 OCT 2017	Our simulation	Difference
TTT (hours)	A5	11,538.48	4,962.43	
	Untolled alternative	509.97	1,3760.72	
	Total	12,048.45	6,323.15	5,727.30
Revenues (€)		10,907.55	28,785.28	17,877.73
Ratio (€/hour)				3.12

Table 1: Summary of revenue and travel time savings effects

4. Conclusions

The results of our analysis of the proposed dynamic toll pricing show that the traffic flow in some locations of A5 is higher with our method and in addition, faster traffic speeds are realized over the entire traffic segment, fulfilling the objective of congestion alleviation. Both current users of the A5 segment as well as new users can benefit from the potential travel time savings, due to the increased speeds. Those who choose to not enter A5 may resort to alternatives such as untolled paths or public transportation, or simply change their driving habits such as a later departure time when the highway is less congested and therefore has a lower toll.

The approach proposed can be applied to other freeways in a straight-forward manner with suitable modifications. Since its structure is modular, it allows flexibility by adapting one or more of its building blocks.

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A Real Time QoS Monitor Architecture Proposal for Cooperative Vehicular Platooning

Ênio Vasconcelos Filho[1], Ricardo Severino[1], Anis Koubaa[2], Eduardo Tovar[1]

[1]CISTER – Research Centre in Real-time & Embedded Computing Systems,
Instituto Superior de Engenharia do Porto, Portugal;
[2]Prince Sultan University, Saudi Arabia
{(enpvf,rarss,emt)@isep.ipp.pt; akoubaa@psu.edu.sa}

Abstract

Cooperative Platooning (Co-VP) depend enormously on their communication capacity, since the information exchanged between vehicles and infrastructure ensures the correct execution of the device's trajectories in most diverse scenarios. In this way, the monitoring of quality of service (QoS) plays a fundamental role in guaranteeing the system's safety, providing local controllers with information so that defensive actions can be taken in a timely manner when the network start to fails. In this work, we introduce the concept of a Real Time QoS Monitor (RTQM) module that can be added to devices that are part of a Co-VP application. The RTQM module performs a link quality estimation (LQE), based on the packet inter-reception time, received signal strength Indication (RSSI) and current vehicles distance. The RTQM will provide information to the local Co-VP controller allowing safety actions and enabling the network handover between different communication standards, namely between ETSI ITS-G5 and C-V2X standards.

Author Keywords. Cooperative Vehicular Platooning, Handover, QoS Monitor, Link Quality Estimation, Safety Maneuvers.

1. Introduction

Cyber-physical systems have evolved, enabling the creation of intrinsically connected Co-CPS capable of operating in critical scenarios and subject to the highest safety's levels. One of these scenarios is the Co-VP, that has the potential to increase the passengers and products transportations over highways, reducing collision risks and fuel consumption. The Co-VP application highly relies on the communication between vehicles to vehicles (V2V) and vehicles to infrastructure (V2I). So, given the criticality of its scope of action and the importance of the information exchanged between devices, monitoring the network QoS assumes a fundamental role in the system's safety. The fast detection of network's degradation enables a quick control systems reaction, allowing them to act to minimize damage and avoiding accidents, namely stopping the platoon in a safe way, or changing the vehicles maneuvers.

In this work, we propose a real-time QoS detection system for Co-VP (RTQM). RTQM is a modular system to be used in conjunction with existing devices, performing a link quality estimation (LQE) in the network links. It informs the controller's device about the network's condition, indicating package delay, signal strength and devices distance to keep the system's safety. The proposed RTQM will enable a network handover between different communication links, increasing the Co-VP application's safety in different scenarios. A 3D simulator integrated into a network simulator (Vieira et al. 2019), a realistic assessment of the suggested scenarios are proposed to validate the system, including two of the most used vehicle's network standards, ETSI ITS-G5 and C-V2X.

2. Context and Motivation

In the Co-VP scenarios, the communication's quality is studied in several works like in (Karoui et al. 2017), where it is possible to observe some solutions for situations where exists a drop in device's communication quality. However, most of the works presented consider only the states in which the network is normal or degraded, without indicating the detection or gradations of that state. The (Marzouk, Rodriguez, and Radwan 2018) propose a bidirectional LQE to choose the best relay option in Co-VP, but focusing on Road Side Unit (RSU) communication while ETSI ITS-G5, commonly used in Co-VP applications, uses the Decentralized Congestion Control (DCC) to check the network congestion based in the Channel Busy Rate (CBR). But those solutions do not provide any information to the device's controller, that keeps unable to perform safety actions to avoid accidents.

Some authors have studied the vertical handover (VHO), between network models or frequencies to keep the Co-VP functionality. The authors of (Khoder et al. 2020) switch between Visual Light Communication (VLC) model for LTE, while (Krupitzer et al. 2018) suggest the RSU's handover to keep the platoon stability, like an horizontal handover (HHO).

3. Real Time Quality of Service Monitor Architecture

The development of the RTQM System responds to the need for Co-VP to detect and monitor the network QoS in real-time. With the information provided by packet inter-reception time, RSSI, current vehicles distance and the number of vehicles in the network, it is possible to estimate the average packet error rate and define some safety levels. These safety levels are informed to the system's controller that will be able to carry out safety actions that prevent accidents, allowing platooning to return to regular operation when communications reestablish.

Figure 1 shows the basic architecture of RTQM, and its interconnection between vehicles and RSUs within a Co-VP application. In this scenario, the vehicles have two radios, using ITS-G5 and C-V2X and the information provided by the RTQM allows the vehicle local controller to choose between the two signals.

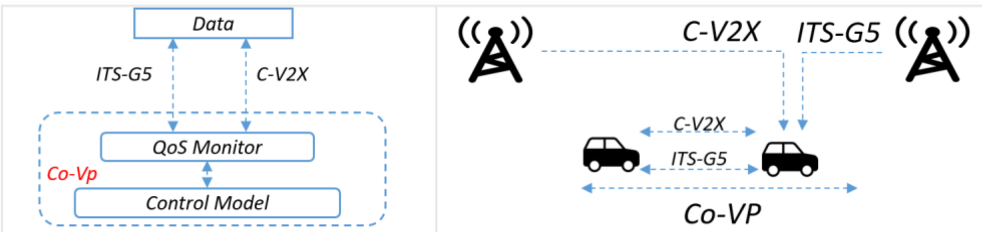

Figure 1: RTQM general View

The use of different communication models reduces the system's susceptibility to possible congestion network environments, that increase the delay between messages, as shown in Figure 2. In this figure, we demonstrate the RTQM average measurement of the delays in messages from ***car1*** to ***car2*** using ITS-G5, regarding the increase off the number of vehicles in the network. We also analyzed several communication profiles, like the Basic Service Profile (BSP), Basic Service Profile for Platooning (BSP-P), and the Custom Service Profile (CSP), defined in (Vieira et al. 2019).

If the communication deteriorates enough, RTQM inform the controller that is responsible for realize safety actions before the network completely deteriorates, preventing accidents, as demonstrated in Figure 3. This simulation was performed with Gazebo, for the a 3D simulation, integrated with Omnet ++, in CopaDrive. This simulation allows a realistic analysis of delays and other network issues. For the simulation of the ITS-G5, the Artery project framework is used, while the C-V2X communication is simulated with Simul-LTE. The integration of these components is done using the Robot Operating System (ROS) as a Broker.

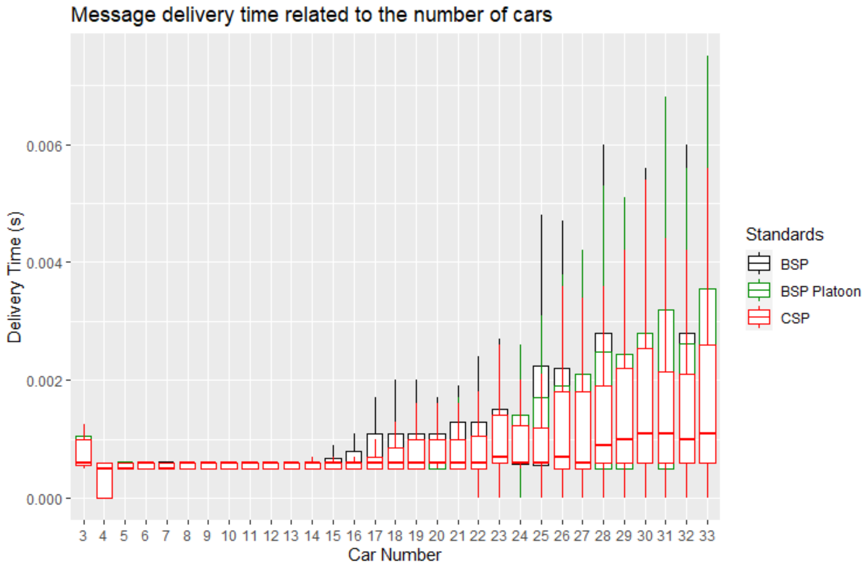

Figure 2: Delay between messages from Car1 to Car2 in ITS.-G5 scenarios

Figure 3: RTQM - Network Delay Detection

4. Conclusions

The addition of an RTQM module to a Co-VP application has potential to minimize the impacts of network issues, increasing the application's safety. Combining the ability to use two different communication standards, with the capacity to analyze the network QoS, it is believed that Co-VP applications may have increased safety. The handover between radio modules is a topic for further studies in the implementation scenario.

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An approach to data collection of university commutes in the context of the Covid-19 pandemic

Gerfenson Barbosa Ribeiro[1], Juliane Érika Cavalcante Bender[1]

[1]Centro Federal de Educação Tecnológica de Minas Gerais, Brasil
{gerfenson19@gmail.com, bender@pet.coppe.ufrj.br}

Abstract

Universities are important points that generate demand and are capable of having significant influence on the social mobility of their cities and local environment. Consequently, it is important to know from all aspects how this constant movement of people influences urban mobility in these cities so they can offer the most effective and relevant traffic solutions. In the context of the COVID-19 pandemic, evaluating this data has become increasingly difficult as a result of the sudden or total reduction in physical access to universities due to recommendations of social distancing. Based on this, this research aims to present a technique for collecting commute data which is divided into three scenarios: before, during and after the pandemic.

Author Keywords: Urban Mobility, displacements in universities, COVID-19 pandemic.

1. Introduction

According to Lima et al. (2019), urban planning is presented as a key alternative for the spatial organization of cities and helps to control their expansions in an efficient and planned way. For this planning to be more accurate, it is necessary to know all the traffic origins-destinations of the interests generating points, in order to offer the best mobility solutions that are relevant to them.

Due to their significant sizes, large populations and often central locations, universities can be considered a significant cause of congestion and a key factor in urban mobility within a city (Machado et al. 2019). With this in mind, several cities around the world have invested in research that helps them to understand the origin-destination of these commutes in order to reduce large traffic jams in their urban centers. In this context, this research aims to present a research technique of origin-destination in relation to university campuses in order to perceive the influences on local urban mobility (Portugal et al, 2003).

2. Adopted methodology

Given that internal communications can be considered the easiest way to contact a wide array of relevant stakeholders. The data-gathering technique presented aims to do this data collection by using online surveys.

In the process of preparing these online surveys, it is necessary to take into account the impact the pandemic has had on people’s commutes to university. It will do this by dividing the survey into at least three different sections: Before the pandemic, where the interviewee would describe how their commute to university used to be; during the pandemic, to find out what was the main changes in their daily movements finally and importantly, post-pandemic should be considered, with the objective of estimating how the user could potentially commute in the future. The table that is shown below, aims to facilitate the understanding how to organize and insert the questions on the survey:

Section 1 – Basic Data
On this section should be asked basic data of the interviewee. There are some examples of them bellow: Type of link with the institution; Age; Gender; Check physical disability, Income, etc.
Section 2 – Before the Pandemic
The objective of this section is to map the entire commutes of the user to the institution. So is recommended to collect this type of data: Origin and destination when accessing and leaving the university; Arrival and departure time; Main mode of transport; Duration of commute time, etc.
Section 3 - During the Pandemic
This section aims to verify if the user continuous to have the same commutes as before and if continuous to use the same modes of transport, here are some examples: Check address change; verify if the user had changes on them commutes and how was this change, etc.
Section 3 After the Pandemic
To finish, is important to add this section to verify if the users think that they will change the modes of transport that they were accustomed to use in the pass, so here are some ideas to ask this: Ask the users if them think that they will have a change in the mode of transport in relation to what they used before, if yes, what will be changed, etc.

Table 1: Table with the instruction of how organize the survey.

As for the collection of this data, a viable alternative would be the mass distribution of this survey to the entire university community through campaigns on social networks, partnership with the educational institutions themselves, and contact with future interviewees through email. It is also important to emphasize that the more people who answer it then the results will have a higher accuracy rating and consequently greater usefulness and applicability.

If the survey is well received and garners a substantial enough response, it will be possible to estimate the primary impacts commutes to and from universities have on the wider context and state of social mobility in the city. The minimum number of responses could be defined based on the university's population, trying to achieve at least 50% of them.

3. Discussion and conclusions

The method of data collection above is a simple technique and without substantial cost, but of great precision, that serves to make an evaluation of the commute in the university centers that generate travel. After processing them, it will be possible to make an estimate of the potential changes in mobility at these points, allowing it to be feasible to plan interventions that meet them.

The same method was applied at CEFET-MG Campus Curvelo in Brazil, and it was possible to verify that the university suffered a series of changes in commute, it was also viable to estimate through the data, a slight change within the academic community preferences for transport modes, in the future when the pandemic ends.

It is relevant to consider that the Campus is located in a small town, and most part of the students come from other cities and regions of Brazil. Taking it into account, most part of them came back to their cities, in result of the Emergency Remote Learning being totally online, causing a strong change on their commutes.

Future work could include a literature review on new methods of evaluation of generating points of interest and how such evaluation can be used to propose new ways for more accurate data collection in different scenarios.

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A decision support system for policy design and sustainability assessment of mobility systems in emerging cities

Juan Camilo Medina Arguello [1,2], Jorge Pinho de Sousa [1,2], Edgar Ramiro Jimenez [3]

[1] Faculty of Engineering, University of Porto, Porto, Portugal
[2] INESC TEC, Porto, Portugal
[3] Centre for Air Transport Management, Cranfield University, United Kingdom

Abstract

Enhancing the sustainability of mobility systems is increasingly critical for cities and metropolitan areas. We must, therefore, understand mobility requirements much better, and need to guarantee a constant monitoring and evaluation of the actions implemented to improve sustainability. Since transportation systems are largely complex systems, the assessment and measurability of their performance, regarding sustainability, are crucial for implementing more effective decisions. In such context, this research develops a decision support system (DSS) for the design of sustainable mobility policies in the case of emerging cities. The approach is based on a system dynamics model to represent the relationships between state and flow variables, organized as feedback loops. We propose a multi-layered model to analyze how the different factors change over time, and visualizing the impacts of those factors on our higher-level goals. For this purpose, a specific conceptual framework to assess sustainability in mobility systems was developed, using multi-criteria decision analysis methods.

Author Keywords: Sustainable transportation system, measuring tools, multi-criteria decision analysis, system dynamics, mobility planning.

1. Introduction

Transport is widely considered as a sector with significant positive and negative externalities, affecting society, the environment and economy, and being therefore directly connected to the sustainable development of cities (Sdoukopoulos et al. 2019). Nowadays, the evaluation of urban sustainability is a hot topic in different scientific fields, with a growing interest for sustainable transportation and transport planning (Litman and Burwell 2006).

In urban transportation systems, policy analysis and planning in general require quite accurate information. Therefore, in this work, we have designed an analysis structure to assist transportation authorities to evaluate their mobility systems regarding sustainability. Here, sustainability indicators (grouped in several dimensions) are fundamental for measuring current or expected levels of sustainability, supporting the design of strategies that target a sustainable development.

Furthermore, a system dynamics approach has been developed to study sustainability of transportation systems (Yevdokimov 2002).

The paper is structured as follows. Section 2 presents the conceptual framework developed to assess the sustainability performance of mobility systems in emerging cities. Section 3 describes how the DSS was developed and how it performs. Finally, Section 4 presents a set of conclusions and opportunities for further research.

2. A conceptual framework to assess sustainability in mobility systems of emerging cities

Indicators are needed to monitor transport sustainability, as well as to compare and analyse sustainability among different cities (Haghshenas and Vaziri 2012). In particular, emerging cities need to have a broad "baseline" analysis structure, that integrates the several dimensions that can affect the performance of their mobility systems in terms of sustainability. The main dimensions of sustainability, usually referred to as the triple bottom line – environmental, economic, and social – should form the basis for any research work in the area, but we have identified other relevant dimensions to evaluate mobility systems in terms of sustainability. This measurement analysis structure is supported by an extensive literature review about sustainability in the transportation sector, as well as by data collected through semi-structured interviews to 19 sustainability experts and surveys responded by 105 people with interest in sustainability topics.

2.1. *A conceptual framework for measuring sustainability*

A preliminary framework was designed, with 5 dimensions and 26 indicators. This structure was the result of the compilation and consolidation of an extensive list of topics and indicators, leading to a reduced and manageable number of indicators. This concise indicator set was tentatively grouped in 5 sustainable dimensions: environment and human health; economic and social; operational; fiscal and governance; and efficiency of the mobility system. Then, this preliminary sustainability indicators framework was enhanced through the analysis of the information gathered by an on-line survey via Survey Monkey. This information was processed using an (exploratory) quantitative and qualitative analysis.

2.2. *Prioritizing dimension and indicators*

We have then developed a confirmatory process (phase) that prioritizes the previously defined dimensions and indicators. This process was developed around two multi-criteria decision-making (or analysis) methods – the Analytic Hierarchy Process (AHP) and a "fuzzy" extension of AHP (FAHP).

Regarding data acquisition, for testing and validating the proposed exploratory framework, we have used an AHP-based questionnaire responded by 19 sustainability experts, thus measuring the relative importance of the different elements at different levels, through pairwise comparison evaluations between those elements.

3. A decision support system for policy design and assessment of sustainable mobility in emerging cities

Transport systems and policies are complex, involving multiple agents or stakeholders, with many feedbacks involved, with different time lags between responses of users, developers, operators and policy makers. System dynamics (SD) not only offers a different perspective to transport planning but can also show the importance of these feedbacks and lagged responses. The qualitative model proposed here is developed based on the data obtained from the qualitative analysis described above.

In our SD model, and to pursue the desired goal, we have established "a more sustainable mobility system" as level 0. This goal is achieved through vertical and horizontal links that connect the sustainability dimensions (as defined in section 2), considered as level 1, with level 2 (sustainability indicators). These indicators are, in turn, connected to high sustainability policies and strategies/actions through variables defined by the decision makers. For this purpose, a decision support system (DSS) for policy design and assessment was developed, applying the conceptual framework recommended by our research.

3.1. *Discussion of results*

The influence of the "green mobility" policy is coherent with the findings of this research, that concluded that environmental integrity is a condition *sine qua non* of the nested model of sustainability. In relation to the "integrating mobility and land use" and "modern governance for efficient and safe mobility”, their influence in the sustainability performance within the model structure is quite low. However, these initiatives are a good starting point to solve some current governance inefficiencies that can generate cost overruns for the municipalities.

Consequently, for decision makers, this implies that the “green mobility” and the “mobility for health and wellbeing” policies should have higher priority and be executed first. These policies have no negative effects on the target factor. The “mobility for competitiveness and quality of life” and the “integrating mobility and land use” policies have also a positive but smaller impact on the entire target factor. Decision makers should, therefore, evaluate their implementation, analyzing the available budget, and giving priority to the policies suggested by the model. The “modern governance for efficient and safe mobility” policy, despite having the lowest influence to achieve the target factor (desired goal) “a more sustainable mobility system”, should be taken into account if the context requires it, since it showed no negative values (negative influence within the system).

4. Conclusions

The proposed conceptual framework showed to be a useful tool for measuring sustainability in transportation systems, being easily adaptable to different city contexts. It can be useful for transportation managers in policy making processes, contributing to the generation of bottom-up (rather than top-down) sustainable mobility policies, and to determine which interventions would have the greatest impact. Moreover, our DSS will provide planners and decision-makers with the ability to look into the future and to decide based on past and present information and also on available forecasts. In particular, it will help analyze the influence and impacts of the proposed sustainability policies, and provide criteria to make a better assessment and management of public spending, in order to achieve sustainable mobility systems.

The developed qualitative model for policy design and assessment is easily adaptable to quite different contexts. Moreover, this research shows the benefits of having a systemic approach towards more sustainable mobility systems. Furthermore, users of the model may easily change the considered factors and relationships, to capture the specific aspects of each particular context. The major benefit of this “open source” modelling is its potential to continue reflecting on important factors that contribute to the achievement of the different sustainability targets.

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Towards a collaborative design framework for policy roadmaps in sustainable urban mobility: an exploratory literature review

Juliana Carvalho[1], Jorge Pinho de Sousa[1,2], Rosário Macário[3]

[1] Faculdade de Engenharia da Universidade do Porto, Porto, Portugal
[2] INESC TEC, Porto, Portugal
[3] Instituto Superior Técnico, Lisboa, Portugal
{julianacarvalhocs@gmail.com, jorge.p.sousa@inesctec.pt, rosariomacario@tecnico.ulisboa.pt}

Abstract

This paper presents the results of an exploratory literature review conducted as part of a research project that aims to contribute to sustainable urban mobility from an interdisciplinary perspective. The main objective of the research is to develop a collaborative design framework for assessing adaptive policy roadmaps in sustainable urban mobility, with a particular focus on the metropolitan scale. Taking the European Guidelines for Developing and Implementing Sustainable Urban Mobility Plans (SUMPs) as the reference planning tool, and placing our attention at the metropolitan scale and collaborative practices, we used the Scopus and the Web of Science databases to retrieve academic publications. A small number of results was identified in the intersections, showing that research in this field is still at a quite early stage. The main implications of this review for the research design are presented in the conclusions.

Author Keywords: Sustainable Urban Mobility Plans, Metropolitan Areas, Collaborative Design Framework, Literature Review.

1. Introduction

The transition of urban mobility systems towards more sustainable models is a central challenge of cities around the world (Sustainable Mobility for All 2019). In metropolitan contexts this challenge involves higher levels of complexity, not only because of the more diverse socio-spatial patterns of large conurbations, but also due to the larger number of actors involved, requiring increased collaboration to achieve common goals (Zegras 2017).

In this context, our research aims at developing a collaborative design framework to support sustainable urban mobility adaptive policy roadmaps, and accordingly, the main objective of the literature review was to map the main advances made in this topic, and to identify the main gaps in current knowledge. This paper presents the results of the literature review of academic papers published in indexed databases, namely Scopus and Web of Science.

2. Materials and Methods

The academic literature review was focused on the concept of Sustainable Urban Mobility Plans. We used both the Scopus and the Web of Science (WoS) databases to conduct the research. Since the consolidation of SUMPs as a key concept is recent, we did not set any initial timespan constraints. However, during data cleaning we have eliminated the documents that appeared before the publication of the SUMP concept as such. The initial search was conducted using the term “Sustainable Urban Mobility Plan*” (the use of the wildcard function served the purpose of including both “plans” and “planning”).

A total of 132 documents were retrieved in Scopus, and 96 in WoS. Combining the results and eliminating duplicated entries, the final list comprised a total of 141 documents. Assuming collaboration as an umbrella concept, encompassing cooperation and coordination, and leading to integration, we used a combination of these key words (collabora* OR coordina* OR coopera* OR integra*) to search for collaborative experiences in the previously selected sample.

The combination of these terms (using the Boolean operator “and” to focus on the intersection of SUMPs and collaboration) resulted in a total of 60 documents. Complementary, we carried out another search using the term “metropo*” (as before, the use of the wildcard (“*”) has allowed us to broaden the search, encompassing similar terms). A total of 15 documents were retrieved in the search for metropolitan experiences with SUMPs. Finally, in the intersection of these previous searches, only 7 documents fit the three general criteria of: (i) SUMPs; (ii) collaborative practices; and (iii) metropolitan scale. The consolidated results are summarized in Figure 1.

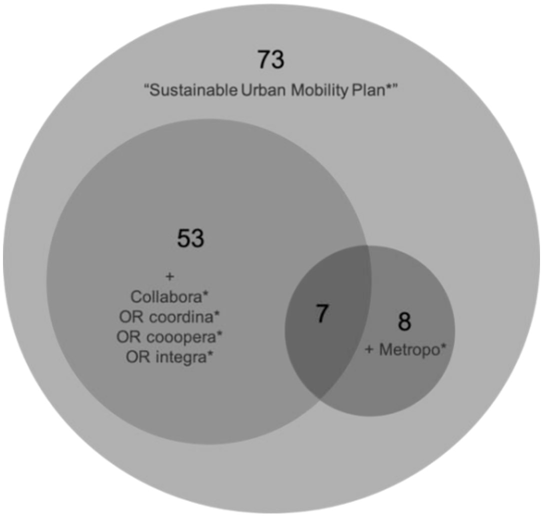

Figure 1: Literature Review Venn Diagram

No document from those seven that correspond to the most interesting intersection presents any comparative analysis of metropolitan cases, rather focusing on a particular metropolitan area or in a specific municipality. Even when analysing the remaining eight documents that are included in the “metropo*” criterion, only three perform comparisons: one is centered in municipalities of the same metropolitan area; one compares cities in one country (Spain); and one compares one metropolitan area in Europe (Lille) with cities in Brazil. This lack of contrasts reflects the still incipient nature of this particular research topic.

3. Discussion

The Sustainable Urban Mobility Plans (SUMP) Guidelines (Rupprecht Consult eds. 2019) claim that planners and policymakers should focus on the functional urban area (OECD 2012). Given the emphasis this concept places on commuting dynamics as a key variable to define the territorial reach of an urban area, the logical implication is that metropolitan areas need to develop mobility plans at this spatial scale, engaging in collaborative practices.

The SUMP guidelines also emphasize the importance of the mobility system to promote accessibility, serving as a justification for further integration of transport and land-use policies (Levine, Grengs, and Merlin 2019). Integration has to go beyond transport and land-use, involving not only other sectors, such as telecommunications and environment (Stead and Meijers 2009), but also engaging citizens and other stakeholders in collaborative processes (Lindenau and Böhler-Baedeker 2014). This implies that a broader set of actors need to collaborate to achieve common goals.

4. Conclusions

The process of reviewing the existing research has allowed us to contextualize our research and has given us inputs to fine-tune our main research question, that can be summarized as "how are metropolitan areas overcoming collaboration challenges in the pursuit of more sustainable urban mobility systems?". This process has also assisted us in defining the more appropriate methods and techniques to address that research question. Given the importance of incorporating a wide variety of actors, and recognizing the complexity of sustainability goals, a multi-actor multi-criteria analysis method will be used in combination with Delphi-surveys. This will allow us to combine different stakeholders' preferences with long-term planning horizons in our analysis.

Considering the small number of publications found on SUMPs at the metropolitan scale, and the even smaller number of comparative studies, in the first stage of our research we will conduct a series of interviews with key informants from metropolitan areas and local governments, in order to collect data on practitioners' experiences. Key policy documents will also be revised. This will enable us to construct a State of Practice of SUMPs at the metropolitan scale. Qualitative content analysis will be used. This technique will be applied to interviews transcripts, Delphi survey results and policy documents, with the objective of identifying and systematizing which characteristics of institutional arrangement promote or hinder collaborative design of plans and policies for promoting sustainable urban mobility at the metropolitan level.

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A sustainable business model for horizontal collaborative logistics

Leandro Carvalho[1], Jorge Freire de Sousa[1], Jorge Pinho de Sousa[1]

[1]Departmento INESC TEC | Faculty of Engineering, University of Porto,
{leandromec@yahoo.com.br, jorge.p.sousa@inesctec.pt, jfsousa@fe.up.pt}

Abstract

Data provided by the European Commission indicates that the "load factor" in logistic transport has great potential for improvement, with a positive impact on the environment, economy, and society. Moreover, this inefficiency is often higher in the last mile delivery, as the transport of goods is largely fragmented between several small companies using small vehicles for the deliveries. The evolution of Information and Communication Technologies and Intelligent Transport Systems fostered horizontal collaboration as an opportunity for companies to reduce the kilometers driven with little or no cargo by sharing information, routes, and orders. This work proposes the development of a conceptual framework able to describe the main patterns that rule different horizontal collaborative strategies on logistics.

Author Keywords: Horizontal collaboration; urban logistics; co-opetition; business models.

1. Introduction

Transportation of goods is an essential activity for the economic development of cities. However, the inefficiency of partially loaded or empty vehicles driving through urban areas impacts traffic, noise and air pollution, energy consumption, and the number of accidents. In horizontal collaboration for logistics, several firms operate simultaneously in the same section of the freight transport, sharing information, resources, infrastructure, or purchase orders, aiming to improve the efficiency of their operations (Cleophas et al. 2019). This type of partnership is based on the use of idle resources, becoming financially attractive to logistic operators, and bringing benefits for society and the environment.

Despite these advantages, establishing trust relations is one of the main barriers to a successful implementation of freight horizontal collaboration (Cruijssen 2020). Many companies fear information disclosure to competitors and sharing the costs and benefits of the partnership. There must be formal procedures and regulations to reduce tensions resulting from the paradox of simultaneously competing and cooperating; in addition, a strategic alignment between firms is necessary to foster an environment of trust (Pomponi et al. 2013).

Thus, this work seeks to develop a *conceptual framework* to define and organize patterns of horizontal collaboration capable of guiding stakeholders interested in participating in this type of initiative. This framework will identify the key controllable and non-controllable variables within a horizontal collaboration in logistics, and will hopefully be an important tool to support decision-making in the design of more efficient and sustainable logistic solutions.

2. Methodology

We have conducted a literature review, limiting the scope of horizontal collaboration to the urban environment. The first step was the investigation of the main stakeholders in horizontal collaboration. Urban logistics affect each stakeholder differently, through complex cause and effect relations, and suggestions for change usually generate tensions between groups holding different and often conflicting positions. Based on this literature review, we have identified five groups of stakeholders for logistics horizontal collaboration initiatives: shippers, receivers, logistic service providers (LSP), regulatory authorities, and citizens/tourists. By researching the main urban logistics stakeholders, the framework aims to understand their expectations, needs, and interests, and the interactions between them. Then we have investigated the main concepts and theories related to horizontal collaboration in logistics, co-opetition, and examples of implementation in practice. This research indicates that the development of horizontal collaboration by the different stakeholders is not yet adequately addressed by the current scientific literature. There is a gap, mainly regarding the investigation of business models implemented by companies participating in freight collaboration.

Thus, the framework will use business models as a tool to understand how logistic companies adapt their strategies to participate in horizontal collaboration initiatives. Firstly, questionnaires will be administered to identify companies that collaborate horizontally. Then, case studies, based on interviews and document analysis, will be conducted to understand how some of these companies adapt their business models for horizontal collaboration.

3. Discussion

In conventional business models, firms formulate their strategies to gain competitive advantages over their rivals. However, the architecture of business models has been evolving to propositions that embrace horizontal collaboration and value creation and acquisition through co-opetitive advantage. This evolution requires a paradigm shift, from a “zero-sum strategy”, where one company wins just if others lose, to a “positive-sum game” that ensures overall and individual gains (Brandenburger and Nalebuff 2002). In our framework, business models describe how companies should adapt their activities to accomplish this change in an organized and standardized way.

A business model forms a link between strategic planning and implemented operations. It covers the main activities of a company through elements such as the customers, a value proposition, operations, and cost and revenue streams. This study will analyze the strategies of companies using an adaptation of the business model canvas (Osterwalder and Pigneur 2010) for city logistics, as proposed by Quak, Balm, and Posthumus (2014). Their main contribution was adding to the canvas a 10th block, to capture the externalities caused by logistic activities. This new block is part of the value proposition analysis.

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Public charging infrastructure placement, a power demand and supply analysis

Luis Leal Pinho de Morais[1]

1 Politecnico di Milano
{luisleal.morais@polimi.it}

Abstract

Due to environmental constraints, the evolution of mobility systems will lead to the decline of internal combustion engines over the next 10 to 20 years. To electrify the current transportation systems, it is widely admitted that the development of charging infrastructure is needed. This study analyses the balance between supply and demand of electric mobility infrastructure comparing both factors with a power and spatial perspective (the unit used was kW/km^2). The model was based on data from electric vehicle (EV) registrations and charging network distribution. The gap between supply and demand is spatialized using QGIS. Milan is the case study of the work.

Author Keywords: Electric Mobility, Electric vehicles, Charging points, Charging infrastructure, GIS, Milan.

1. Introduction

Carbon constraints and the more stringent emissions directives pave the way for zero emission mobility. Electric vehicles during their operation do not produce any tailpipe pollutants such as NOx or CO contributing to improve local air quality and public health. The electrification of urban transport requires new supporting infrastructure, creating new and complex challenges for engineers and city planners (Maia et al. 2019; Enel Foundation and Politecnico di Milano 2015). The location of charging points is a well described problem in literature, but each approach carries its specific advantages and limitations, an overview of the different methodologies can be found in (Pagany et al. 2018).

The presented approach helps to identify the imbalances between charging points and electric vehicles currently present in the MUR (Milan Urban Region).

2. Materials and Methods

Charging infrastructure planning should guarantee that the supply is enough to cover the demand and that additional resources are not wasted to serve demand that is not there.

To access the balance between supply and demand a power comparison was made between the two. The demand in this study is defined as the amount of power needed to charge the electric cars of a specific area and supply as the amount of power provided by the charging points in a specific area. To compare these two factors the common unit - kW/km^2 is used. All the data used was regarding the year of 2019 since this was the latest available data at the time of this article. To investigate the balance between demand and supply the power gap was calculated by subtracting the two factors. The data was aggregated at a municipal level with the administrative borders of the municipalities being extracted from the ISTAT (The Italian National Institute of Statistics), the results were then spatialized in QGIS. The case study of this work is the MUR, the MUR can be defined as a transregional territory including 964 municipalities with dimensions similar of a 10000 km^2 square centered in Milan. A study done on the region can be found in (Pucci 2021).

2.1. ***Demand***

Vehicles need to be charged in accordance to how much they are driven and the driving conditions. To calculate the demand five variables were used as described in equation (1).

$$De = \frac{C * D * NEV}{T * MA} \tag{1}$$

De – Demand (kW/km^2)	C – Vehicle consumption (kWh/km)	D – Distance travelled (km)	NEV – Number of EVs	T – Time availability to charge (h)	MA - Municipal Area (km^2)

The vehicle consumption can vary according to the weather conditions (temperature, rain) and to the speed (highway or city driving). The value of 18 kWh/100km was used as the reference (average value from Tesla Model 3 ev-database.org/ consumption). In future works the consumption would be calculated taking in consideration the average car speed travel of the municipality. For the distance travelled, the values used were based on the ACI car report (Automobile Club d'Italia 2012). The value of 31 km per day was fixed for the entire region. The number of electric vehicles registrations per municipality were extracted from the ACI open database opv.aci.it/. The time availability to charge variable tries to define the available time during a day that an electric vehicle could be plugged, the 8h value was selected from the range of average parking duration described in (de Gennaro et al. 2013). The municipal area was calculated using QGIS area function for the ISTAT administrative shapefiles.

2.2. ***Supply***

Charging stations differ significantly in terms of capacity, some are capable to charge multiple cars with high power while others are only capable to slow charge a single vehicle. For the supply analysis the data was obtained from opencharegemap.org/ database and aggregated at a municipal level. To calculate the supply, five variables were used as described in equation (2).

$$S = \frac{P * NP * NS * U}{MA} \tag{2}$$

S - Supply (kW/km^2)	P - Power of the charging station (kW)	NP - Number of Plugs	NS - Number of stations	U - Usage of Public Charging %	MA - Municipal Area (km^2)

The electrical power, number of plugs, and number of stations (a total of 1397 stations) were extracted from the open charge map database. According to the smart mobility report (Energy&Strategic Group 2019), around 20% of the total charging in Milan is done at public chargers, so that was the value used in the usage of public charging variable. The municipal area was calculated analogously as the supply.

3. **Results and Discussion**

In Figure 1 is possible to see the heat map of the power gap over the MUR. Color coding was used to visualize the power gap distribution ranging from red (negative values) to green (positive values). Brown colors are indicative of intermediate values of absolute value closer to zero. Since the power gap is constructed from the subtraction of demand to the supply, negative values indicate that there is more demand than supply and positive values indicate that there is more supply than demand. Absolute zero values indicate that there is neither supply or demand, or that they have exact values and cancel each other. Milan (and adjacent municipalities) and Bergamo are both displayed in green meaning that there is more supply than demand but these two urban poles are disrupted by a red region indicative of a poor electrification in this mobility corridor. The North part of the MUR can be seen with alternating colors of green and red suggestive that the region has demand that is only covered by some municipalities. In the South part of the MUR the brown tones are dominant revealing a lack of both demand and supply meaning that e-mobility is underdeveloped in this part of the MUR.

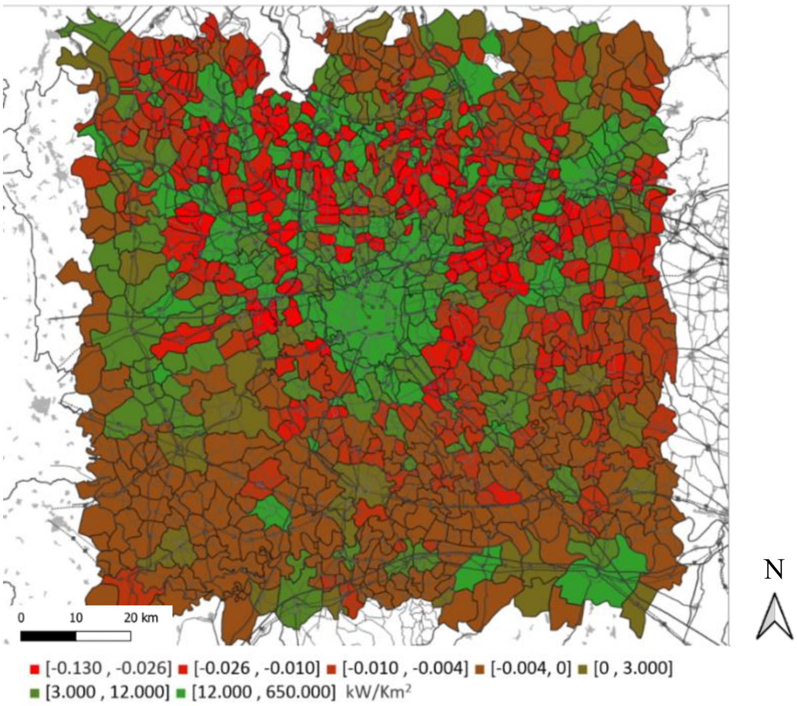

Figure 1: Spatial distribution of the power gap (supply and demand) for the MUR.

4. Conclusions

The main highlights to be extracted are that: most of the Milan urban region does not have any charging infrastructure (66% of the municipalities ≈ 6000 km^2). There is an over dimensioning of supply in several municipalities (Villa di Serio, Binasco, Ponte San Pietro) with supply values having an order of magnitude higher than demand 620 >> 0.5 kW/km^2. The North part of the MUR is more developed in terms of electric mobility, but the charging point distribution is not homogenous.

The accuracy of the model could be improved by incorporating the origin destination matrixes of the different municipalities, the current approach assumes that cars will mostly remain inside their municipalities. In the case of available data on municipal EV registrations, the approach could be easily replicable to other cities and territories of similar scale since the charging points were extracted from a global database.

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Towards mobile ticketing design principles: an empirical study

Marta Campos Ferreira[1,2], Teresa Galvão Dias[1,2], João Falcão e Cunha[1,2]

[1] Faculdade de Engenharia da Universidade do Porto, Porto, Portugal
[2]INESC TEC, Porto, Portugal
{m.c.ferreira@fe.up.pt, tgalvao@fe.up.pt, jfcunha@fe.up.pt}

Abstract

Mobile ticketing services allow urban transport passengers to travel easily and conveniently, enhancing their travel experience. In recent years, several mobile ticketing services have started to be developed and launched, but much remains to be done in terms of their effectiveness, efficiency and innovation. In June 2018, a mobile ticketing system, called Anda, was launched to allow the payment of public transport services in the Metropolitan Area of Porto (AMP), Portugal. The solution was previously tested in a real environment, at AMP. The tests involved 140 real passengers, who used the mobile app during their daily trips. This paper presents the evaluation methodology that was followed during the development of Anda and a set of design lessons that were learned from the field tests, constituting important contributions to the design of future mobile ticketing services.

Author Keywords: Mobile ticketing, pilot trial, urban passenger transport, service design, user-centered design.

1. Introduction

In June 2018 the *Anda* mobile ticketing solution was commercially launched in the Metropolitan Area do Porto, Portugal, and is being used by thousands of passengers every day (Ferreira et al. 2021). A total of 19 transport operators, consisting of metro, train, one public bus operator and 9 private bus operators, accept *Anda* as a mean of payment for the trips of their passengers. The *Anda* solution is based on a check-in/be-out scheme, where the customer intentionally checks-in at a vehicle/station, by tapping the mobile phone on an NFC reader. The alight station is automatically detected, as well as intermediary stations along the trip. The price to be paid by the customer is calculated by a fare optimization algorithm that minimizes the cost for the passenger. Before being launched, the *Anda* solution has been extensively evaluated and tested for over a year, through a field trial involving around 140 real passengers.

There are several research studies on mobile ticketing, however Dahlberg, Guo, and Ondrus (2015) argue that researchers continued to focus on a small number of topics, particularly in consumer adoption and technology aspects. While consumer adoption research has led to a limited number of new findings, the description of technology solutions has been failing to provide proper evaluation of the proposed solutions, with few insights about how it works in real world. Hence, when presenting a new mobile payment system, it is important to provide proper evaluation results, by collecting data from the real world, through field tests or experiments. This remains a weakness in the existing literature, and this paper intends to overcome this weakness by presenting the results that have emerged from the field trial.

2. Materials and Methods

The evaluation of the Anda solution consisted on testing the mobile application and the other components during a pilot trial. These tests were performed in a real environment, in the city of Porto, during 1 year, from April 2017 to June 2018, involving 140 real passengers, who used the mobile application during their daily trips. Passengers interacted daily with the research team via a dedicated Facebook group or email. The evaluation methodology consisted of four different phases:

1) Pilot presentation and training session;
2) Survey for sample characterization;
3) Experimental pilot;
4) Focus group sessions.

Data was collected using different methods: a questionnaire, experimental tests, observation, and focus groups. A descriptive analysis of the questionnaires was carried out, allowing to characterize the sample and understand the initial perception of customers about mobile payments.

The content of the Facebook group, emails and the transcription of the focus group sessions were analyzed based on the grounded theory approach (Corbin and Strauss 2008). First, a literature review was made, focused on the study of consumer adoption and new technological solutions. Then, each comment on the Facebook group, emails and each relevant excerpt from the transcribed focus groups were analyzed and assigned provisional conceptual codes. Considering the relationships between the codes, codes were then aggregated into categories. These categories were continuously compared with ideas and concepts that had emerged from the literature review. The objective was to systematically improve and relate categories. At the end, the categories were integrated and refined (Corbin and Strauss 2008). The objective was to find high-level categories of mobile ticketing design principles, as presented in the next section.

3. Discussion

This section presents the five mobile ticketing design dimensions that emerged from the qualitative analysis of the experimental pilot. These dimensions consist of: 1) cognitive adaptability; 2) value proposition, 3) privacy and security perception, 4) perceived risk, and 5) user experience (see Figure 1).

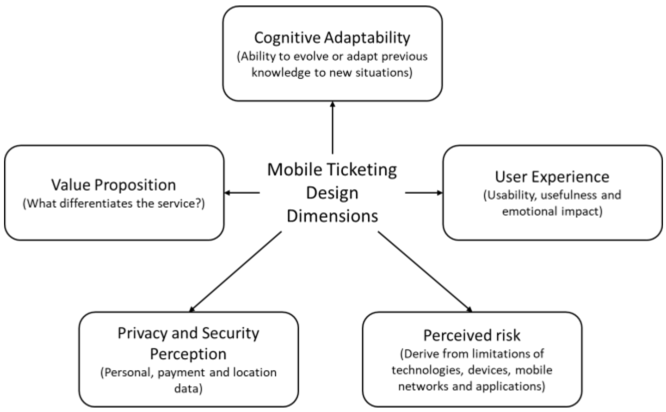

Figure 1: Mobile ticketing design dimensions

1) Cognitive Adaptability

From the cognitive adaptability dimension, it became clear that adapting to a new ticketing media takes time, especially if it differs from the media to which people were accustomed. During the pilot, participants reported difficulties in carrying out the validation, as they were using prior knowledge on similar situations (card validation) to handle new situations (mobile phone validation). In order to deal with this problem, transport operators can adopt strategies that help customers to understand and adapt to the new validation procedure and thus accelerate the learning curve. Examples include: videos and tutorials explaining the new validation procedure, or even front-line employees providing training to customers.

2) Value Proposition

The adoption of a mobile ticketing solution is directly linked to the value proposition that this service offers. In the case of Anda, the optimization of the price to pay, the lack of need to know the transport network and its fare rules and to buy tickets before using the service, proved to be determinant factors to adopt the mobile phone as a mean of payment. Service providers must ensure a clear demonstration of their benefits and strive to raise customer awareness to attract more customers.

3) Privacy and security perception

The security perception of a mobile ticketing solution is closely related to the privacy of customer data, namely personal, payment and location data. In general customers perceive that mobile ticketing solutions are secure, because they transfer their trust in online payments to mobile payments, considering that their data is also well maintained in the mobile context. Customers also consider that access to location data by transport operators is already normal in the context of the use of public transport.

4) Perceived risk

Perceived risks often derive from the limitations in mobile networks, technologies, devices, and the actual ticketing solutions. Mobile networks have limitations in connection, speed, and coverage; mobile phones have short battery life; sensors are prone to errors; and software failures may occur.

5) User Experience

User experience in mobile ticketing include the influence of usability, usefulness and emotional impact while interacting with the solution. Obviously, the goal is that the user experience recalls positive emotional impacts, such as joy of usage, pleasure, fun, excitement, novelty, curiosity, aesthetics, surprise, happiness and delight. However, it is possible that certain situations trigger negative emotions, such as stress, uncertainty, discomfort or anxiety. This may happen, for instance, if the application crashes in the middle of a trip, running out of battery, or failing to validate the entry into the vehicle. It is intended that the overall emotional impact is positive and that the customer feels satisfied with the interaction with the service so that he wants to use it again and that it becomes meaningful for him.

4. Conclusions

The *Anda* solution has been thoroughly tested for over a year, before its market launch, through a field trial involving 140 real passengers. The application of different research methods – questionnaire, experimental pilot, observation, focus groups – allowed to obtain a deep knowledge about the solution in particular, and about mobile payments in general. The analysis of the collected data resulted in a set of design lessons that were materialized in five dimensions, being important contributions to the design of future mobile ticketing services.

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Optimal Design and Evaluation of more Sustainable and Equitable Public Transport Networks

Mudassar Shafiq[1], António Lobo[1], António Couto[1]

[1] Faculty of Engineering of the University of Porto, Research Centre for Territory, Transports and Environment, Porto, Portugal
{mudassasrshafiq10@gmail.com, lobo@fe.up.pt, fcouto@fe.up.pt}

Abstract

The world's population and the number of people living in and migrating to the urban areas for better opportunities has increased rapidly over the last two decades. This has resulted in greater levels of car ownership in urban areas, congestion, higher emissions and environmental pollution, over-burdened road infrastructure and insufficient alternate transport facilities. These trends have led to many social disparities among the societies and people while accessing the services and opportunities available in the area.

Efforts are being made all over the world to plan and design public transport networks which are more efficient, equitable and sustainable, so that they emerge as a preferred mode of transport and serve the needs of all the groups of the society.

This work targets the design of efficient, equitable and sustainable public transportation networks using two multi-objective (bi-level) optimization models. In the first phase, the model will minimize the total user cost and maximize the accessibility to the services, using horizontal and vertical equity constraints. Then, in the second phase, the model will consider the modal choice and modal share for public transport (demand effect) that will serve as an indicator of sustainability, along with efficiency and equity.

These network design models will be applied and validated to a real-world case study that will lead to an optimized network with equity, and greater modal share and maximized accessibility, in comparison to the existing transit route network.

Author Keywords: Accessibility, Efficiency, Equity, Multi-objective Optimization, Public Transportation (PT) Network Design, Sustainability.

1. Introduction

Public Transport systems are becoming vitally important for mobility, as societies are becoming more urbanized than ever before. The public transport systems are evolving as an important mode of transportation mainly for the two reasons. First, increasing car dependence and high number of trips by car travel have very damaging consequences on our physical well-being, health, the environment (Litman, 2002; Shannon et al., 2006). Mitigating adverse effects such as increased emissions, road congestion, and traffic accidents, by reducing car travel is improbable unless other modes of transport are integrated in the system and available to readily access the daily life activities and destinations (Mavoa et al., 2012). Improvements and advances in the services provided by well-planned and designed public transport systems have led to drops in the total travel time and cost associated with travel (Kim et al., 2019).

The other significant aspect in the provision of public transport in an urban environment relates to equity issues. Irrespective of the accomplishment of policies to reduce car ownership and car travel, there has always been a significant percentage of the population in a society who cannot afford private cars and are dependent on public transport services, and this population is likely to grow in the future. The traditional planning, design, and provision of public transport services results in a serious spatial and social inequity to the travellers who do not have enough or direct access to them (Mavoa et al., 2012).

The current structure and distribution of the public transport services not always provide enough service to meet the increase in demand for transit mode. So, there is a need to provide better access to these services and as per the needs of the people by incorporating these factors in the planning of public transport systems. This study aims to define and select suitable measures for accessibility and horizontal/vertical equity based on demographics data at the urban scale, and to incorporate these measures in the formulation of mathematical multi-objective optimization models to design public transport networks.

2. Methodology

The aim of this study is to develop a methodology and decision tool that helps plan and design the public transportation network by considering the demographic characteristics at the lowest spatial scale possible in the form of equity measures and to enhance the efficiency of public transport by maximizing the accessibility and coverage of the services provided, thus reducing travel times. Two multi-objective optimization models are formulated to explicitly consider the horizontal and vertical equities: first, a model will consider the public transport supply and optimize the PT network using efficiency-equity; then, a second model will consider the demand effect for different modes and evaluate the demand-sustainability of the system due to modal shift in an equitable PT network.

These universally applicable models are applied to a real-world case study, specifically the public transport network in Porto, Portugal, thus showing its potential.

In the context of measuring equity for the individuals and groups of society, accessibility i.e., a person's ability to reach necessary or desired activities (Geurs & van Eck, 2001) is used as a measure for user-centred efficiency of a public transport system. There are numerous measures of accessibility widely used depending on the spatial scale and the context in which they are applied. Gravity measures considering the travel time and distance to access the services and activities in the specified zones will be used as a decay function and attractiveness of the opportunities.

Measuring the equity and incorporating it in the development of public transport systems is key in this research work. The Gini index has been used to measure equity in several studies (Welch, 2013; Kaplan et al. 2014). Thus, a Gini coefficient, adapted to reflect the distribution of transit supply, will be used as a measure of horizontal equity to describe the distribution of transit supply throughout an urban region. For vertical equity, a revised Gini coefficient according to Camporeal et al. (2018), and a weighted supply index and public transport need (PTN), as a social indicator (Currie, 2010; Foth et al., 2013), will be used as instruments capable of identifying underprivileged groups lacking access to goods and resources. The modification of these measures is dependent upon the details of the data received, i.e., the aggregation level.

Incorporating the accessibility and equity measures in the optimization models is a big challenge. The Transport Network Design Problem is formulated with the goal of minimizing the objective function under conflicting objectives of several stakeholders. These subjects usually have different goals, and a trade-off among their interests must be achieved.

The objective function is the generalized cost, which includes the user costs, generally measured in travel distance or time to reach destinations. Other important inputs are the transit network layout, location of the stations, and the origin-destination demand matrix. Constraints are generally the resources availability, budget constraints, and practical guidelines.

3. Closing remarks

In a sustainable urban environment, it is important that public services like public transport fulfil the very purpose they are built for, which should be ensured by planners, designers, policy makers and decision makers. The social and physical structures of the urban society are critical in the context of the problem. There is a need to improve the traditional design and planning approaches by promoting more accessible and sustainable public transport systems and avoiding solutions that lead to social exclusion. In this work, the developed models will allow to plan and design public transport networks that are:

i) more equitable: equal opportunity for everyone living in an urban area and satisfying the needs for specific classes/groups of the society;

ii) accessibly efficient: in a way that people can easily reach and have access to public transport services by walking;

iii) demand sustainable: by designing it in a way that it is more equitable and accessible, so that more and more people benefit from the services provided, resulting in a shift of commuters previously using private cars to public transport.

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A multidisciplinary approach for urban mobility

Sérgio-Pedro Duarte[1], Jorge Pinho de Sousa[1], Jorge Freire de Sousa[1]

[1]Departmento INESC TEC / Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-265 Porto, Portugal
{s.duarte@fe.up.pt, jorge.p.sousa@inesctec.pt, jfsousa@fe.up.pt}

Abstract

Cities are complex dynamic systems where multiple stakeholders interact to obtain value for their personal activities. Regarding urban mobility, those stakeholders have access to resources that are managed by municipalities and transportation services. Moreover, technology has had a big influence on how people use those resources and in the evolution of the transportation services. With the current concerns about climate change and citizens quality of life, municipalities are seeking new solutions for creating sustainable cities. Traditional approaches to urban mobility focus mainly on one perspective of the city. We believe that a multidisciplinary approach can support the development of sustainable solutions for both policy makers and mobility service providers. Adopting a service-dominant logic, we have developed a multidisciplinary framework for urban mobility with four dimensions for urban mobility and three pillars from the S-D logic. This work resulted from experts and practitioner consultation, in the Porto region, in Portugal.

Author Keywords: urban mobility, service-dominant logic, service design, smart sustainable cities.

1. Introduction

The increasing complexity of metropolitan areas, with a consistent growth of population, has raised several challenges regarding urban mobility and logistics. Seeking to improve the quality of life of the citizens, municipalities are investing in new solutions for the use of public spaces and the mobility of people and freight. However, the increasing level of digitalization and the multiplicity of information and technology communication tools led us to a socio-technical transition period (Spickermann, Grienitz, and Von Der Gracht 2014) with visible changes in the behaviour of people and the development of new business models, thus creating even more challenges for urban planning and urban mobility. Common strategies to tackle these problems are based on designing new policies (Rupprecht 2019) or improving transportation networks, either by investing in infrastructure or optimizing transport services and operations (Farahani et al. 2013). Nevertheless, if the ultimate goal is to improve the quality of urban life, those solutions must be centred on the needs of urban stakeholders, mainly the citizens.

The current socio-technical transition period, grounded on the digitalization trends and the awareness of a need for integrated solutions, provided the opportunity to design and deploy a multidisciplinary approach for handling the current challenges. This approach builds on viewing cities as complex systems and is designed by applying concepts commonly used in service design, such as service-dominant (S-D) logic and value co-creation (Lusch and Nambisan 2015). In this work we describe the basis of this multidisciplinary approach, and discuss the underlying choices.

2. Materials and Methods

The adopted research methodology included a mixed approach of literature review, expert consultation, and interviews with practitioners.

The research started with a literature review to identify common practices in urban mobility planning and management. It included scientific papers and guidelines from the European Commission for policy design. Then, we have consulted experts (one civil engineer from the urban planning domain, one civil engineer from the transportation domain, and one geographer from the territorial and land use domain) to identify the main research topics to take into account in the urban mobility context. These experts were from the fields of urban planning, urban mobility, and geography.

Finally, we have performed interviews with practitioners from seven municipalities of the metropolitan area of Porto (AMP), in Portugal. Considering the different organizational structures and different socio-demographic characteristics of the municipalities, the practitioners contacted represented different areas of the administration (urban planning, urban mobility, city infrastructure, citizen support) in a total of 15 people. These interviews gave us insight on how municipalities are tackling urban mobility issues, namely regarding policy design, infrastructure management and citizen interaction.

3. Discussion

Although there is a common goal in creating a sustainable city and tackle the climate crisis, the quality of urban mobility services is influenced by the characteristics of the urban space regarding the urban infrastructures and public spaces; by the socio-demographic characteristics of the population; and by the way the municipality is organized. Moreover, the available technological resources can be used to improve urban mobility solutions.

Considering all of the above, we developed a multidisciplinary approach that encompasses four dimensions (Figure 1): *urban*; *social*; *technological*; and *organizational*.

The *social* and *urban* dimensions focus on people and their interactions and activities in the urban context. The *technological* and *organizational* dimensions are related to the processes supported by information and communication technologies. The *organizational* dimension also relates to decision-making processes, as the organizational structure of the municipality (departments, divisions, etc.) impacts the flow of information before it reaches the decision-maker and/or the citizen.

The dimensions proposed in this work consider the elements of the S-D logic (*service ecosystems*; *service platforms*; and *value co-creation*) and the meta-theoretical foundations of the S-D logic framework (*actor-to-actor networks*, *resource liquefaction*, *resource density*, and *resource integration*).

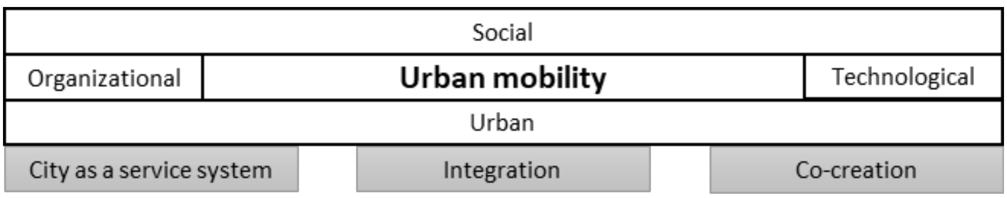

Figure 1. Pillars and dimensions for urban mobility multidisciplinary approach.

Service ecosystems and *actor-to-actor* networks are visible when we compare cities to service systems and, as a result, deal with a network of stakeholders and their many-to-many interactions. The concept of *service platform* is present in the proposed holistic vision of the city as the place where service exchanges occur, and the consequent *resource integration*. Though S-D proposes the integration of resources, we consider integration refers to more than resources, and we propose the integration of the study of land use and mobility, the integration of different management levels and the integration of stakeholders (through active participation). Finally, the concept of *value co-*

creation is also present in our approach, as participation of different stakeholders allows for the co-creation of information and knowledge about the city and transportation systems, thus creating value for the different stakeholders' groups. These concepts provide the support for the four adopted dimensions and can be considered the pillars of our multidisciplinary approach: *city as a service system*; *integration*; and *co-creation*.

4. Conclusions

Applying a S-D logic to urban mobility allowed us to adequately study the complexity of a multiple stakeholder context such as urban mobility. Using the S-D logic we have considered a multidisciplinary approach supported by three pillars: *city as a service system*; *integration*; and *co-creation.*

Understanding the city as a *service system* reinforces the idea that there are customers (those who benefit from the city) and service providers (those who are responsible for providing a good quality of life). Moreover, the broader concept of service leads us to understand that in any given moment, anyone can become a service provider or a customer, depending on their role in that moment. This also points towards the importance of value co-creation in the urban context, where any stakeholder can retrieve value from interacting with other stakeholder. Fostering *co-creation* in this context assures the development of a collaborative and participatory environment among stakeholders. Having *integration* as a main concern helps us in overcoming organizational barriers, pointing out the need to integrate resources (information, people, tools, etc.).

These three pillars support the four dimensions of the approach: *urban*, *social*, *technological*, and *organizational*. These dimensions relate to the main ways of improving urban mobility, by dealing with urban problems, for urban population, through new technological solutions and better organizational and management processes.

The multidisciplinary approach will support the development of new methods to design urban mobility services, considering all the above four dimensions in an integrated way.

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Towards visual programming dataflows for semantic integration of public transport data

Thiago Sobral[1,2], Teresa Galvão Dias[1,2], José Borges[1,2]

[1] Faculdade de Engenharia da Universidade do Porto, Porto, Portugal
[2] INESC TEC, Porto, Portugal
{thiago.sobral@fe.up.pt, tgalvao@fe.up.pt, jlborges@fe.up.pt}

Abstract

The semantic integration of heterogeneous public transport data is often carried out by domain experts acquainted with Semantic Web technologies and graph databases. This short paper outlines the methodology of a research proposal concerning a visual programming approach to facilitate such a task, making it more accessible to experts, aiming to reduce the inherent technical burden. Visual programming allows manipulating and connecting intuitive graphical blocks, nodes and edges, in the form of dataflows that would encapsulate complex procedures inherent to data integration, e.g. mapping dataset attributes onto the concepts declared into one or more domain ontologies. Such an approach has a simpler conceptual model that can be more appealing to transport experts. The approach will be validated against real data from the public transport network of Porto, a network that went through several changes in terms of fare zone structure and new public transport operators.

Author Keywords: Visual programming, semantic data integration, public transport.

1. Introduction

Ontology-based data integration allows the interoperability of data retrieved from heterogeneous sources. In public transport, Intelligent Transport Systems are the backbone of activities such as operations management, ticketing, and monitoring. These activities and systems are conceptually different, as transport concepts and instance data are expressed in several data models, yielding misunderstandings when trying to interact with other actors and systems. Throughout time, systems are updated and replaced, yielding an accumulation of heterogeneous data with conflicting syntaxes, schemata, or ambiguous information (Sobral et al. 2021).

The interest in ontologies among the transport community has increased recently. Still, enabling data interoperability with ontologies is a complex task that requires domain-agnostic tools, often ill-documented, and expertise in ontology engineering. In practice, transport experts are either unacquainted with this discipline, or do not have the required time or specialized human resources to adequately address these problems. Such difficulties have hindered the widespread application of ontologies into practical contexts (Sobral et al. 2020). The lack of interoperability across systems may cause data to be isolated and analysed in data silos, leading to short-sighted interpretations about urban mobility phenomena.

The recent expansion of the integrated fare system of the metropolitan area of Porto, in Portugal, altered the fare system structure and introduced new routes, stops, operators. Updates have been performed on a per-system basis, building upon existing data heterogeneity. A curation of data that varies across space, time, and multiple actors and systems is required. Such data is provided by systems such as Advanced Traffic Management Systems, which manage operational resources like fleet, stops, routes, vehicle and crew scheduling. Automatic Vehicle Location and Automated Fare Counter systems allow for fleet monitoring and ticketing, respectively, and could serve as input for evaluating the performance of the operational plan, such as schedule adherence, and informing citizens with more accurate real-time timetables and network conditions through Traveller

Information Systems. Moreover, interoperable data would allow one to conduct deeper analyses of mobility patterns, such as origin-destination flows from various spatio-temporal granularities, and detection and prediction of anomalous behaviour on routes and ridership levels. Currently, such analyses are difficult to materialize.

This short paper outlines the initial stages of a visual programming approach to facilitate the semantic integration of public transport data, making it more accessible to transport experts. Visual programming allows manipulating and connecting intuitive graphical blocks, e.g. nodes and edges, in the form of dataflows that would encapsulate complex procedures inherent to data integration, e.g. mapping dataset attributes onto the concepts declared into one or more domain ontologies (see Figure 1). Such an approach has a simpler conceptual model that can be more appealing to transport experts. The approach would be validated against real data from a public transport network by means of a prototype tool, to be evaluated with public transport experts. This study aims to:

a) conceptualize and model the required constructs of visual programming dataflows to enable the mapping of datasets onto ontologies, building upon *de facto* language standards for ontology modelling.

b) develop a visual programming prototype to be validated against real data, subject to usability evaluation with transport experts.

Ontologies are formal, unambiguous models that capture the semantics of a domain of knowledge; they provide the foundation for integrating disparate data sources, so that the meaning of data can be understood and reasoned upon by machines, which is an advantage when compared to database schema integration (Katsumi and Fox 2018). Our previous work concerned the development of the Visualization-oriented Urban Mobility Ontology (VUMO) (Sobral et al. 2021, 2020), which provided a semantic foundation for knowledge-assisted visualization tools for spatial events extracted from ITS data, e.g. ticketing data, journey plans, and origin-destination data. In most works, data integration is done by ontology experts with ad-hoc code implementations, or domain-agnostic tools, e.g. R2ML (Pittl and Gill 2018). Both strategies require acquaintance with technical standards and ontologies to be used, which can prevent the use of knowledge-based applications in practice or outside academic studies. Visual programming allows for encapsulating complex logic into intuitive graphical elements connected as a dataflow graph (Pittl and Gill 2018). Applications of such method in ontology studies are still scarce, e.g. (Pittl and Gill 2018; Sousa 2012), thus we argue that this is a research topic worth exploring.

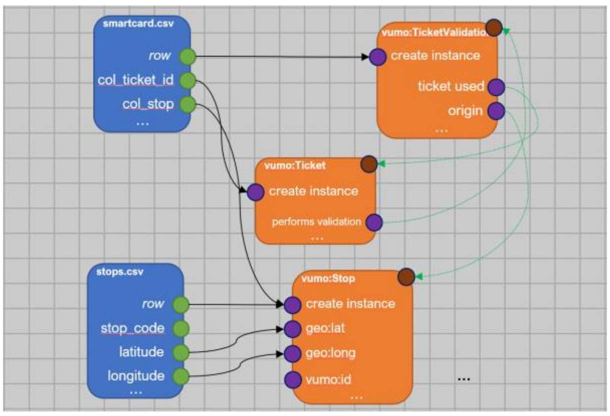

Figure 1: Semantic integration of raw datasets using visual programming. The blue nodes represent the raw datasets. Orange nodes depict ontological resources in human-readable form, abstracting complex ontological specifications. The user can manipulate the black arrows to specify how attributes should be integrated. Green arrows show the implicit semantic relations between concepts.

2. Materials and Methods

Given the exploratory nature of this work, the first activity consists of the definition of the conceptual model upon which visual programming dataflows will be designed, building upon the domain ontology that was proposed in our previous works (Sobral et al. 2021, 2020; Katsumi and Fox 2018) . Such a model should define:

i) the visual constructs, e.g. nodes and edges, and the interaction mechanisms that a user can manipulate to specify the dataflows, i.e. how raw datasets should be semantically integrated and represented in terms of such domain ontology and the mapping the attributes of datasets onto ontological constructs, e.g. classes and properties;

ii) the procedures and inference rules to be encapsulated into the visual constructs, which will automate the logic inherent to semantic data integration, expressed as pseudocode and logical dataflows.

After the first iterations of the conceptual model, the visual constructs, procedures and rules will be modelled using semantic technologies like Web Ontology Language (OWL), Resource Description Framework (RDF), SPARQL, and SPARQL Inferencing Notation (SPIN). The outcomes will be incorporated into a visual programming tool prototype, to be developed and evaluated in a practical context.

The prototypical dataflow-based visual programming tool will be developed and evaluated to assess the practical utility and validity of our ontology-based approach, from the transport experts' point of view. The prototype will support one or two illustrative domain tasks which will require experts to integrate heterogeneous data to carry out a set of analyses and perceive the conceptual model inherent to our approach. The prototype tool will store the resulting knowledge graph in a graph-based (triple) store, e.g. GraphDB, neo4j, with support to automated reasoning using inference engines found in frameworks, e.g., Apache Jena.

3. Value for Society

The outcomes of this study are expected to form the basis for an intuitive domain-specific, dataflow-based visual programming language for semantic integration of public transport data, to facilitate the task of expressing heterogeneous data into current reference standards, such as those recommended by the European Union, e.g., Transmodel, NeTEx, and SIRI. We expect that the rationale and results of this study can be reused and scaled to other transport contexts, thus effectively increasing the use of ontology-based approaches in practical situations besides the academic context.

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AUTHORS INDEX

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www.fe.up.pt/dce21

dce@fe.up.pt