DCE 19 3rd DOCTORAL CONGRESS IN ENGINEERING

DOCTORAL CONGRESS in ENGINEERING

Book of Abstracts

1st Symposium on Transport Systems and Mobility

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

DCE 19 3rd DOCTORAL CONGRESS IN ENGINEERING

Book of Abstracts

of the

1st Symposium on Transport Systems and Mobility

Editors

Jorge Pinho de Sousa

Marta Campos Ferreira

Porto
June 2019

This volume contains the abstracts presented at the Symposium on Transport Systems and Mobility, within the 3rd Doctoral Congress in Engineering - DCE19, held in Porto, between June 27th and 28th, 2019.

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WELCOME

The one-day symposium on "*Transport Systems and Mobility"* held in the scope of the 3rd Doctoral Congress in Engineering (DCE19) is an excellent opportunity for doctoral students 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 topics of research and for surveying the main trends in this area.

This year's meeting covers topics on urban mobility and city logistics, and will surely promote an informal networking of the participants, and in particular of young researchers and doctoral students.

Master students may also enjoy participating, and therefore discover this fascinating inter-disciplinary area of research and professional activity. Transport systems and mobility are, in fact, having an enormous growth and are an important part of everybody's lives. But they are also a field for a large and broad range of activities, from applied research to the development of new business models and start-ups.

Research and technological trends such as 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.

The challenges are immense but we will all be ready to face them by developing high quality research, together with companies, authorities and operators, in order to help solve some of the biggest societal problems of today.

Porto, June 2019

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Symposium on Transport Systems and Mobility

Chair: Jorge Pinho de Sousa

Location: B031

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João Rui Marrana

Managing Director

Transportes Intermodais do Porto

Topic: Sustainable mobility: zooming from the planet to the ticket

Academic Background

Master in Urban Engineering (1996, Faculty of Sciences and Technology – Coimbra University).

Graduation in Civil Engineering (1986, Faculty of Engineering – Porto University).

Professional Activity

Nowadays: Managing Director of TIP (Porto Ticketing Consortium) (2016 - …) and Assistant Professor of Portucalense University, Lecturing Transport and Mobility (1996 - ...).

In the past: Member of the Board of Directors of several organizations, namely of the Regional ERDF Programme (2012 – 2015), AMTP (Porto Transport Authority) (2010 – 2012), STCP (Porto Bus Company) (2003 – 2009).

Participation in technical and professional organizations

Honorary Member of UITP – International Association of Public Transport (2013 - …), acting as Vice-Chair (2009 - 2011) and Chair (2011 - 2013) of the Transport & Urban Life Commission.

Nuno Ulisses Costa

Logistics Project & Innovation Country Manager

Luís Simões

Topic: Luís Simões: innovative and sustainable logistics

Academic Background

Lic. in Electrical and Computers Engineering, from the Faculty of Engineering of University of Porto.

Master in Logistics from the Polytechnic Institute of Porto.

Open Executive Program in Project Management from Porto Business School.

Professional Activity

16 years of experience in supply chain management (national and multinational companies).

15 years of experience as trainer.

5 years of experience as project manager.

6 years as a university lecturer.

19 years as a leisure activity manager.

Participation in technical and professional organizations

Member of the GS1 Good Practice Committee.

Participation in seminars, conferences, pitches.

ABSTRACTS

Costs and benefits of public transportation: an urban mobility plan for Fortaleza, Brazil

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Abstract

The allocation of budgetary resources in urban mobility plans naturally causes positive and negative externalities on different sectors of the society. The objective of this study is to estimate the costs and benefits of the Urban Mobility Plan developed for Fortaleza (Brazil) that defines urban strategies until 2040. According to this plan, the expansion of the public transportation system, associated with other urban actions that bring closer the supply and the demand of services, will result in a significant reduction of journeys (measured here in vehicle-kilometer). For this purpose, a cost-benefit analysis was made for a period of 20 years. The main economic benefits identified are associated to property appreciation and to the reduction of vehicle accidents and journey time, these benefits being higher than the benefits associated to the reduction of air pollution. Among the costs, most of them result from the investments in public transportation lines.

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Keywords. Urban mobility; public transportation; cost-benefit analysis.

1. Introduction

Public transportation is essential in developing countries. As the public transportation offer requires medium and large vehicles, its operation requires a lot of different resources as well as special infrastructure, either through systems that prioritize the circulation of buses or through the implementation of systems on rails. For this reason, it is always necessary to discuss and evaluate the means of acquiring the necessary resources for the operation of a good public transport system. The objective of this study is, therefore to estimate the costs and benefits of the Urban Mobility Plan developed for Fortaleza (Brazil) that defines urban strategies until 2040.

2. Context and research objectives

The economic principle of a Cost-Benefit Analysis (CBA) of public transport is that uncovered and unpaid costs lead to a misuse of public equipment – especially traffic (CCE, 1995; Quinet, 1993). The study of externalities has many theoretical and practical difficulties. The theoretical difficulties are related to the complexity of the theme, the many variables involved and the different valuations that can be made of those variables. An important part of the problem is associated to: the valuation of externalities, since many of them have no current monetary expression, as pollution; the fact that they are not part of the market transactions, as the clean air; and to the fact that philosophically they do not admit valuation, as life. The practical difficulties can be associated to the measurement of those externalities, not only because of the problems' dimension, but also because many of them are intangible. However, those externalities should be calculated. Some effects are easy to be measured, such as the time excess imposed by one-way congestion, while others are difficult to measure, such as the effects of pollution on people's health. In the case of

traffic, the simplest indicator is the excess travel time in relation to what would occur in a non-congested condition, as adopted in the IPEA / ANTP study (1998), for example. In addition, the most relevant factor for public health is the concentration of pollutants in the atmosphere, which depends on atmospheric conditions such as wind speed and its direction. Thus, large emission volumes may not result in a direct public health problem if there are high-speed local wind speeds. On the other hand, small emissions can cause great damage if atmospheric conditions are unfavorable.

3. Adopted methodology

After the literature review, the methodology used to estimate both benefits and costs caused by the implementation of the Urban Mobility Plan (Fortaleza 2040) is presented. Among the benefits we have: reduction of air pollution, avoided cost with the purchase of fuels, avoided operational cost of individual transport, real estate valuation, reduction of the number of accidents and reduction of travel time. The estimation of carbon credits potentially caused by the reduction in the use of fossil fuels was calculated through the avoided volume of its consumption and through the technical CO2 emission coefficients for each type of fuel extracted from Fortaleza 2040 Energy Plan.

According to the Mobility Plan, the expansion of the public transportation system, associated with other urban actions that bring closer the supply and the demand of services, will result in a significant reduction of journeys (measured here in vehicle-kilometer). For this purpose, a cost-benefit analysis was made for a period of 20 years. The major estimated economic benefits were in real estate valuation, followed by economic gains with the reduction of accidents and travel time, well above the benefits of reducing air pollution. Among the costs, most of them result from the investments in public transportation lines.

4. Conclusions

This research work showed that the greatest economic benefits, as estimated in the plan, were in real estate valuation, followed by the economic gains with the reduction of accidents and travel time, being well above the benefits of reducing atmospheric pollution. Moreover, according to the mentioned premises, the expansion of collective transportation, in detriment of individual transportation, will result in a net present value of 1.4 million dollars of economic benefits between 2017 and 2040, which demonstrates the excellent viability from the project. It is important to note that the results of this research can guide the analysis and decisions of the government in improving public transport. Regarding the limitations of the research, other externalities need to be explored, as it is the case of the opportunity cost of public transport users. This may influence the results of the CBA.

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Two-tier distribution systems based on mobile depots used in the context of *city logistics*

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Abstract

Urban freight transport is an important enabler for economic and social development in cities, but it is also responsible for important negative externalities such as congestion, pollution, noise and less safety. The rise of the urbanisation rate, the economic improvement in urban areas and the increase in e-commerce are aggravating factors that will most certainly contribute to increase the demand for transportation in urban areas. To tackle the negative externalities of urban freight transport, several *city logistics* solutions have been proposed.

Two-tier distribution systems and urban distribution systems based on mobile depots have been proposed in the context of *city logistics* to mitigate the negative externalities of urban freight transport, particularly for larger and highly congested urban areas. We have surveyed and reviewed cases from the literature, trial reports and online resources. We have characterized the two-tier distribution systems according to the mobility of the first-tier transport mode, types and characteristics of the vehicles used at each tier, the type of loads and operational rules, such as the ability of transport modes to perform multiple trips during a working day.

The aim of this work is to better describe two-tier distribution systems based on mobile depots, to support the selection of the most adequate models and solution methods for each variant of the system.

Keywords. City logistics; two-tier distribution systems; mobile depots.

1. Introduction

Transportation of goods constitutes a major enabling factor for economic and social activities in urban areas but it is also responsible for generating important negative externalities including traffic congestion, pollution, noise and overall less safety (Demir, 2015). Furthermore, aggravating factors such as the increase in population and urbanization rate, the economic improvement in urban areas, and the rise of e-commerce, have also significantly contributed for the ongoing growth in the demand of goods and transportation services in urban centres (Browne, 2012).

City Logistics plays an important role in creating efficient, environment friendly and safe urban freight transport systems (Taniguchi, 2001; Rodrigue, 2016). In this context, several policy measures, such as urban consolidation centres, regulations of access control to city centres, off-peak hour deliveries or low emission zones have been tested and implemented, alone or in tandem, in urban areas of cities around the world to achieve the goals of mobility, sustainability and liveability (Muñuzuri, 2005; Russo, 2012).

Two-tier distribution systems have been proposed in the context of *city logistics* as a response to the challenges in urban freight transportation, particularly for urban centre zones with a high population density and high levels of commercial and leisure activities and having therefore high

demand levels for freight transportation (Crainic, Ricciardi, & Storchi, 2004; Crainic, Ricciardi, & Storchi, 2009). These systems extend the concept of single-tier urban freight consolidation schemes, such as urban consolidation centres (Allen, 2012), by considering additional transfer points in the logistic chain (*satellites*), where loads coming from facilities in the periphery of the city are transferred, and possibly consolidated, into smaller and more environmentally friendly transport modes better suited to operate in the city centre (Crainic, Ricciardi, & Storchi, 2004). Furthermore, distribution systems based on mobile depots have emerged as a response to the high costs of installing physical infrastructures in the city centre (Arvidsson, 2017; Patier, 2018). These distribution systems consider that transfer locations require very little or no infrastructure and that there is no storage capability at those locations, thus requiring direct load transfers between vehicles operating at each tier. Therefore, to minimize the impacts of freight vehicles transferring loads, load transfers between vehicles should be as seamless as possible. This implies that vehicles should only be at the transfer location the minimum time required to transfer loads, and ideally, they should be synchronized so that waiting would not occur at those locations.

2. Characterisation of two-tier distribution systems based on mobile depots

Several articles have already presented classifications of city logistics solutions (Russo, 2012; De Marco, 2018) but, to our knowledge, the survey, analysis and characterisation of two-tier distribution systems based on mobile depots, with no storage capability, has not yet been properly addressed.

We have conducted a comprehensive literature review on *city logistics* and on two-tier urban freight distribution systems based on mobile depots. We have collected information on the mobility and accessibility of vehicles operating at the first-tier, and the types and characteristics of the vehicles used at each tier, the type of load and of *satellites* used, as well as the operational rules, such as the potential of having vehicles performing multiple trips during a working day. This characterisation is intended to support the identification of the different types of two-tier distribution systems based on mobile depots, and to help select and design the most adequate mathematical formulations to address the different variants.

3. Discussion and conclusions

Most of these cases have been implemented in European cities, with the most used transport mode at the second-tier being environmentally friendly cargo bikes, even if first-tier transport modes still mostly use diesel fuel. Moreover, there seems to be an increased interest in using standardised, modular containers for the seamless transfer of loads between vehicles. The collection of information on these types of systems is, in general, difficult, since quite often the surveyed literature does not report the systems' characteristics in enough detail.

Future work will encompass a review of the scientific literature on operations research models and methods for the design and planning of different distribution systems and their variants, as a way to identify the most adequate modelling decisions for each of the proposed types of two-tier distribution systems based on mobile depots.

Acknowledgments

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Intelligent traffic lights: a person-based method

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Multi-Agent Systems have become a popular paradigm for exploring intelligent solutions in traffic management problems. Traffic control is a geographically distributed paradigm, which takes place in a dynamic environment and where interactions between components are highly complex (Bo and Cheng, 2010). Market-inspired ideas have also been proposed, in recent years, as a paradigm for controlling traffic signal systems (Vasirani and Ossowski, 2009, Vasirani and Ossowski, 2011)

The Multi-Agent System metaphor was selected for designing the architecture of the proposed traffic control system, and auction-based principles are used to develop the signal control strategy. The auction-based planed intersection-control mechanisms allow concurrency between all traffic streams of an intersection, including pedestrian crossings. The traffic signal control should yield a high degree of concurrent utilization of the intersection considering all traffic streams and, at the same time, prevent vehicles from colliding.

Instead of using the traditional vehicle-based optimization perspective, in which the approach is to look at the vehicle traffic condition as dependent on standard metrics such as vehicle flow and vehicle delay, a person-based strategy is instead employed. It seems an interesting possibility to look at the traffic condition distinguishing vehicles with different occupancy, thus allowing a control based on people present/expected at the intersections. In a perspective of society management, it should be more important and valuable to minimize “people” delays or other person-based metrics, instead of vehicle performance measures.

For this purpose, a novel auction-based intersection-control mechanism for traffic signal control was developed. The present methodology underlies a negotiation process, involving all the traffic streams to manage the green time between those streams. The proposed routine decides on a time period (auction frequency), an extension of green time by another interval, or an ending of the present green period, based on current demand and aiming at minimizing the person’s delay. At the end of the green light, a second decision is made in order to select which traffic streams should receive the green light.

All bids are grouped into phases, and a traffic stream bid can be included in more than one “bid phase”. The winners are the traffic stream agents which perform the “bid phase” with the highest delay value. The winning agents gain the green traffic light for the next phase after the inter-green period (if needed) and they receive an accept proposal message from the initiator, whereas the other traffic stream agents that are not in the selected phase receive a reject proposal message. In this case, a new auction will occur after the minimum green time period.

Negotiations are very dynamic, and are initiated in short intervals (i.e. just a few seconds). This mechanism employs a first-price, single-item auction. The global architecture of the proposed traffic control system is designed using a Multi-Agent Systems for isolated intersections. Each intersection operates independently from other intersections, so that each intersection has the freedom and flexibility to calculate and implement any traffic control settings.

In this work two different methods of grouping the bid in phases are tested, as described below.

The first method is named “With Plan”: there is a traffic signal plan in implementation and bids are grouped according to the phases of this plan. Therefore, a new traffic signal plan design can be assumed, i.e. a plan with different phase sequence.

The second method is “Without Plan”: the bids are grouped testing all feasible phase compositions, and, therefore, there is no traffic signal plan constraint.

This system was assessed in a microscopic traffic simulation model.

The preliminary findings from the simulation are encouraging and suggest that there is value in viewing signal control based on persons instead of vehicles. The approach gives more flexibility and freedom to the system so as to manage the green time more efficiently. The phase composition and timing are assumed to be not fixed in this approach.

Keywords: Traffic signal control; person-based traffic control; urban mobility; auction mechanisms.

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Analysis of the pedestrian-vehicle crossing interaction

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Abstract

A big focus has been given to soft modes of transportation. In this way, it is necessary to create the best safety conditions for those who are the most vulnerable users of the road network, with the greatest emphasis to pedestrians. The main goal of this work is to identify the factors which contribute to risk-taking behavior by these road users, by analyzing pedestrian's crossing behavior using data collected through video recordings in real crosswalks and the execution of experiments in a virtual environment. First results show that the proximity of the bus stops to the crosswalk, the width of the streets occupied by parking spaces and the average width of the sidewalks, the crosswalk width and the pedestrian traffic volume were the variables with significant impacts on the vehicle-pedestrian interaction.

Keywords. Pedestrian safety; pedestrian behavior; virtual environments; vehicle-pedestrian interaction; risk assessment.

1. Introduction

There is currently a constant interest in road safety. Several initiatives are taking place each year with the emphasis on soft modes of transport, including cyclists and pedestrians, due to the social and environmental advantages they have. Seeking to prevent the occurrence of accidents that could have serious consequences, promoting greater comfort and safety for all users of the road network is a priority. As far as pedestrians are concerned, there is still a hard work to do. In 2018, in Portugal, 130 people died while they were walking, which corresponds to 22% of the deaths that happened on the roads in that year (ANSR 2018, European Comission 2018). The present work had the main goal of assessing the vehicle-pedestrian interaction at crosswalks, to identify and evaluate factors that might influence the pedestrians' safety, aiming to contribute to the process of improvement of their safety conditions.

2. Adopted methods

This work is based on two fundamental parts. First, video recordings of pedestrians crossing of six different crosswalks were made and data about pedestrians and vehicles' trajectories and speeds was collected. The minimum time-to-collision (TTCmin) was calculated for all the encounters occurred between pedestrians and vehicles (see Hayward (1972)). The influence of the variables such as the slope, the width of the road, the width of the parking lot, the crosswalks and sidewalks' width, the bus stop proximity, the pedestrian and vehicular traffic volumes, the type of road surface, the road functional classification and pedestrians' age and gender was analyzed. The six streets were later modelled to be used as scenarios for experiments to be conducted with human pedestrians in a virtual environment (Figure 1). From the data acquired in the real environment, different types of vehicle approximation movements to the crosswalk were modeled.

Figure 1: Example of a modelled street

The second part involves a set of experiments in a virtual environment. At this time the experiments are being performed. A previous experiment was carried out with 10 participants using two of the six virtual scenarios developed, aiming to validate their implementation. Each participant assessed a set of stimuli corresponding to the passage of a virtual vehicle. The time-to-collision (TTC) was registered to the time they started the crossing and compared with the values obtained with the video recordings at those streets.

3. Discussion

Regarding the video recordings data analysis, only the bus stop proximity, the width of the parking lot and the average width of the sidewalks were found to have significant influence on the TTCmin. The TTCmin verified in the crosswalks with a bus stop placed at less than 50 m away was lower than in those which the bus stop was located more than 50 m away from the crosswalk. The width of the parking lot and the average width of the sidewalks had the same impact on the TTCmin: the bigger their values, the bigger the TTCmin. Concerning the previous experiment in virtual environments, a big similarity was found between the TTC obtained in virtual environments and in real environments.

4. Conclusions

Some interesting results were found in the analysis of the pedestrian-vehicle crossing interactions, even if the data sample used was quite small. In the future, we plan to perform this kind of analysis based on TTC and other surrogate safety measures, using a data sample with two times larger than that used in this work. The virtual scenarios and the experimental approach were validated. Nonetheless, the results allowed to identify some areas of improvement to work on, regarding the experimental procedure.

Acknowledgments

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Quantifying robustness of public transportation timetables at the route level

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Keywords. Robustness; slack optimization; timetables; public transports.

1. Introduction

The timetabling stage of the Public Transportation (PT) planning process is normally pursued envisaging the minimum cost of operations. However, daily operations of PT are highly exposed to uncertainty arriving from non-foreseen events, such as congestion, weather conditions or mechanical failures (Farahani et al. 2013). Uncertainty originates delays, decreases the quality of the PT service, and increases its costs (Naumann et al. 2011). Primary Delays correspond to the occurrence of delays due to disruptions that cannot be prevented (e.g., congestion or roadblocks). Secondary Delays occur when the late arrival of a trip segment prevents the following trip segment to depart on time. The inheritance of delays is called Delay Propagation (Naumann et al. 2011). Ensuring that the PT service can recover quickly from Primary Delays increases the overall quality of the service. In addition, it can avoid the costs of dynamic re-planning required to implement recovery strategies at the operational stage.

The management of uncertainty in PT systems can be strengthened with optimization techniques at their planning process. The timetabling stage is best suited for pursuing this goal within the PT planning process, as it allows to incorporate slack time specifically designed to absorb delay propagation at strategic locations of the PT network. These strategic locations are stops or stations that have the adequate infrastructure to hold vehicles in case they are early, and where deviations from schedule are systematically recorded for service quality assessment. They are called Time Control Points (TCP).

Reliability and Robustness are two intertwined concepts in PT. A transportation service is reliable when passengers can count on it, when passengers can trust that trips are going to be performed as planned and on time. There are many aspects influencing reliability, but one with special importance is the robustness of timetables. A timetable is robust when it is designed to absorb delay propagation as much as possible.

This work details robustness measures that are adequate to be incorporated into the timetabling stage, specifically designed to promote slack optimization processes at the route level. These measures were defined after an in-depth comparison of studies addressing robustness in PT planning.

2. Methodology

Robustness of timetables can be quantified for each timetable. To this end the following measures were proposed in Hora et al. (2016). The Average Delay (AD) quantifies the absolute average vehicle delay at each TCP. The Average Anticipation (AA) is defined in an analogous way to the AD, but accounting for anticipations instead. The Proportion of Delays (PD) returns the proportion of trip segments classified as delayed during a period (e.g., one day). The trip segment is classified as

delayed when it exceeds a tolerance threshold previously defined. PD can be interpreted as the probability of a passenger arriving on time at a TCP to wait more than the tolerance threshold specified. The Proportion of Anticipations (PA) is defined in an analogous way to PD, but accounting for anticipations.

Moreover, the robustness of two alternative timetables for the same route can be compared simply and intuitively through the ratio of the previous measures. Without loss of generality, let us relate the ratio denominator to a reference timetable, and the ratio nominator to a new timetable. Accordingly, the Average Delay ratio (ADr) is built dividing the AD of the new timetable by the AD of the reference timetable. Analogously the remaining ratios are: the Average Anticipation ratio (AAr), the Proportion of Delays ratio (PDr) and the Proportion of Anticipations ratio (PAr). When these measures have values lower than 1, it means that the new timetable performs better than the reference timetable regarding robustness.

3. Conclusions

Most studies address robustness in PT planning using tailored definitions and measurements. This work contributes to provide consensus in the quantification of timetable robustness at the route level. The measures detailed are adequate to be incorporated into slack optimization processes, which provide the best allocation of slack time in TCPs at the timetabling stage. Improving the robustness of timetables aids PT service to operate as planned even when unforeseen events occur, therefore contributing to enhance transportation reliability.

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

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The main problems that cities face in order to achieve sustainable development are related to mobility and urban form (EC, 2011). Cities and their legislators face enormous pressures trying to meet current mobility challenges (ARCADIS, 2017) with the aim of consolidating sustainable cities, in which "social and economic development must consider the need to safeguard the human environment for present and future generations" (UN, 1972). This is especially critical as cities have become the main human environment: more than 70% of the European population live in cities (UN-HABITAT, 2016).

European cities are among the most sustainable cities in the world (Newman & Kenworthy, 1999) (Haghshenas & Vaziri, 2012). However, there are in these cities clear trends that threaten the three pillars of sustainability (society, environment and economy) (Alonso, 2017): demographic decline, polarization and exclusion; pollution and depletion of natural resources; spatial and social segregation, inefficient service delivery, land occupation and development and competitiveness under pressure.

To deal with these threats, cities need to consolidate urban systems that promote social progress, proximity and integration, since agglomeration allows more efficient services through economies of scale and density. Therefore, transport systems are key to sustainable urban development, and strategies to articulate transport with land use may play an important role in this area.

In general, four factors explain unsustainable transport systems in cities of the European Union (Alonso & Monzón, 2018): i) modal split, with a greater proportion in the use of the private vehicle; ii), urban dispersion; iii), underperforming Gross Domestic Product (GDP); iv), small agglomerations with low population density.

But, in practice, there is no single strategy for shaping cities with sustainable urban mobility systems, since mobility challenges differ from one city to another and vary according to geographical, ecological, economic and political characteristics (ARCADIS, 2017). Therefore, this research proposes a multicriteria conceptual model as a support tool for the definition of interventions that improve the sustainability of urban mobility systems in emerging cities.

The model assesses actions and strategies for the design of public policies, optimizing performance indicators related to sustainability. A system dynamics simulation model is used for measuring the sustainability of mobility systems in emerging cities, for planning purposes and for assessing the global impact of transport policies, taking into account their behaviour over time and the relationship and interaction of the different elements.

Keywords. Sustainable urban development; mobility; transport systems; multicriteria decision-making; emerging cities; systems dynamics.

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Analysis of pedestrian behavior in individual and group displacements

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Abstract

Many of our actions are influenced by the social context, in particular, by the actions carried out by other people. Within pedestrian flows, people tend to walk in groups such as friends, couples, or families. In this sense, an important aspect that needs to be analyzed is the influence of the relationship between the properties of each person and the collective properties resulting from the social interaction between people. The main goal of this work is to develop a methodology to acquire and analyze empirical data about the movement (characteristics of the gait and speed) and pedestrians' actions (distance, spatial formation), through the realization of field experiments before and during road crossings in urban areas, using wearable inertial sensors and video recordings.

Keywords. Pedestrian behavior; Social interactions; Pedestrian groups; Gait parameters

1. Introduction

The study of pedestrian behavior is essential for the proper planning and design of different types of urban infrastructures. The use of models is a tool that can support transport engineers in managing pedestrian flows. The purpose of any simulation package is to model the characteristics and the interaction of all elements of a system to accurately predict what will happen if a situation changes. It is therefore necessary to try to maintain the rationality of each individual without neglecting the identification of the preexisting social structures (pedestrians' groups) and their interaction within a crowd. According to previous works, the gait parameters provide higher capability of distinguishing how the pedestrian respond to different types of interactions, since pedestrian speed alone may not be adequate (Hussein and Sayed 2015).

2. Adopted Methods

Information about pedestrians' behavior, isolated and within in a group, is being collected through the field experiments before and during the road crossing in urban areas. Video recordings of each experiment will allow to calculate pedestrians' trajectories and speeds by using a semi-automated tool for video processing (T-Analyst 2014). Additionally, one pedestrian will be instrumented with a system for a human wireless motion tracker– Xsens MTw Awinda (Paulich et al. 2018). This tool will allow the collection of gait parameters (e.g. step frequency, step length) and also the speed (Figure 2).

The pedestrians' groups will be organized according to: the size of the group (2 and 3 members), the gender (women, men and mixed), the age (between 18 and 44 years old) and the difference

between height of the group members in three levels: (i) lower than 3cm, (ii) between 3 and 7cm, (iii) more than 7cm.

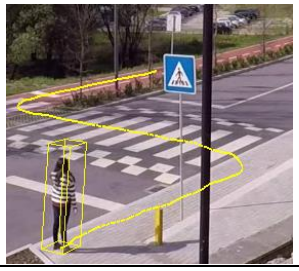
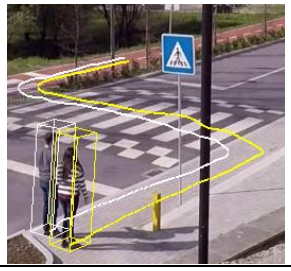
Gait parameters	Analysis with semi-automated tool for video processing		
			
Equipement	Isolated pedestrian	Isolated pedestrian	Pedestrians in group

Figure 2: Example of materials and methods

3. Discussion

The analysis of pedestrian behavior in individual and group displacements is used to describe, in a more rigorous way, the behavioral responses of pedestrians to social interactions, given their ability to adapt movement in response to stimuli of other individuals. Thus, new parameters will be determined to define the internal coordination between the members of the same group.

4. Conclusions

There is a need to better understand the pedestrian behavior in order to enhance existing pedestrian simulation models. To study human behavior, video recordings of the pedestrians' flows in a public place are used. However, the exact conditions of individual characteristics and interactions between people are generally unknown, for example: age, psychological profile, motivations, constraints or relationships between people. Therefore, a more controlled approach should be used regarding this observation types.

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A decision support system for investments in public transport infrastructure

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When public authorities face the need to improve a transportation system, they normally have to make a difficult choice among a set of technological and operational alternatives. To help the correct evaluation of each alternative and its impacts, costs and benefits, it would be useful to have a decision support system (DSS) based on approaches such as Multi-Criteria Decision Analysis (MCDA) and/or Cost Benefit Analysis (CBA).

Among the many impacts caused by a public transportation system, typically those on the land use are not adequately considered in the decision-making processes, mainly because they are hard to monetize, they are often considered as value transfer instead of value creation, and they are too complex to be assessed by traditional transport modeling tools. To overcome these weaknesses, the objectives of this research are to identify and measure the impacts of transit systems on land use and accessibility, and to consider those impacts in decision-making processes, along with more traditional financial and transport related impacts. For this purpose, a DSS, combining a land use and transport model with a MCDA model, was developed. This system was assessed in a small case study, where Bus Rapid Transit (BRT) and Light Rail Transit (LRT) projects are presented, and in a real case study, the *Green Line extension* project in Boston, USA.

The DSS incorporates a range of criteria and subcriteria organized in a hierarchical manner, covering a variety of decision aspects, expert opinions and sensitivity and risk analysis. It aims to more accurately, and realistically reflect uncertainties and exogenous conditions that may significantly affect the costs and the benefits of a project. Consequently, it facilitates public debate about investment alternatives, since it makes it possible to present, in a structured way, the decision problem to the affected community and decision-makers.

Keywords. BRT; LRT; multi-criteria decision analysis; land use and transport; investment analysis.

How to design mobile payment services? Lessons learned from field tests

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Mobile payments, commonly defined as the use of a mobile device to initiate, authorize and confirm an exchange of financial value in return for goods and services, have become a major focus for research and business activities in recent years. A large number of trials have been made across many countries, covering a broad range of payment situations, technical approaches and business models (Ferreira et al. 2014, Rodrigues et al. 2014, Ivan and Balag 2015). While it is already possible to find multiple payment solutions, mobile payments still remain essentially an emerging technology, seeking to fill the gap between its envisioned potential and widespread usage. Therefore, it is important to identify the reasons associated with this somewhat limited success.

Existing research work have focused on the study of factors that influence the adoption of mobile payment services (Fontes et al. 2017, Thakur and Srivastava 2014). Yang et al. (2012) propose and validate a theoretical model with results that suggest that the main factors determining the adoption of mobile payments are related to perceived usefulness, perceived ease of use, perceived risk and compatibility. Koenig-Lewis et al. (2015) extended theoretical foundations for understating mobile payment adoption by introducing perceived enjoyment and social influence as adoption factors. Kim, Mirusmonov, and Lee (2010) demonstrated the existence of clear differences between early and late adopters. Therefore, mobile payment service providers need to apply different business models and strategies depending on the user groups and diffusion stages of mobile payment services.

Due to the complexity of the phenomenon, it is clear that the investigation of consumer adoption in isolation only provides a limited understanding of mobile payments. Furthermore, there is no significant research based on data collected from real users through field tests, experiments and experiences (Dahlberg, Guo, and Ondrus 2015). This research work intends to fill this gap in the literature by presenting a set of challenges and insights associated with mobile payment services, based on data collected from real-world payment situations. It also identifies service design strategies for designing future mobile payment services.

The authors were involved in the design, development and test of two different mobile payment services. One, called MobiPag, was based on Near Field Communication (NFC) technology and allowed customers not only to make payments but also to receive and redeem meal and bus tickets and discount coupons. This solution was tested by 34 participants, in real environment, at the University of Minho Campus (Guimarães, Portugal), during one week. The other, called MobiPag STCP, was based on wireless technology (Wi-Fi, 3G and 4G) and allowed customers to purchase and validate travel tickets. It was tested in the city of Porto, Portugal, by 26 real passengers, during two weeks of their normal use of public transport services.

After both experiments, 60 in-depth individual interviews were conducted, recorded, literally transcribed and analyzed following qualitative tenets (Charmaz 2006). This data was enriched with the comments of the participants and the notes and observations of the researchers during the experimental procedures. A careful and extensive review of the literature was also carried out. After the analysis of the data and the literature, provisional conceptual codes were assigned to the data.

These codes were then aggregated into categories, according to the relationships between them. They were iteratively aggregated and refined, enabling the identification of a rich set of challenges, insights and customer experience factors associated with mobile payment services.

Results show that the ability to integrate tickets and discount coupons directly into the payment process were highly appreciated and clearly seen as a differentiating element that could lead to people's adoption of mobile payments. However, this flexibility comes with a cost in the complexity of the procedures and cognitive overload for users in payment situations, representing a big challenge in the design of such services. The added flexibility leading to a myriad of added services integrated with payments is simultaneously one of the strongest points and one of the biggest challenges in interaction design. What could be a simple payment procedure may become very complex for users when multiple types of coupons, discounts and loyalty schemes become part of the payment transaction.

It was also clear that offering a different payment method to customers is not enough. Exploring the unique characteristics of mobile phones to offer additional and complementary services to the payment process is crucial to contribute to a wider adoption. Customers are expecting to do more tasks with the mobile phone than just paying. They want, for instance, to be able to check the balance and the transactions history, to search for information about the service and service provider and even to interact with other customers.

The perception of security, a major concern in every acceptance survey of mobile payments, was clearly mitigated during the real-world experiments. Providing proper feedback about the transactions and ask for a PIN seems to have a positive impact on customers' confidence in the mobile payment service. Thus, other payment systems should focus on how to achieve a positive initial user experience and how to leverage upon real-world contact with the technology to create a solid path for gradual acceptance through the development of new practices and the perception of value.

The very positive attitude of participants regarding the use of the technology showed that people are open to the new possibilities offered by mobile payments. Thus, managing expectations is crucial. First impressions should be strongly focused on quickly creating a sense of confidence, familiarity and added value with the service, providing the foundation for a sustained use and subsequent exploration of additional services. Designing for emerging practices and not letting people down can mean focusing at the beginning on simple procedures that, albeit limited in regards to the range of technological possibilities, are much safer and less likely to disappoint and drive users away.

Keywords. Mobile payments; user centered design; field tests.

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An integrated information system to support decision-making in the context of transportation systems

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Abstract

In the context of transportation planning and operation decision-making, multiple stakeholders are using the same type of data for their activities. To improve the positive effects of the decisions, everyone that interacts with transportation systems should have easy access to information derived from that data. This access can be improved by an integrated information system that stores all that data and uses it to provide different information to every stakeholder group.

The advantages of an integrated system include fostering multimodality, thus leading to a more sustainable city. Besides, integrating information about the transportation of people and goods can result in new collaboration scenarios that will help decrease congestion.

In our work we have developed a five-phase framework for the development of integrated information systems. In this paper, we present the first phase of the framework that focuses on mapping the decisions of each stakeholder and identifying available data sources.

Keywords. Urban mobility; smart sustainable cities; integrated information systems; enterprise architecture framework; multi-user platforms; decision-making.

1. Introduction

The performance of transportation systems is strongly dependent on the quality of the decisions made regarding supply and demand. It is easy to understand that a well-designed network, with well-planned operations has higher probability of performing well. But if it does not respond to the existing demand, a good network and good operations are not enough. It is necessary to account for the behavior and the desires of the users. Thus, an information system (IS) that aids stakeholders to make well-informed decisions may significantly improve the efficiency of the transportation system. If that IS can integrate stakeholders and different transportation services, it will foster collaboration, multimodality and, in the end, it will increase the sustainability of the city.

Based on Enterprise Architecture Frameworks (EAF) from the literature (Urbaczewski and Mrdalj 2006) and using a Service Design approach from the Multilevel Service Design method (Patrício, Fisk, and Falcão e Cunha 2008), we developed a framework for integrated information systems and applied it in the context of transportation systems.

The first phase of the framework (decision mapping) suggests that there should be a map of decisions that the system will support. In this early-stage work, we characterize the groups of stakeholders that may interact with transportation systems and present some of the topics that they decide about. Then, we will use that information to create the mentioned decision maps.

2. Methodology

The main objective of this work is to characterize the groups of stakeholders and the decisions they make when interacting with transportation systems. We aim at including all type of decisions: strategic (e.g. network design, policy and regulation), tactical (e.g. public transportation timetable, traffic light), and operational (e.g. traffic light managing in real time).

To achieve this goal, we have used the information found in the literature. Several works describe the activities performed by the different groups and allow us to understand what decisions those groups take. Following the first phase of the framework, we categorize the stakeholders and the decisions they make in their activities. We use the literature to describe the type of decisions that stakeholders make. Interviews with experts can complement the information collected in the literature. Moreover, associating different data sources to each decision type will allow to complete the second level of the framework (data sources identification).

3. Discussion

At a high level, the decision process is similar for every group, starting with the collection of data, which is then analyzed. From that analysis, different scenarios will produce results that will be compared, leading to a decision. However, different levels of decision have more, or less, impact in the long term. While strategic decisions may require an iterative process, operational decisions may occur in real time, and there is no opportunity to go through the process twice. Besides, strategic decisions have long term effects and may be complemented with tactical decisions. On the other hand, operational decisions have immediate impacts and need to be managed immediately since there is no time to reverse them.

In our approach, we consider two major groups of stakeholders: service providers and users. The service providers group includes the stakeholders that design the network or use the existing network to provide a service (urban and mobility planners, transport operators and carriers). The users group include the stakeholders that use the existing network to perform their activities (travelers, shoppers, business owners, etc.).

4. Conclusions

City sustainability can significantly improve if all stakeholders make decisions that minimize the negative impacts of the transportation systems. That can be achieved when information is available to everyone. We have developed a framework for an integrated information system in the context of urban transportation. The approach to build the framework includes mapping the decisions of the stakeholders, and identifying the data used to feed those decisions. Such approach allows to enhance the participation of the stakeholders and assures that the IS will respond to their requirements and expectations.

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Leveraging ontologies and semantic web technologies for automating visualization of urban mobility data

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Abstract

Visualizing data may be technically demanding for transportation decision makers. Choosing appropriate visual representations of data is not trivial and requires visualization knowledge. This work explores the use of ontologies and Semantic Web technologies to automate visualization of urban mobility data. The main contribution is the Visualization-oriented Urban Mobility Ontology (VUMO), a formal knowledge representation model to support the development of knowledge-assisted visualization tools. The ontology allows for semantic integration of urban mobility data, and annotation of visualization techniques and expert knowledge. VUMO is built upon a conceptual model that interrelates spatial events, visualization techniques, and expert knowledge. Data from the city of Porto and Boston were used to validate our approach.

Keywords. Urban mobility; data visualization; semantic web; ontologies.

1. Introduction

Intelligent Transportation Systems (ITS) generate an enormous volume of data which can be analyzed to provide a better understanding of mobility phenomena, and to devise actions to improve transportation systems. From a technical perspective, ITS data are structurally heterogeneous, as each system contains different specifications for data representation. Visualization tools usually require a dataset with a specific structure, which impairs their reuse and interoperability with other datasets.

Visualization is a powerful means for extracting knowledge from datasets. Domain users usually possess data in various file formats and schemas. Such data may not have metadata, i.e., data about data. Metadata can provide semantics to datasets by aligning their attributes and values to a pre-defined knowledge representation model.

Concerning the human standpoint, the choice of an appropriate visualization for a dataset is nontrivial. Visualization knowledge is required to encode data into visual tokens properly. Failure to do so might hinder the identification of hidden patterns and features in data.

Our research aims to foster the development of knowledge-assisted visualization tools for urban mobility analysis, with a focus on events' data, such as ticket validations, journey plans, traffic sensing, and the like. Such tools can recommend visualization techniques based on data characteristics (structural knowledge) and subjective user preferences and perceptions about visualizations (empirical knowledge).

Ontologies and Semantic Web Technologies can help to reduce the gap between theory and practice. The main contribution of this research is the Visualization-oriented Urban Mobility Ontology (VUMO). The ontology provides a formal model of concepts related to urban mobility events and visualization theory. Transportation analysts (researchers and practitioners) can use it as a foundation for semi-automatic tools oriented to transportation analysts. A distinctive feature

of VUMO is the ability to semantically describe empirical, subjective knowledge from domain experts, concerning visualization techniques and their compatibility. These subjective features are also fundamental for the process of data visualization, and can be used to enhance the quality of recommendations.

2. Adopted approach

We studied a variety of ITS datasets from cities such as Porto and London, to identify concepts that are often present in that type of data. This process also required a formal understanding of how space and time are modeled in those datasets. Visualization concepts were retrieved from acknowledged theoretical works (Aigner et al. 2011; Andrienko and Andrienko 2006).

VUMO implements logic rule sets to support the recommendation of visualization techniques. A distinctive feature is the ability to formalize not only their intrinsic, static features (e.g., visual tokens, spatial and temporal dimensionalities) but to semantically assert and infer complex criteria such as their compatibility and appropriateness concerning data types and user preferences. Compatibility relates to a successful match between extracted data and a visualization technique at its pure structural level. Appropriateness is asserted in terms of human perception factors (empirical knowledge). Such distinction is important: a visualization might be compatible with a data set, but not appropriate to depict it.

For the recommendation stage, two approaches were simultaneously adopted. Compatibility is inferred by embedded meta-queries that analyze the structure of queries. Appropriateness is inferred through Collaborative Filtering techniques that gather users' perception of visualization techniques in several dimensions and users' analytic profiles. Finally, we defined an algorithm that suggests the most appropriate visualizations. To evaluate our work, we have developed and evaluated a VUMO-based functional prototype with analysts from the cities of Porto and Boston. The prototype aimed at recommending visualizations for actual analytical tasks of decision makers.

3. Conclusions

The proposed approach facilitated the users' workload by reducing the technical burden often found in tasks such as data integration and transformation, and visual encoding. From our experience, analysts showed considerable interest in thoroughly using Information Visualization techniques to complement their analytical toolbox, which often consists of Geographic Information Systems and statistical software. Unfortunately, some analysts stated that such techniques are still far from practical contexts. We expect that our work contributes to shifting the researchers' focus towards developing visualization tools that can effectively reach transportation analysts in practice, and enhance decision making.

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Ticketing data to improve the urban public transport system

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Innovation in urban mobility is not new. In the last years, some Urban Public Transport (UPT) agencies have adopted sophisticated Information and Communication Technologies (ICT). Success or failure of implementation will depend on a package of "soft" management measures that involve understanding stakeholder behavior and managing the system in an integrated, efficient and dynamic (real-time) way, rather than on "hard" physical infrastructure or new vehicles (Robusté 2010). Such technologies allowed, among others, the beginning of Automatic Data Collection Systems (ADCS) which has created an opportunity to generate, at low marginal cost, large quantities of precise and disaggregate passenger trip data, and transit operations data (Foell et al. 2015). However, for this information to be useful to both transit operators and the population, detailed and correct data exploration should be made.

The exploitation of this data to assess UPT systems and predict some events are the main goals of this work. To achieve that, ticketing validations of one bus line throughout a year (January 2013 to December 2013) was considered.

In the case of buses, ticketing validation happens when the user is inside the vehicle, ready to start the journey. Thus, at each bus stop, the first validation occurs a few seconds after the bus has stopped. The last validation occurs a few seconds before the bus leaves the stop. Thus, based on ticketing validations, it is possible to know the travel time between stops, as well as the time the bus is at each bus stop. The sum of these times gives us the total time the vehicle led to travel the entire route. Additionally, having these time, it is possible to deduce the mean velocity to travel in the associated intervals.

The application of data mining technics will allow us to find some mobility patterns in urban public transport and simulate them in order to predict events and improve mobility.

Keywords. Ticketing data; urban public transport; events' prediction.

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