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Transportation Research Procedia 21 (2017) 110–129

Transportation Research Procedia

www.elsevier.com/locate/procedia

2016 International Symposium of Transport Simulation (ISTS'16 Conference), June 23~25, 2016

Analysis and Operational Challenges of Dynamic Ride Sharing Demand Responsive Transportation Models

MP. Linares, J. Barceló*, C. Carmona and L. Montero

Universitat Politècnica de Catalunya-Barcelona Tech UPC – Carrer Jordi Girona 1-3 08034 Barcelona

Abstract

There is a wide evidence that sustainable mobility is not only a technological question, automotive technology will be part of the solution as a necessary but not sufficient condition, sufficiency is emerging as a combination of a paradigm shift from car ownership to vehicle usage consequence of socio-economic changes, with the application of Information and Communication Technologies (ICT) that make possible for a user to have access to a mobility service from anywhere to anywhere at any time. Among the many emergent mobility services Multiple Passenger Ridesharing and its variants look the more promising. However, implementations of these systems accounting specifically for time dependencies, and time windows reflecting users' needs raise challenges in terms of real-time fleet dispatching and dynamic route calculation. On the other hand the feasibility and impacts analysis in terms of the many factors influencing the behavior of the system, as for example the service demand, the size of the service fleet, the capacity of the shared vehicles, the time windows requirements, soft or tight. This paper analyzes both aspects. The first is approached in terms of a Decision Support System whose solutions are computed in terms of ad hoc heuristics of variants of Pick Up and Delivery Problems with Time Windows and Feasibility and Profitability criteria rooted on Dynamic Insertion Heuristics. For the evaluation of the applications a Simulation Framework is proposed based on a microscopic simulation model that emulates real-time traffic conditions and a real traffic information system, and interacts with the Decision Support System feeding it with the required data to make the decisions that are implemented in the simulation to emulate the behavior of the shared fleet. The proposed simulation framework has been implemented in a model of Barcelona's Central Business District. The paper is completed with the discussion of the achieved results.

Keywords: Demand Responsive Transport; Pickup and Delivery with Time Windows; Dynamic Fleet Management; Microsopic Traffic Simulation

* Corresponding author. Tel.: +34 93 401 70 33; fax: +34 93401 58 55.
E-mail address: jaume.barcelo@upc.edu

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Selection and Peer-review under responsibility of Dept. of Transportation Engineering, University of Seoul.
10.1016/j.trpro.2017.03.082

1. Introduction

Urban areas must address from a holistic perspective the challenges and threads of sustainability namely in providing services to companies and citizens. Cities are complex systems, any city must be thought as a “System of Systems”, and Mobility is only one of the components of such complex systems, a non-isolated component strongly interacting with all other components and therefore its implications must be analyzed in the context of these interactions. Frost & Sullivan, in a recent analysis of the Future of Mobility and New Mobility Business Models, (Sullivant & Frost 2015) identify the growing trend of “Ride Sharing” models as one of what they call “Transformational Shifts in Mobility”. This trend can be seen as one of the consequences of the paradigmatic shift from “car ownership” to “vehicle usage”, leading to a new concept of multi modal mobility network, as a way of overcoming the limitations of conventional public transport systems, made possible by the pervasive penetration of Information and Communication Technologies (ICT). Technology enables a comfortable seamless real-time point to point travel service.

Demand Responsive Transport (DRT), Dial-a-Ride Transit or Flexible Transport Services, according with the definition of the European Commission, Directorate-General for Energy and Transport “are emerging user-oriented forms of public transport characterized by flexible routing and scheduling of small/medium vehicles operating in shared-ride mode between pick-up and drop-off locations according to passenger needs”. DRT were initially thought to provide public transport services for areas with low passenger demand where regular bus services would not be available. However, this concept is quickly evolving enabled by the ICT deployment, initiatives like KUTSUPLUS (Anon 2015), an on-demand minibus service run by Helsinki’s public transit authority, letting riders choose their own route summon a trip with a smartphone, decide the start and end point of their trip and choose whether to share a journey or not. It is a new Demand Responsive Public Transport service designed to achieve maximum flexibility.

This concept of Demand Responsive Transport is rapidly evolving to services provided by private companies operating point to point with full dynamics and flexibility, also offering the possibility of sharing trips. E-hailing is a process of ordering a transportation service by a private car (e.g. Uber services), special taxi services, etc. The system has currently a variety of implementations but, in essence, the variant we are interested in this paper, assumes that the customer books or hails the trip electronically providing the pickup location (that can be automatically identified by GPS current customer location), the drop off location, and the desired pickup up and drop off time windows, and that multiple passengers can share the trip. In order words our research addresses specifically the variant known a “Multiple Passengers Ridesharing System”.

A state-of-the art-survey on the variants of ridesharing systems, their alternatives and likely future evolution can be found in (Furuhata et al. 2013), according to their classification the variant studied in this paper corresponds to the called Detour Ridesharing with Multiple Passengers, in which multiple passengers, with relatively close but different origins and destinations share rides which can partial or totally overlap. Our research has analyzed the potential utilization uses of special fleets of dedicated vehicles in an urban area, assuming than further than the pickup and drop off location and time windows, the system is also aware of the current and desirably short term forecasted traffic conditions to timely determine the optimal routes satisfying customers’ time constraints. That is we assume that the system is operating in a network for which an Advanced Traveler Information System (ATIS) provide the travel time estimates. This type of real-time ridesharing system has also been studied by (Ma et al. 2015) but with simplifications concerning the availability of traffic information. The special case when the fleet of service vehicles is composed of autonomous vehicles has deserved special attention from the agent-based simulation approach, a general perspective can be found in (Fagnant & Kockelman 2014) that analyze the environmental impacts, while (Martinez et al. 2015) propose a general agent-based simulation to assess the impacts, and apply it to the city of Lisbon. This work has been the basis for the report of the International Transport Forum (OECD - International Transport Forum 2015). One of critical aspects highlighted in these last references concerns the operational efficiency of the system, determined, among other factors by the fleet management dispatching system, in terms of the decisions process and its dependencies with the size of the fleet and the demand, an aspect that has been studied in (Boesch et al. 2016) for a simplified dispatching strategy. Consequently our work has dealt namely with the Decision Support System supporting the decision making process of which vehicle assign to optimally