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# Application of agent based simulation for evaluating a bus layout design from passengers' perspective

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ABSTRACT

This paper shows that agent based simulation can evaluate the performance of different bus layout designs from passengers' perspective, thus helping bus manufacturers to design new layouts that are more attractive for passengers. Including agent-based simulation in the bus design process is an inexpensive and efficient procedure to evaluate new design concepts (wheel-well position, number of doors, etc.) in relation to the preferences, needs and expectations of current and future passengers. Its main advantage is that these new design concepts are evaluated well before manufacturing the first physical prototype. Bus passengers are modelled and simulated as autonomous agents. Eight different types of passengers, which were elaborated from observations of actual passengers, have been modelled. Passengers' preferences and features have been implemented using a calibrated making decision algorithm. The paper also presents two case-studies to analyse the sensitivity of the performance of two different bus layouts with different number and distributions of passengers.



## 1. Introduction

Congestion in urban areas and its immediate and wider consequences on the climate are pushing central and local governments to instigate sustainable transport policies. One measure towards achieving sustainability would be to attract more people to public transport and a possible way to accomplish this is to increase the service quality that consists of some variables conditioning the users' decision (e.g. waiting time, reliability or journey time) (dell'Olio et al., 2010, 2011). There is an extensive literature on the service quality factors. For example Fearnley et al. (2011) studies the Universal Design concept that refers to the requirements on facilities and vehicles in order to accommodate and increase the accessibility of as many passengers as possible. Rosenkvist et al. (2009) study Universal Design in accordance to special needs groups. Hensher et al. (2003) develop the Service Quality Index and investigates ways of quantifying service quality from a user perspective and comparing the levels within and between bus operators. However, as stated by Hensher et al. (2003), many previous work in that field focused on measuring only the cost efficiency and cost effectiveness of bus service and operators (e.g. Rufolo, 1986; Lowson, 2004; Holmgren et al., 2008; Jara-Díaz et al., 2008; Iseki, 2010). The definition of service level has tended to ignore the quality of the service; hence many regulators have been unsuccessful in developing a robust specification of service-quality levels (Hensher, 2007). Most of the work in this field is based on surveys taking into account such factors as cleanness of the vehicle (e.g. dell'Olio et al., 2011), fares (e.g. Stradling et al., 2007) or reliability (e.g. dell'Olio et al., 2010) but there are only few studies analysing the correlation between layout constraints and passenger needs and preferences (e.g. Jung et al., 1998; Schaller et al., 1998).

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Currently manufacturers' knowledge in the early stage of the design of a new concept relies on experiences with buses already in service and statistical data about passengers. Schaller et al. (1998) state that designs which do not address customer's concerns could have serious problems in terms of customer's acceptance. Thus evaluating these concepts from a passenger's perspective is imperative but unachievable without access to a prototype of the real vehicle. Nowadays a feasible alternative is the use of agent based simulation, which is an inexpensive and efficient procedure to analyse new design concepts (such as wheel-well position and number of doors) in terms of dwell times, passenger flow, and personal space among the factors that feature passenger's acceptance. In our approach, passengers' preferences and behaviour are modelled with respect to modern bus layouts, among others: seat typologies and orientations, types and number of doors, and position of ticketing machine.

In this paper, the authors propose an agent-based simulation methodology that makes feasible the evaluation of new bus designs in terms of passenger preferences and needs. In the proposed simulation framework, which is described in the next section, passengers are simulated by autonomous agents who mimic their behaviour. The process of modelling agents' personality from real observations is described in Section 3. Then, the feasibility and advantages of the proposed approach are demonstrated with two case-studies. In these, a 3-door bus layout is compared against a 4-door bus layout in terms of accessibility times (entry, exit and dwell) and passenger preferences (entry and exit door selection). Simulation results are discussed in Section 4. Finally, Section 5 discusses and summarizes the main contributions of this work.

## 2. Solution approach

Our simulation tool has been created within Xjtek's AnyLogic, which is a multi-paradigm simulation framework <http://www.xjtek.com/anylogic/why_anylogic>. AnyLogic supports the simulation of pedestrians within a virtual environment, implementing the social force model algorithm (Helbing and Molnár, 1995). Passengers have been modelled using AnyLogic's library of pedestrians as a starting point and then their behavioural capabilities have been augmented through several decision making algorithms (e.g. entry/exit door choice, seat choice, etc.). Briefly, the simulation tool consists of several essential parts:

- A flowchart describing the life-cycle of bus passengers, which begins when they arrive to the bus stop and ends when they get off the bus at the end of the journey.
- The virtual environment where simulation occurs: the bus and all the elements on-board, with which passengers are to interact (e.g. doors, seats, and ticket machines). It includes the description of the bus layout (geometry) and its functionality (semantics).
- A library of passenger models: set of methods, variables, lists responsible for the passenger's preferences and decisions.
- The results module generates all the output data that will be required for the evaluation. It can measure different accessibility times (entry, exit, dwell) and up to 48 other magnitudes.
- A user's interface that helps to set-up and govern the experiment.

The simulation tool can analyse the case of one single bus stop situation where some passengers, initially on the bus, are getting off the bus while the passengers that are waiting in the bus stop are getting on. It also allows simulating the case of a complete bus line. Passenger's flow during a simulation depends on many random factors (e.g. passengers' initial position at the bus stop or passenger blocking) and thus the same experiment repeated twice will never give the same results. To exploit this random nature, the simulation tool can run a large number of repetitive experiments. Simulation performance is faster than real-time: for instance, on an Intel® Core™2 Quad CPU @ 2.83 GHz with 3.25 GB of physical memory, 100 experiments with 30 passengers at one single stop took less than 160 s.

## 3. Passenger model

Bus passengers are not a homogeneous group. They differ in age, size, and gender, as well as in physical and psychological features. Also the level of knowledge about the public transport system and the rules and regulation that may apply can be different. Their personalities are diverse and so is the way they comply (or not) with stipulated rules. Their background, idiosyncrasy, education, etc. could be very dissimilar. As a result, their behaviour during a bus journey must be modelled taking into account such differentiating factors. Currently, in most cases passengers are simply classified in terms of age – young, middle-aged, elderly (e.g. Alam and Werth, 2008) – or in terms of frequent or seldom users of public transportation. These last two classifications of passengers are not sufficient to characterise the complex decision making processes that show their behaviour during a bus journey. Consequently, in order to create an agent-based simulation tool it is necessary to model the behaviour of passengers in a different way.

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