A Practical Demonstration of a Variable Incentive Model for Bike-Sharing Systems Based on Agent-Based Social Simulation

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Abstract. Bike-Sharing Systems (BSSs) have been implemented in numerous cities around the world to reduce the traffic generated by motorized vehicles, due to the benefits they bring to the city, such as reducing congestion or decreasing pollution generation. Caused by their impact on urban mobility, the research community has increased their interest in their study, trying to understand user behavior and improving the user experience. This demonstration shows the simulator developed to analyze the impact of a variable incentive model for BSSs based on Agent-based Social Simulation. The model has been developed using data collected directly from BiciMad, the BSS of the city of Madrid, Spain. The developed simulator uses OpenStreetMaps as a route generator software. The simulated scenario for this demonstration consists of a 7-day series of simulations with different traffic flows to observe the impact of different policies according to different traffic intensity.

Keywords: Bike Sharing Systems · Variable incentive model · Agent-based systems

1 Introduction

There is a growing interest in the Sharing Economy because of its impact on individuals, businesses, and governments. In a particular case, Bike-Sharing Systems (BSSs) bring benefits to users, societies, and the environment, making sustainable mobility an essential pillar of society.

The optimization of these services helps to introduce these services into the routine of the users. One significant problem that should be improved is the lack of availability of the service. This problem is most noticeable during peak hours in areas with a high density of population. This paper studies the implementation of a variable incentive system during those peak hours. During the simulation process, we analyze the availability of the system and the associated cost for the company providing the service.

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2 Main Purpose

The objective of this study is to observe the consequences of implementing a system of variable incentives on a BSS during high demand hours. For this purpose, an Agent-Based Model (ABM) model has been developed with Mesa, an open-source tool for Python.

The system implements two different incentive policies: (1) One variable incentive policy is implemented in a station-based system, where the user must access the station to rent/park the bicycle. (2) The system also implements a policy of fixed incentives per day.

These incentives are applied as a discount to the fare of the trip, so that the amount of the discount can never be higher than the cost of the service. In order to benefit from these incentives, users must help to balance the load of the stations. Based on Ban et al. [1], that load balancing can be achieved by renting at a station with a high capacity load (greater than 70%) or by parking at a station with a low capacity (less than 30%).

To measure the influence of the policy, we collect data from the simulation and its agents (users, stations, and employees). The primary variable that we observe is the Quality of Experience (QoE) rate per user/agent, which shows a relationship between trips made successfully and those that could not be completed. Once a bicycle has been rented, it must be returned to a station. The model considers that when a user does not find an available bicycle within his action range, the trip is unsuccessful. The QoE rate is defined according to the following formula.

$$QoE = F/(F + S) \tag{1}$$

where F is the number of failed trips and S is the number of completed trips.

Moreover, due to the nature of the policy in modifying user behavior, the duration of the trips is an important variable. We assume a higher predisposition to shorter trips, so a considerable increase in the duration traveled means a decrease in the QoE perceived by users. Besides, the variation in the number of full stations (with no available slot to park the bike) or empty stations (with no available bikes to rent) will be meaningful in the QoE. Finally, the deviation of incomes can also be observed, showing us the economic benefits perceived by the system operator.

3 Demonstration

Simulation results are stored for its analysis. Table 1 presents the results of the scenario mentioned above. A 7-day series of simulations have been carried out to test the influence of the policies on the system. The simulations have been programmed in different scenarios, according to the traffic flow (30,000, 74,000, and 150,000 trips), both with the variable and the fixed incentive policies. In this way, we can observe the impact of each policy according to traffic intensity.

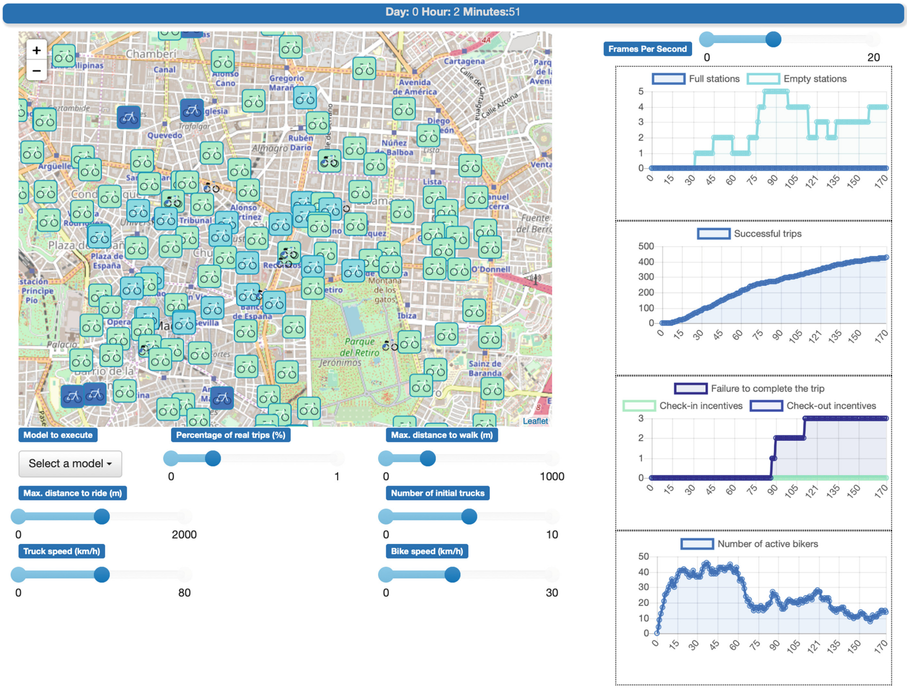

Fig. 1. Visualization of the simulation.

User behavior has been model based on a probabilistic estimation using the real data of trips, provided by the operator company Municipal Transport Company of Madrid, *Empresa Municipal de Transportes* (EMT) on its web portal[1]. Based on that estimation and using the library OpenRouteService (ORS)[2], routes are calculated, enabling a better calculation of the travel times and its visualization through the web interface developed using the Folium library[3].

The simulation system has been deployed as a web application with a graphic user interface that enables the configuration of the model in a fast and intuitive way. This graphical interface also enables the visualization of the simulation results in real-time, as shown in Fig. 1, where the distribution of the station loads along the city of Madrid can be observed. More details can be found in the full paper [2].

According to the results obtained when applying the incentive policy, a growing trend in travel duration can be observed, with 1% and 1.55% for low and medium traffic scenarios respectively. However, for high traffic, a reduction of 3% has been obtained. So we can assume that the implementation of the pol-

1 BiciMAD Open Data Repository: http://opendata.emtmadrid.es/Datos-estaticos/Datos-generales-(1).
2 OpenRouteService GitHub Site: https://github.com/GIScience.
3 Folium GitHub Repository: https://github.com/python-visualization/folium.

Table 1. Output variable results from simulation.

	Variable policy	Trips duration		QoE		Income	
		μ (sec.)	σ (sec.)	μ (%)	σ (%)	μ (€)	σ (€)
30,000 trips	True	755.24	346.32	5.82e−04	3.4e−08	12959.86	71.52
	False	747.71	332.12	6.22e−04	5.54e−08	12971.23	86.76
74,000 trips	True	1083.09	597.5	0.075	2.03e−05	32374.17	98.46
	False	1066.56	570.58	0.103	3.54e−05	32313.79	69.70
150,000 trips	True	1244.39	606.93	0.684	6.85e−04	63852.91	130.77
	False	1281.85	650.97	0.804	8.505e−04	63679.16	136.57

icy does not have a misleading impact on the overall user experience in terms of travel time. In the case of the QoE ratio, a reduction has been obtained in every case. The most outstanding is the average traffic, with a decrease of 27.2%. Regarding the revenues received by the system operator, no differences are observed between the two strategies (with and without policy). One potential explanation is that the higher costs associated with the variable incentive are compensated by the increase in the number of trips.

4 Conclusions

In this paper, we have presented a demonstration of an agent-based system to assess the impact of implementing a variable incentive policy in a BSS. Our main conclusions are that significant improvements are obtained in terms of service availability, not resulting in either a decrease in income or an increase in travel duration.

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Preface

Research on agents and multi-agent systems has matured during the last decade and many effective applications of this technology are now deployed. An international forum to present and discuss the latest scientific developments and their effective applications, to assess the impact of the approach, and to facilitate technology transfer, became a necessity and was created almost two decades ago.

PAAMS, the International Conference on Practical Applications of Agents and Multi-Agent Systems, is the international yearly tribune to present, discuss, and disseminate the latest developments and the most important outcomes related to real-world applications. It provides a unique opportunity to bring multi-disciplinary experts, academics, and practitioners together to exchange their experience in the development and deployment of agents and multi-agent systems.

This volume presents the papers that were accepted for the 2020 edition of PAAMS. These articles report on the application and validation of agent-based models, methods, and technologies in a number of key application areas, including: advanced models and learning, agent-based programming, decision-making, education and social interactions, formal and theoretic models, health and safety, mobility and the city, swarms, and task allocation. Each paper submitted to PAAMS went through a stringent peer-review process by three members of the Program Committee composed of 136 internationally renowned researchers from 27 countries. From the 64 submissions received, 12 were selected for full presentation at the conference; another 17 papers were accepted as short presentations. In addition, a demonstration track featuring innovative and emergent applications of agent and multi-agent systems and technologies in real-world domains was organized. In all, 17 demonstrations were shown, and this volume contains a description of each of them.

We would like to thank all the contributing authors, the members of the Program Committee, the sponsors (IBM, Armundia Group, EurAI, AEPIA, AFIA, APPIA, FBKI, CINI, CNRS, KUL, AIR Institute, and UNIVAQ), and the Organizing Committee for their hard and highly valuable work. We are thankful for the funding/support from the project "Intelligent and sustainable mobility supported by multi-agent systems and edge computing" (Id. RTI2018-095390-B-C32). Their work contributed to the success of the PAAMS 2020 event.

Thanks for your help – PAAMS 2020 would not exist without your contribution.

April 2020

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