Simulation-based analysis of the effects of differences in demand on user behaviour in multi-user warehouses

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Abstract. The paper at hand proposes a simulation model in order to simulate how different characteristics of users influence the overall performance of a multi-user warehouse. Therefore, the model depicts an order picking process in a simple warehouse design used by two users. First investigations have been carried out to analyse the effect of different order arrival rates of users on the usage of a common resource, in this case a shared order picker. Results show how different order arrival rates not only influence the picker usage but also the order completion time for orders of both users. In the future, the model can be used to develop and test a pricing model which is able to account for different customer behaviour in multi-user warehouses.

1 Introduction

The current worldwide trend of urbanization fundamentally changes the structure of logistics systems in urban areas. Companies delivering to inner city destinations are facing several new challenges such as for example time windows for inner city driving or environmental restrictions [1, 2]. Another challenge is the so-called “Urban Logistics Sprawl”, i.e. logistics facilities being forced to move to the city border [3]. This expulsion leads to longer delivery times for logistics companies as well as an increase in inner-city traffic and thus imposes additional stress on the inner-city road infrastructure [4].

So far, new technologies and business models like cooperative warehousing and distribution concepts are discussed in order to meet those challenges [5, 6]. For small and medium sized logistics companies, which are often characterized by limited financial power, especially cooperative usage of urban logistics facilities seems favourable as investment and risk can be shared [7]. Urban consolidation centres and multi-user warehouses are just two examples of such cooperative logistics facilities [6, 8, 9, 10].

In the past, many cooperative urban logistics concepts based on horizontal cooperation between logistics service providers (LSP) have failed due to a lack of economic viability [6]. Especially the exploitation of information asymmetries as well as asymmetries between users (e.g. differences in partner’s size or demand behaviour) have led to disruptive behaviour and missing obligation of partners towards the cooperation [6, 11]. The paper at hand focuses on multi-user warehouses as cooperative urban logistics facility. The research goal is to analyse how different demand characteristics of users affect the overall performance of the urban logistics facility. If the behaviour of one user within the warehouse significantly lowers the overall warehouse performance influencing the individual performance of other partners as well, it should be investigated if partners feel less obligated to behave cooperatively.

To investigate the effect of single partner demand characteristics, the paper at hand presents a simulation model. The model aims at systematically identifying conditions under which causes for opportunistic behaviour are minimized.

The remainder of this paper is structured as follows: In the subsequent chapter, the simulation model is described in detail. After that, results of a first simulation experiment are presented briefly. The final chapter draws a conclusion and outlines further research potentials of the simulation model.

2 Modelling Approach

To investigate the complex interdependencies between cooperation partners and the overall logistics facility performance, an agent-based simulation model is developed, because it is most suitable to depict heterogenic behaviour of multiple actors. Furthermore, agent-based simulation allows for modelling complex interdependencies between agent decisions and strategies and outputs their effects on the overall system [12]. For the simulation, the software AnyLogic 8 is used, which is a well-established and flexible simulation tool based on Java [13].

The model simulates a multi-user warehouse used cooperatively by two LSPs. The warehouse with rectangular design consists of ten storage rows with 25 storage locations on each side, yielding a total of 100 storage locations within the warehouse. The warehouse layout can be seen in Figure 1, with dotted lines depicting possible picker routes. Similar warehouse layouts are widely used in warehousing literature [e.g. 14, 15].

The LSPs are modelled as users A and B of the warehouse, storing their goods together in a random storage assignment. At predefined times during the model runtimes, both users place orders, requesting goods to be picked from the warehouse. While the number of items per order is also predefined by a fixed value, the exact item to be picked (i.e. its position within the warehouse) is randomly selected. This is done by using a uniform probability function which assigns the same probability to each item of one user within the warehouse. For reasons of comparability, only one order picker is simulated, who picks orders from both customers from the warehouse (multi-order picking) until its maximum carrying capacity is reached or until all goods of all open orders have been completely picked. At this point, the picker puts the picked goods at a nearby depot location and receives the next orders to be picked. Orders are assigned to the picker using a simple FIFO scheme according to the time of the order’s arrival at the warehouse. The movement of the picker through the warehouse is defined by an S-shape strategy, which is a common routing strategy in practice [16]. The equal time the picker needs to pick goods can also be defined by a parameter individually for each customer. As in the first step only the picking process is of interest, the warehouse is automatically re-stocked making sure that there are always enough goods available to fulfil all incoming orders. All mentioned parameters of the model can be defined before each simulation run, allowing for systematic variation in order to analyse the effects of each parameter on different warehouse performance measures, such as for example the average picking time per order or the picker utilization of each user.

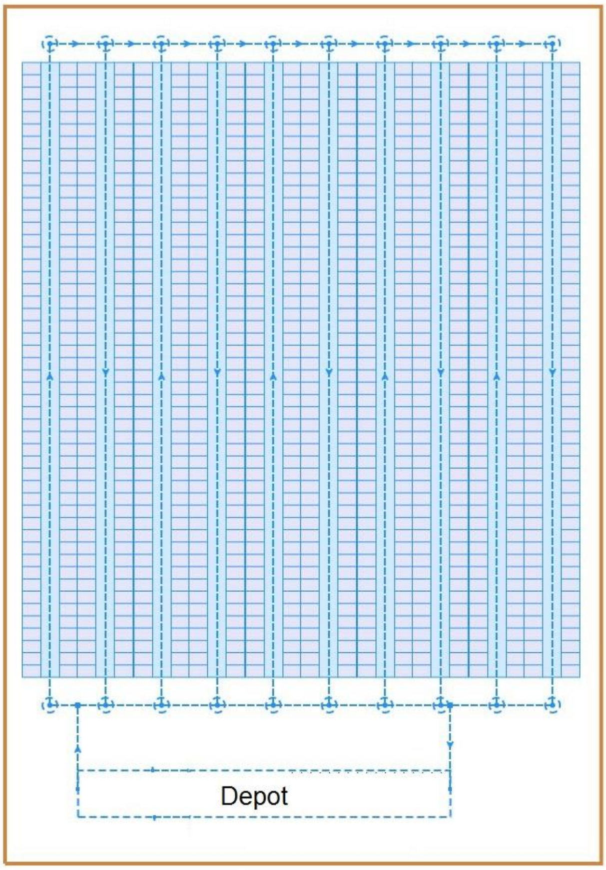

Figure 1. Warehouse layout in the simulation model.

3 Simulation experiment

Using the basic simulation model, experiments have been conducted in order to validate the model. Furthermore, some first experiments have been conducted in order to analyse the effect of different user characteristics. To do so, all parameters are set to identical values for both customers. The idea is to then systematically alter only one parameter for one of the two users and to measure the effect on the overall warehouse performance.

One factor worth investigating is the users’ rate at which orders are placed at the warehouse. Due to differences in good’s demand, one user might have a much higher rate at which orders are placed. This will result in a higher number of necessary picks for this user. Even if both users have agreed on an overall equal rate at which orders are placed, one user might decide to order more items at certain points in time due to time windows and cut-off times in his operations. Therefore, the influence of unequal order rates and peaks in order placements needs to be analysed.

Figure 2 shows the results for systematically altering the rate at which user A places orders at the warehouse. The value is constantly increased in steps by one, reaching from 20 to 50 orders per hour, while all other parameters are being kept constant. Throughout every simulation run, user B has an order arrival rate of 30 orders per hour. The complete configuration of all parameters can be seen in Table 1.

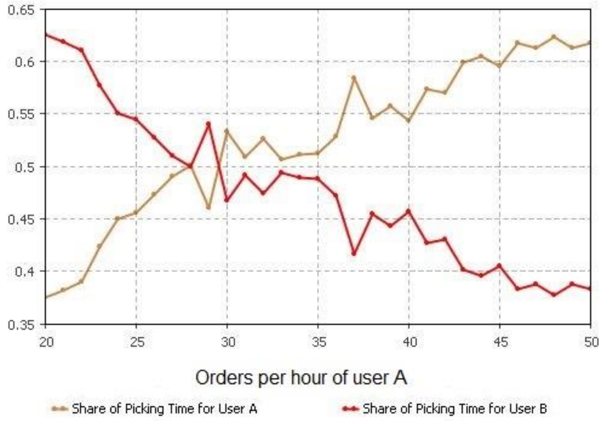

Figure 2: Picker time share for different numbers of orders per hour for user A with a fixed number of 30 orders per hour for user B.

For each order arrival rate of user B, a total model time of 28,800 seconds (i.e. a complete 8 hour shift) is simulated. In Figure 2, the share of picker usage is measured i.e. the share of overall picking time accountable for each of the two users. As can be expected, the share of picking time for user A rises with an increasing number of orders per hour. It can be observed that only in the range between 26 and 36 orders per hour of user A, the picking time is more or less equally distributed between users. The increasing order arrival rate of user A also results in rising order completion times for both users, i.e. the time which is needed until an order is completely picked and arrives at the depot. Average order completion times for both users for each simulation run can be seen in Figure 3. During times of an uneven usage of the common resource (i.e. the picker), additional pickers might thus be of need in order to ensure all orders of both users are picked in time. Also, for ongoing unequal resource usage, a financial compensation for the disadvantaged user might be necessary to ensure this user's obligation towards the cooperation.

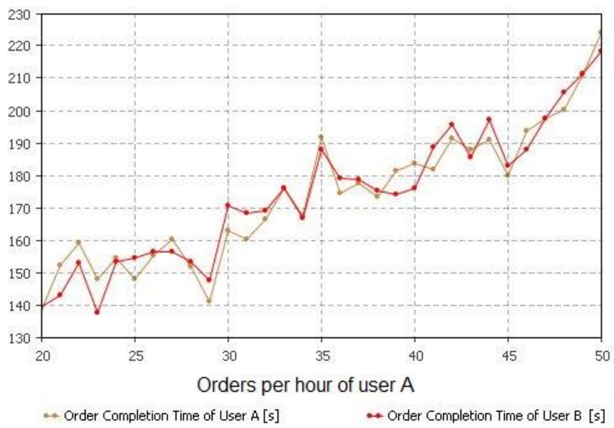

Figure 3: Order completion time in seconds for different numbers of orders per hour for user A with a fixed number of 30 orders per hour for user B.

4 Conclusion

This paper proposes a modelling approach in order to systematically analyse different demand characteristics of users within a multi-user warehouse. Therefore, parameters in the model can systematically be changed for individual users to measure the effect on the overall warehouse.

In a first experiment, the influence of unequal order arrival rates of the users on the picker usage has been investigated. By that, the model shows how order completion times rise for both users due to the change in the demand of only one user. This gives a basic idea at which point additional resources are required to ensure predefined order completion times. Also, the model can be used to analyse when compensation for one user might be of need in order to account for uneven resource usage. In future work, the model can be used in the same way to test different model parameters as well.

Nevertheless, these first results are only of conceptual nature and are not yet applicable to real-world warehouses. To do so, further investigation should be carried out in order to find parameter values that are able to depict realistic warehouses. If information on the willingness of users to tolerate uneven resource usage is also available, the model can then be used to determine under which circumstances compensation is advisable. One idea for future research is to use the model results in order to develop a pricing model for multi-user warehouses that is able to account for the effects of different user characteristics. The model can also be used to test such pricing models under different, uncertain conditions by using stochastic values for selected parameters.

Table 1: Selected parameter values for the simulation experiment.

Parameter	Value
Picker capacity	40 items
Size of orders of customer A	5 items
Size of orders of customer B	5 items
Pick up time per item of customer A	3 s
Pick up time per item of customer A	3 s
Order arrival rate of customer A	20-50 orders p. h.
Order arrival rate of customer B	30 order p. h.

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