ASSESSING THE PERFORMANCE OF A RESTAURANT THROUGH DISCRETE SIMULATION IN SIMIO

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ABSTRACT
For the purpose of evaluating the level of service of a Portuguese self-service restaurant, a simulation model was developed in Simio. The purpose of such model was to quantify specific performance indicators. In this sense, data was gathered by conducting observations of the field, which allowed the authors to find relevant problems in the system. The simulation model was validated and, afterwards, simulation experiments were conducted, which suggested some changes that could be implemented, without reducing the performance of the restaurant and reduce the utilization of workers, who become available for other tasks with more added-value, such as supplying critical items (e.g., main dishes and soap). Moreover, the potential impact of the introduction of an information device used to warn workers responsible to supply items was assessed through simulation, indicating that it would lead to benefits both for customers and workers.

Keywords: Discrete-Event Simulation, Simio, Object Modelling, Performance indicators.

1. INTRODUCTION
Today's competitive market companies make efforts to improve their service level, thus aiming to eliminate waste and pursue continuous improvement, which is in accordance to lean philosophy (Womack J.P., Jones D.T., Roos D. 1990). Lean philosophy is a production organizational model with focus on overall client's satisfaction and continuous improvement, through waste elimination. It should be noted that this philosophy can also be applied in other non-production systems. In this regard, one of the ways to achieve this customer satisfaction, waste elimination and continuous improvement is through the assessment of the efficiency of processes, according to performance indicators, such as queue size and customer waiting time (Gross 2008).
This study originated from the need the assess the performance of a restaurant in Portugal. Therefore, the purpose of this paper is to document the work conducted in this project, namely to:
Identify possible bottlenecks in the system and propose improvements. More specifically, reasons for the waiting time per client, the queue size and the work in process (WIP) should be found.
Improve the utilization rate of workers. This can be done by identifying flaws in the workflow, changing work locations, task allocations, etc.
Simulation is oftentimes considered as the best choice to tackle this kind of problems, due to its capability of addressing stochastic systems and the possibility of dealing with uncertainty. Moreover, simulation can also be used to test alternative scenarios that would lead to considerable costs if they were experimented on the ground. Thus, a simulation model was developed in Simio, an object-oriented simulation tool. Thus, it is possible to model the behaviour of clients in the restaurant and the workflow of workers, to test alternative scenarios.
The next section focuses on reviewing literature related to the topics of this study. The third section described the case study in question and the data gathering process, as well as the main problems that were identified in the restaurant. The main steps to model the system in question are described in the fourth section and the fifth describes the main simulation experiments conducted and discusses the results. Lastly, conclusions are discussed in the last section.

2. LITERATURE REVIEW
The literature on modelling and simulation is vast (Longo F. 2011, Jiménez E., Martínez E., Blanco J., Pérez, M., Graciano C., 2014, Mangina E., Vlachos I. P., 2005). When searching literature for papers trying to improve the service level of restaurants using simulation, it is possible to notice a lack of such studies.
Ju and Wang (2010) specifically used simulation to a similar problem. The authors used WITNESS to simulate the behaviour of a restaurant, to try to identify bottlenecks and propose improvements, with the goal of improving the level of service. Zhao X., Lau R.S.M. and Lam K. (2002) used ProModel to simulate a similar problem. The authors of both studies agree on the benefits of simulation to this kind of problems.
As can be seen, there is a lack of such studies using discrete-event simulation models in these kind of problems, even though simulation is considered the most appropriate tool for these problems.
There is a great number of simulation tool options, thus tool comparison becomes a very important task. However, most of scientific works related to this subject

analyse a small set of tools and evaluate several parameters individually, avoiding to make a final judgement, due to the subjective nature of that task (Dias L.M.S, Pereira G.A.B. and Rodrigues G. 2007, Dias L.M.S, Pereira G.A.B., Vik P. and Oliveira J.A., 2011, Dias L.M.S, Vieira A.A.C., Pereira G.A.B. and Oliveira J.A. 2016).

Hlupic V. and Paul R. (1999) compared a set of simulation tools, distinguishing between users of software for educational purpose and users in industry. In his turn, Hlupic V. (2000) developed a survey on the use of simulation software of academic and industrial users, which was conducted to discover how the users were satisfied with the simulation software they used and in which ways could the software be improved.

In their turn, Dias and Pereira et al. (2007, 2011, 2016) compared a set of tools based on popularity on the internet, scientific publications, WSC (Winter Simulation Conference), social networks and other sources. According to the authors, popularity should not be used as the only criteria, otherwise new tools, better than existing ones would never get their market share. However, a positive correlation may exist between popularity and quality, since the best tools have a greater chance of being more popular. According to their study, the most popular tool is Arena, however, the good classification of Simio is also noteworthy. Based on these results, Vieira A.A.C., Dias L.M.S., Pereira, G.A.B. and Oliveira J.A. (2014) and Oueida S., Char P.A., Kadry S. and Ionescu S. (2016) compared both tools, considering several factors. WITNESS, the tool used in the study of Ju and Wang (2010) finished in 5th place in this ranking, in a very close classification to the 2nd, 3rd and 4th ranked tools. In its turn, the tool used in Zhao X., Lau R.S.M. and Lam K. (2002) – ProModel – finished in 2nd place in this ranking.

Simio was created in 2007 from the same developers of Arena and is based on intelligent objects (Sturrock and Pegden 2010, Pegden 2007, Pegden and Sturrock 2008). Unlike other object-oriented tools, in Simio there is no need to write programing code, since the process of creating objects is completely graphic (Pegden and Sturrock 2008, Pegden 2007, Sturrock and Pegden 2010). The activity of building an object in Simio is identical to the activity of building a model. In fact, there is no difference between an object and a model (Pegden 2013). A vehicle, a costumer or any other agent are examples of possible objects and, combining several of these, one can represent the components of the system in analysis. In other words, the user can use realistic representations of the objects that compose the real system being modelled and, thereafter, at a lower level, define additional logic to the model, through the development of processes for instance. This way, Simio complements the main object paradigm with other paradigms such as events and processes.

A Simio model looks like the real system, which can be useful when presenting the results to non-familiars with simulation concepts. In Simio the model logic and animation are built in a single step (Pegden and Sturrock 2008, Pegden 2007), which makes the modelling process very intuitive. In addition to the usual 2D animation, Simio also supports 3D animation as a natural part of the modelling process. Moreover, Simio provides a direct link to Google Warehouse, a library of graphic symbols for animating 3D objects (Oueida S. Char P.A., Kadry S. and Ionescu S. 2016).

3. CASE STUDY

The case study of this problem is discussed in this section. The first subsection focuses in describing the system to be analysed. In its turn, next subsection describes the data gathering process. The last subsection discusses the main problems that were identified.

3.1. System Description

The system at hand can be divided in 2 main areas. The first consists in the kitchen, wherein workers prepare the food to supply the second area, where costumers pick intended items, such as trays, food and cutlery. Figure 1 shows a 3D view over the simulation model, with some labels of the layout of the restaurant.

As the figure depicts, when costumers arrive to the restaurant, they enter through a common entrance. At this point, they can choose from 2 available access ramps: access ramp 1 (AR1) or access ramp 2 (AD2). Furthermore, at the beginning of AR2 the path forks into AR1_1 and AR2_2.

The observations conducted on the ground allowed the authors to verify that, usually, customers decide on which ramp to take by evaluating the size of the queues. Yet, even if the queue of AR2 is higher than the one of AR1, costumers may still opt for this former, since it has forks into two ramps, and thus dispatches customers faster; this choice is rather subjective. After choosing an access ramp, customers collect intended items (e.g. trays, cutlery, food, etc.), in different sequences, depending on the access ramp.

The restaurant's kitchen, as Figure 1 illustrates, is located at the centre of the plant, in order for workers to be able to equally supply items to both ramps. The existing workers are divided by tasks, which can go from preparing food, supplying it to the ramps and serving it to customers on the queues. There are other tasks involved, however these are the main ones which are critical for the system in analysis, as was observed by the authors when conducting in loco observations on the field. It should be noted that some workers can do more than one of these tasks and, depending on the task, workers can even help each other, comprising interesting situations to model in Simio

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Figure 1: 3D view of the restaurant

3.2. Data Gathered

To develop a simulation model representative of the real system at hand, data related to the self-service restaurant was gathered through field observations. These observations allowed the authors to observe that cutlery and trays are only supplied before the opening of the restaurant, thus in the simulation model these resources were not considered.

Table 1 shows some of the data that were gathered.

Table 1: Sample of data collected on the field

Item	Time to collect (seconds)	Customers that want an item	Quantity at the restaurant opening			Number of supplies		
			AR2_1	AR2_2	AR1	AR2_1	AR2_2	AR1
Tray	1 to 3	100%	-		-	-	-	-
Bread	2 to 5	60%	100		100	5		3
Cutlery	1 to 3	100%	-	-	-	-	-	-
Dessert	2 to 5	60%	120	120	120	-	-	-
Soap	2 to 6	80%	60		60	12		7
Cup	4 to 6	85%	150	150	100	-	-	-
Main dish	3 to 9	100%	50	50	50	7	6	11
Juice						4	7	6

When picking items, customers can either take a cup with a drink, or take an empty cup, if there are no filled cups. If there are no cups with water or juice, there is a proper places to fill cups– 15% of the clients fills the cup with water. Yet, on some ramps workers do not fill cups, thus customers have to fill their own, which takes them about 4 to 6 seconds.

Apart from the indicators presented in

Table 1, the number of meals served per day were also recorded, which in average, was roughly1500. Additionally, it was also found that the average time for a customer to pick the items and exit the ramps to the eating room is around 20 minutes. Moreover, at the entrance of the restaurant, it was also found that roughly 40% of the customers chose the AR1 access ramp, whilst the remaining take AR2 ramp. From these, 60% chose AR2_2 and the remaining chose the AR2_1. Lastly, it should be noted that the gathered values were introduced in the simulation model by conducting proper distribution fitting.

3.3. Problems Identified

In the light of the exposed, the authors identified two critical workers, which perform several activities and whose delay can severely affect the overall performance of the system. In this regard, the following is the list of such workers along with the tasks they perform and the name which will be used throughout the remaining of this document to refer to those workers:

- worker A - responsible for supplying dessert, juice and bread to both AR2_1 and AR2_2 access ramps;
- worker B - responsible for supplying the main dish at both AR2_1 and AR2_2 access ramps, supplying soap in all ramps and juice, bread and dessert at the AR1 ramp. Since this worker supplies critical item, such as soup and main dish, he is also responsible for constantly monitoring these, in order to supply them when needed.

In its turn, the following were the main problems identified in the restaurant, while conducting in loco observations:

1. Worker A is responsible for preparing and supplying juice containers in both AR access ramps. Yet, this worker travels a long distance to perform this task. There are other closer and available places, which could be used for this task, thus it should be assessed if it would lead to benefits to the system;
2. As stated in the previous subsection, in AR2_1 and AR1 no worker fills cups with juice and this did not seem to affect the performance of the system. Therefore, it should be assessed if stopping worker A from filling cups with juice in the remaining ramp would affect the system;
3. It was found that the monitoring performed by worker B was not efficient, since it could take him much time to notice lacking items, since he also had to do other tasks. To overcome this situation, the authors would like to test the impact of implementing an information device to warn the workers that an item needs to be supplied.

4. MODEL DEVELOPMENT

To enhance the animation of the model, 3D objects of persons, food and others were downloaded from Google Warehouse. The restaurant opens during specific times of the day, for customers to have lunch and dinner. In this regard, during the time the restaurant is open, the income flow of clients changes throughout the time. In this regard, different interarrival time rates of customers were defined in Simio, in accordance to the data gathered on the field. Thus, Figure 2 shows how to define these different interarrival time of customers in Simio.

When customers arrive at the restaurant, they pick items in different orders, depending on the access ramp they take. When a customer tries to collect an item, he executes a process to verify if the item in question is available. To this end, a different process is executed for each item in question. The process represented in Figure 3 illustrates the process executed to verify if the item bread is available, when a given customer executes this process.

From (hour:minute)	To (hour:minute)	Average arrival rate per hour
12:00	12:05	1373
12:05	12:10	1280
12:10	12:15	739
12:15	12:20	634
12:20	12:25	620
12:25	12:30	1404
12:30	12:35	768
12:35	12:40	624
12:40	12:45	972
12:45	12:50	1392
12:50	12:55	1560
12:55	13:00	888
13:00	13:05	1080
13:05	13:10	468
13:10	13:15	1656
13:15	13:20	672
13:20	13:25	708
13:25	13:30	288
13:30	13:35	120
13:35	13:40	216
13:40	13:45	300
13:45	13:50	144
13:50	13:55	156
13:55	14:00	24
14:00	14:05	120
14:05	14:10	120
14:10	14:15	96
14:15	14:20	0
14:20	14:25	0
14:25	14:30	0

Figure 2: Interarrival time rates used

When this process is executed, customers check the value of a state variable in Simio, which stores the quantity available of a certain item. If the value is not 0, the state variable in question is updated, indicating a reduction in the number of available items, i.e., the item is picked. On the other hand, if the item is not available, the customer waits a certain time to check again, until the item is available. When a customer waits for an item, other customers behind him, are not allowed to proceed, forming a waiting queue. Figure 7 shows the developed simulation model during run time in 3D.

The process of modelling workers in Simio is very simple, which is not true to all discrete-event simulation tools (Vieira A.A.C., Dias L.M.S., Pereira G.A.B. and Oliveira J.A. 2014). Yet, in some situations, modelling complex behaviour of workers in Simio can also become a complex task. These more complex situations to model will now be described:

I. *Set the processing time of a task depending on the number of workers*

To model workers who help other workers, and thus the respective task is done at a faster pace, the process represented in Figure 4 and Figure 5 is executed.

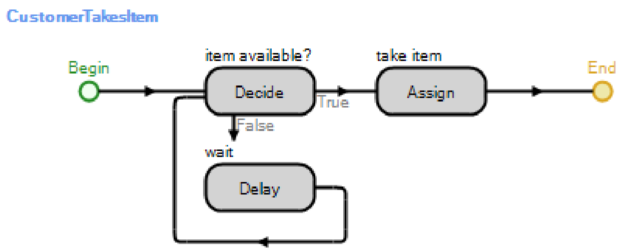

Figure 3: Process executed by customers to take bread

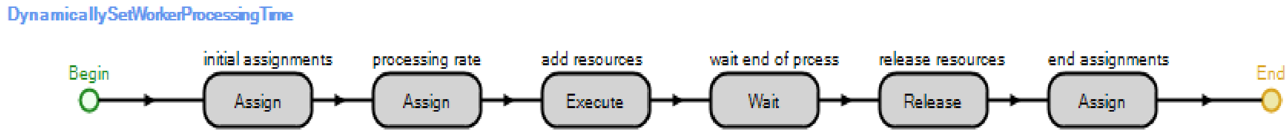

Figure 4: Process executed to dynamically assign the processing time of a task

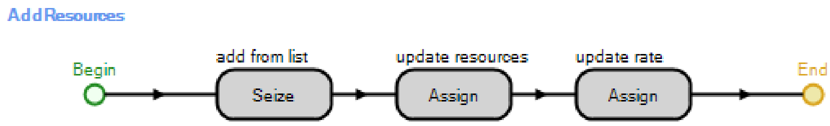

Figure 5: Process executed to seize additional workers

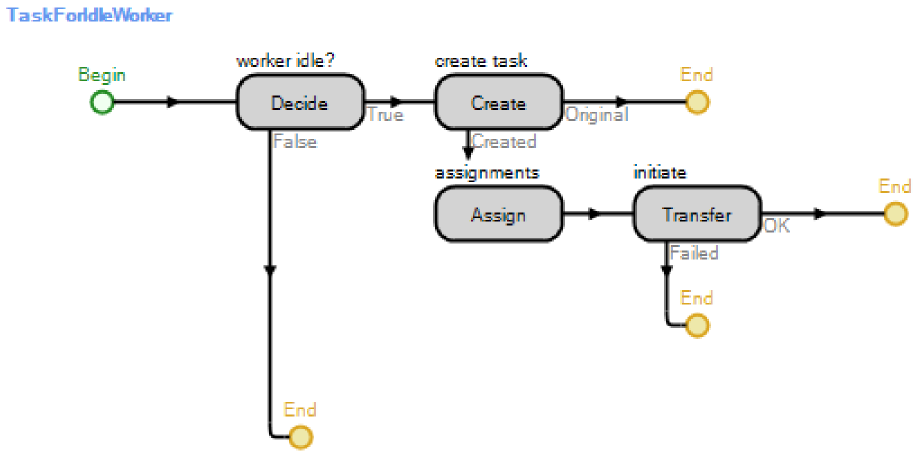

Figure 6: Process executed by worker on idle

Figure 7: Simulation model during run time

In this process, the first three steps are responsible for assigning the processing time of the task in question as proportional to the number of workers seized to perform the given task. Thereafter, the process represented in Figure 5 is executed. In this process, a new worker is assigned to the same task and the processing time of the task is updated according to the number of resources. After executing this process, the previous one continues (Figure 5). Thus, when the task finishes, the seized resources are released.

II.Worker performs a given task on idle status

To make a worker perform a specific action when he is on idle, i.e., when there are no tasks assigned to this worker, the process represented in Figure 6 was created. The workers who execute this process start by executing a step which checks if the worker in question is on idle. In this case, if the worker is on idle, the process will make him refill cups with juice. Thus, in this case, an entity is created which seizes the worker to perform the task in question. This way, a new task is assigned to the worker on idle.

4.1. Model Validation

In order for the developed simulation model to correspond to the self-service restaurant in analysis, the validation is an important step. Thus, this subsection briefly addresses the steps conducted in this process, by showing the obtained results for some indicators that can be compared to the data gathered on the ground. In this regard, Table 2 presents some of the obtained simulation results. By conducting this validation process, it is expected that the confidence level in the developed model is increased.

Table 2: Sample of data used to validate

Item	**Number of supplies**		
	AR2_1	**AR2_2**	**AR1**
Bread	5		3.1
Soap	12		7.7
Main dish	7.2	6.2	12.3
Juice	3.5	7.1	6.7

Regarding the average crossing time per customer, a value of 20,19 minutes was obtained, which is a similar value to the obtained and discussed in last section. As can be seen, the comparison of these values with the ones presented throughout the previous section allows to consider that the model has been properly validated.

5. SIMULATION EXPERIMENTS

One of the major benefits of using Simio is the possibility of conducting experiments to assess the performance of the simulated system. A simulation experiment is a set of scenarios, each one executing the model with different values on the properties of the model, which produces results in the identified Key Performance Indicators (KPI). Thus, to properly assess the performance of the system, the authors identified the following KPI of the restaurant system:

- total time required for a customer to go to the eating room;
- time customers are stopped on the queue;
- utilization rate of workers A and B.

To use simulation experiments, it is necessary to define the properties of the model that produce changes on the performance of the system (in Simio these are called responses). In this sense, the properties of the model consist on a possible solution to each of the problems identified in section 3.3, i.e., 3 different solutions were addressed:

- scenario 1: current scenario;
- scenario 2: worker A prepares the juice in a closer place;
- scenario 3: worker A does not fill cups with juice in AR2_2;
- scenario 4: model the system with an information device that helps workers notice the need to supply lacking items;
- scenario 5: scenarios 2 to 4 together;

The experiments were run with 10 replications with a simulation time of 2.5 hours.
Table 3 summarizes the obtained simulation experiments results

Table 3: Simulation results

	Customer centric KPI		Worker centric KPI	
Scenario	Total time (minutes)	Waiting time (minutes)	Utilization of Worker A	Utilization of Worker B
1	18.3	9.3	71.7 %	81.5 %
2	18.2	9.2	74.6 %	85.1 %
3	18.8	9.8	59.6 %	81.2 %
4	16.1	7.1	74.9 %	19.9 %
5	14.8	5.8	60.7 %	19.2 %

The considered KPI were divided in two groups: customer and worker centric, since the total time spent on the system and the waiting time are KPI which are mostly felt by customers, whilst the utilization rates are felt by workers. It is true that, globally, the two groups affect the system, but if one considers the view-point of customers and workers, then these two groups can be set. By analysing scenario 2, it is possible to see that the results do not present significative changes, for both groups, when comparing to scenario 1. This suggests that the place where the worker prepares the juice is not relevant for the performance of the system. Therefore, other metrics should be assessed. In its turn, it can be noted that the proposed scenario 3 also achieved a performance similar to scenario 2, regarding the customers KPI. On the other hand, on the workers KPI, it can be noted that the utilization of worker A decreased around 12%, which indicates that this solution could be used in the restaurant. Therefore, it is verified worker A may perform tasks other than filling cups, being available for more added-value tasks, which could culminate in improving the customers' KPI.

By analysing the results concerned with scenario 4, it can be seen that a reduction of more than **2.5 minutes** of average waiting time and average total time per customer, is obtained. Even so, the greatest gain comes from the reduction of the percentage usage of workers B, which was responsible for monitoring lacking items – a reduction of more than **60%** could be verified. Therefore, it can be concluded that the worker in cause could be used for several other activities.

Regarding the last scenario, it can be seen that the results are similar to scenarios 3 and 4, with further improvements in the KPI of customers, leading to a reduction of **3.5 minutes** of waiting time and total time spent on the system.

6. CONCLUSIONS

This paper documented the work conducted to assess the performance of a restaurant in Portugal. In this sense, a simulation model was developed to evaluate the performance of the system, by quantifying several performance indicators concerned with the service provided to the customers and the utilization of the involved workers. In addition, the model was also used to test alternatives scenarios.

The data used in the simulation model was collected through field observations, which also allowed to identify problems in the system in analysis. The developed model was validated by comparing the results obtained with the ones observed during the data collection process, thus contributing to increase the confidence level in the simulation model.

The experiments suggested that, from the previously hypothesized scenarios that could improve the performance of the system (see section 3.3 and the list of the 5 considered scenarios), only scenario 3 and 4 lead to significant improvements on the system, with scenario 2 indicating that the location where worker A performed a particular task did not impact the performance of the system.

Regarding the KPI considered for costumers, it was found that their waiting times could be reduced from 2.5 to 3.5 minutes if one of two solutions, which impacted different workers, was adopted: have customers fill cups with juice, freeing worker A for other tasks, or implement an information device to warn worker B of lacking items, thereby fastening the replenish of lacking items and also freeing this worker for other tasks, which could further improve the performance of the system.

This paper presented findings from a real case study consisting of Portuguese restaurant. The findings were reported to the management staff and are currently being pondered. Moreover, this paper also aims to contribute to the simulation community, more specifically the users of the Simio tool with some complex modelling situations that were faced during this project.

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