SIMULATION MODEL OF A QUEUING SYSTEM: THE CASE STUDY OF A FAIR TRADE MANIFESTATION IN NOVI SAD

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Abstract: *The main idea of this paper is to evaluate supply processes at a Fair Trade (FT) manifestation in Novi Sad. To successfully organize such a manifestation detailed preparation plan and transparent exhibitors' arrival schedule are required. In our case, exhibitors' arrivals are random, which may result with long queues and bottlenecks. Simulation model is created in MATLAB to evaluate whether the FT manifestation was overload with queuing during supply processes. According to obtained results all vehicles that entered manifestation are serviced without the need for long queuing.*

Keywords: *FT exhibition, simulation model, supply processes, performance evaluation.*

1. INTRODUCTION

This paper analyzes performance evaluation of a Fair Trade (FT) manifestation. According to the World Fair Trade Organization, FT is a trading partnership, based on dialog, transparency and respect, which seeks greater equity in international trade (WFTO, 2015). Observed FT manifestation is located in the second largest city in Serbia – Novi Sad. It spreads on the area of 226.000 m^2 and the indoor exhibition area covers 60.000 m^2. There are 37 halls, among which the most up-to-date is the Master Hall, which spreads on 5.970 m^2 of exhibition area. Tourism FT manifestation was in the main focus of this analysis. It was held in the Master Hall.

The main idea of this paper is to provide an answer should the stochastic schedule of exhibitors' arrivals be reorganized and replaced with deterministic timetable? The main dilemma is whether there is a short time window in which exhibitors' set up their exhibits? If so, the execution of supply processes will be dysfunctional. Simulation model provides calculation of various performance parameters which should give the answer to key question in this analysis. Performance parameters (1) *utilization (U)*, (2) r*ejected exhibitors (R), (3) mean number of vehicles in the queue (Lq), and (4) mean time vehicles have spent in the queue (Wq)* are selected as the main indicators.

The rest of the paper is organized in the following way. Section 2 describes a discrete event simulation and queue modeling in logistics. Section 3 considers the methodology. Section 4 explains simulation model and provides simulation results. Concluding remarks and future work follow in Section 5.

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2. DISCRETE EVENT SIMULATION AND QUEUE MODELING IN LOGISTICS

Discrete-event simulation (DES) is modeling approach widely used as decision support tool in logistics and supply chain management. Specific examples of the issues that these DSS address are supply chain design and reconfiguration, inventory planning and management, production scheduling and supplier selection (Tako and Robinson, 2012). Simulation models are usually built to understand how systems behave over time and to compare their performance under different conditions. DES can be applied at operational and tactical level (Figure 1). Several papers have suggested that DES is not suitable for strategic modeling as it does not normally represent systems at an aggregate level (Baines and Harrison, 1999). For strategic modeling, system dynamics (SD) is more adequate modeling approach. In some cases the use of hybrid simulation approaches combining DES and SD gives the best results (Rabelo et al., 2005).

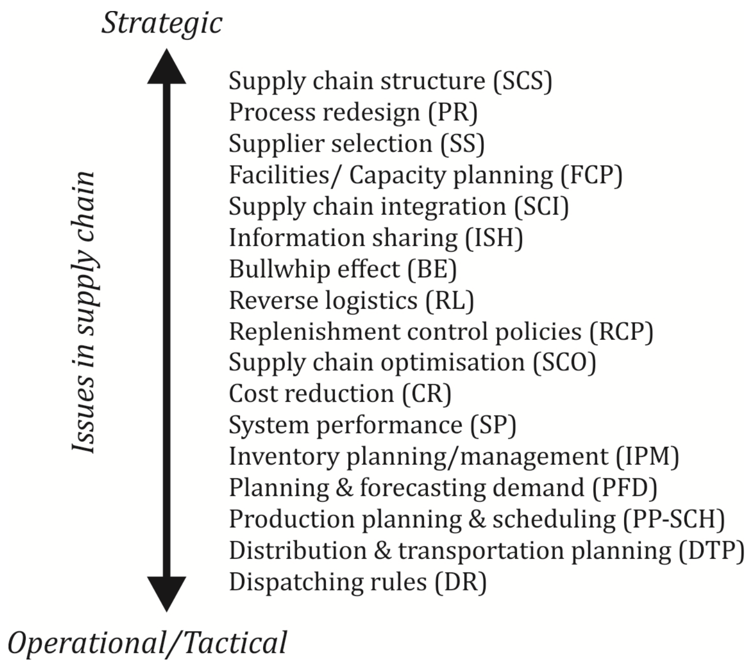

Figure 1. Ordering of logistics issues into strategic and operational/tactical (Tako and Robinson, 2012)

DES models systems as a network of queues and activities where state changes occur at discrete points of time. In DES entities (e.g. objects, people) are represented individually. Specific attributes are assigned to each entity, which determine what happens to them throughout the simulation. Statistical calculations are usually performed to describe entities' attributes.

Queuing models are widely used in service facilities, production, material-handling systems, and in situations where congestion or competition of scarce resources can occur. Generally, a queuing system is described by defining its population, the nature of arrival, the service time and mechanism, queuing behavior, and the queuing discipline (Jahn et al., 2010). The purpose of queuing models is to provide information about important performance parameters such as queue lengths, response times, waiting times, utilization, probability that any delay will occur, probability that some customers will be rejected, probability that all service facilities will be idle, etc. (Bhaskar and Lallement, 2010).

In our approach, *U, R, Lq,* and *Wq* are targeted performance parameters in the simulation model. Performance parameter - *U* - should reveal how high the percentage of the system usage is? The higher value of utilization is shown, the higher value of system usage is implied. Performance parameter - *U* - measures what percentage of daily supply activities has been operational. The key parameter was time on the basis of which simulation results are calculated and proposed.

Performance parameter - *R* - should show whether there were rejected exhibitors from servicing. Exhibitors are rejected in case of excessive queuing. Those situations are unacceptable in practice. Considering that exhibitors arrive randomly, organizers of the FT manifestation need to make available sufficient number of places for vehicles that are waiting in a queue. Performance parameter - *Lq* - should indicate what is the average number of vehicles during queuing. Correspondingly, performance parameter - *Wq* - should show what is the average time that vehicles have spent in the queue.

3. METHODOLOGY

The most efficient method for data collection was quantitative research. The total number of monitored vehicles at the Tourism FT was 56 at two servicing channels. Servicing channels are places in front of entrances into exhibition halls. They can be compared with regular parking places, but each servicing channel can serve only one vehicle at once. The size of entrances into exhibition halls and vehicles' dimensions restrict that only one exhibitor can set up its exhibits simultaneously. Observed FT manifestation is medium sized exhibitions. It lasted for three days. A sampling frame was identified through Novi Sad exhibition web site and organizational scheduling program. Table 1 shows the framework of this research.

Table 1. Basic information about the research

Observed FT manifestation	Tourism Fair Trade
Type of research	Quantitative research
The aim of research	To identify main characteristics of arrival rates (λ) and service rates (μ) during supply processes
Target groups	vans, cars
Obtained results	56 vehicles recorded
Research period	October 2013.

With the FT management support, the lead author and three research helpers were able to approach exhibition on-site and conduct the research at servicing channels. After arriving at exhibition area, the helpers were assigned to different entrances to Master Hall to ensure systematic coverage of supply processes. The illustration of the FT manifestation is presented to visualize similarity with the queuing system (Figure 2).

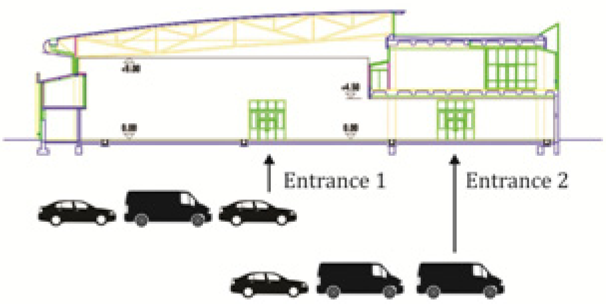

Figure 2. Master Hall at the FT exhibition in Novi Sad

It can be noticed that there are two entrances into Master Hall in front of which exhibitors unload their exhibits. Both entrances are observed in the context of one queuing system, not separately. If more than one vehicle arrives at the same time queuing will occur. Organizers of FT manifestation need to provide sufficient space for vehicles when queuing occurs. Exhibitors' arrivals are random. All supply processes are organized one day before the FT manifestation becomes opened for visitors.

4. SIMULATION MODEL AND RESULTS

Collected data from the quantitative research are merged into one dataset. The first step was to perform statistical analysis and define the input parameters for the simulation model. To determine probability distributions of collected data software MINITAB has been used. The main criterion during statistical analysis was that the p-value from obtained statistic results be, at least, at the 5% of the significance level. The p-value indicates the probability that tested data are in correlation with selected distribution. Obtained results from statistical analysis imply that arrival rates are in correlation with Normal distribution (p-value = 0.743) and service rates are in correlation with Weibull distribution (p-value = 0.187).

Software MATLAB and its graphical programming tool Simulink are used to create simulation model. MATLAB provides a relatively easy-to-use, versatile, and powerful simulation environment for investigating the basic, as well as advanced, aspects of dynamics systems (Hung, 1998). Simulink is simulation software developed for simulating and analyzing dynamic and discrete systems, which is widely used within industry for representing process behavior and control systems (Asbjörnsson et al., 2013). The simulation model is created using Simulink's SimEvents section with different blocks. The graphical drag-and-drop interface in Simulink was environment in which a discrete-event simulation model was build (Figure 3). The key features include (1) Libraries of predefined blocks, such as queues (first-in-first-out (FIFO) queue), servers (N-server), generators (Time-based entity generators) and sinks (Entity sink) for modeling system architecture, (2) Built-in statistics such as number of entities timed-out and utilization, and (3) M-function for calculating the main results (Inyiama, 2012). Event-Based Random Number block generates random numbers from specified distribution, parameter and initial seed. Depending on the type of determined distribution input parameters for arrivals and servicing are statistically determined. Time-Based Entity Generator block generates entities using integration times that satisfy specified criteria. The integration time is the time interval between two successive generation events. Start Timer block associates a named timer to each arriving entity independently and start the timer. Read Timer block reads the value of a timer that the Start Timer block was previously associated with. FIFO Queue block stores entities in sequence first-in, first-out for undetermined length of time. N-Server block stores up to N entities, serving each one independently for a period of time and then attempting to output the entity through the OUT port. Entity Sink block accepts all blocks entities and provides a way to terminate an entity path.

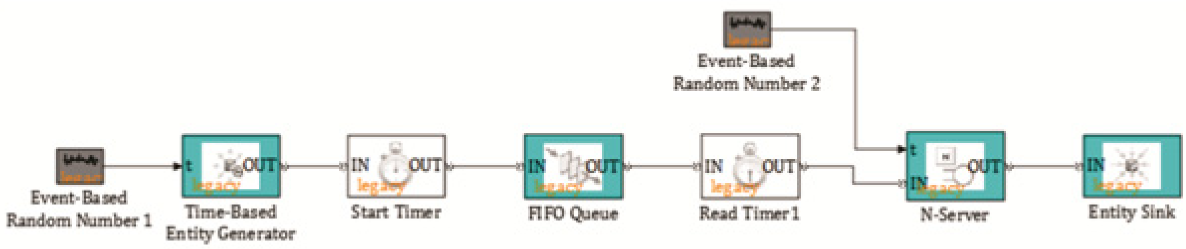

Figure 3. Basic blocks in the simulation model

Arrival rates and service rates are measured during 12 hours period, as long as supply processes lasted. In some cases, supply processes may last longer depending of the exhibitors' dynamics of arrivals and exhibition size, in general. The main criterion for determination of the upper limit of prediction period was average duration of supply processes of medium-sized FT manifestations. According to FT managers' expertise and experience the upper limits is five additional hours.

Therefore, the simulation and prediction results of parameters *U, R, Lq,* and *Wq* are calculated correspondingly (Table 2).

Table 2. Simulation and prediction results from the simulation model

	Time intervals					
Key performance parameters	12h	13h	14h	15h	16h	17h
R	0	0	0	0	0	0
U	67.7%	68.2%	68.8%	69.1%	69.5%	69.8%
Lq	3.41	3.62	3.84	3.91	4.02	4.13
Wq	10.43 min	10.64 min	10.73 min	10.85 min	11.06 min	11.22 min

Table 2 shows that performance parameter - *R* - has value 0 for simulation period of 12 hours, as well as for all prediction periods. Performance parameter - *U* - shows that system hasn't been used up to its limits, considering that obtained values from the simulation model are smaller than 100%. Performance parameter - *Lq* - shows average value of 3.41 vehicles in the queue during simulation period. Prediction results for - *Lq* - indicate that there is no large increase in obtained values considering that the greatest value is 4.13. Correspondingly, performance parameter - *Wq* - shows average value of 10.43 minutes for each vehicle during queuing. Similarly, prediction results for - *Wq* - do not show a significant difference compared to simulation result.

5. CONCLUDING REMARKS AND FUTURE WORK

The aim of this analysis was to provide an answer should the stochastic schedule of exhibitors' arrivals at the FT manifestation be reorganized and replaced with deterministic timetable? According to obtained results from the simulation model all vehicles that entered manifestation are serviced without the need for long queuing. Performance parameter - *R* - has value 0 for all simulation periods, which implies that there are no rejected exhibitors from servicing. Performance parameter - *U* - suggests that manifestation has not been overload with queuing during supply processes. Prediction results imply that at the current operating regime Tourism FT manifestation can efficiently function for 17 hours considering that 30% of time during daily supply activities system hasn't been used. Performance parameter - *Lq* - also supports effectiveness of FT manifestation because FT's managers easily can organize up to 10 waiting places in front of each entrance into Master Hall. Performance parameter - *Wq* - implies that exhibitors need to wait to unload their exhibits around 10 minutes. Unloading of exhibits at Tourism FT manifestation is relatively fast, because the exhibits are mostly composed of promotional tourism material. Simulation results of performance parameters imply that at a present operating regime stochastic schedule of exhibitors' arrivals at Tourism FT manifestation is quite efficient supply strategy.

Future research can be focused towards more comprehensive analysis with larger number of performance parameters, such as mean number of vehicles on servicing, mean number of vehicles in the system, mean time vehicles have spent on servicing and mean time vehicles have spent in the system. Also, different sized manifestations may be analyzed and compared. Additional data are required in that case. Proposed simulation model is universal for each manifestation held at the FT in Novi Sad. Additional blocks can be added in cases when larger-sized manifestations are being analyzed.

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