SIMULATION METHODS IN THE COMPARATIVE ANALYSIS OF CAR SPARE-PARTS DISTRIBUTION SYSTEMS

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Abstract

Car spare-parts must be frequently provided in after-sales service. Customers have great expectations in terms of the delivery and availability of spares. Orders realisation and flexible services are the most important among these expectations. The main aim of the paper is to consider two different distribution systems that occur in one entrepreneur. The reason of this consideration is to identify, which of the distribution systems is more effective regarding the order completion time and the level of customer service. In case of these aims realising, the simulation models analyses are proposed.

Keywords: Car spare-parts, distribution systems, simulation models, simulation methods

1. INTRODUCTION

In [1], Christopher defined the logistics spare-parts as: logistics spare-parts contains the market-oriented planning, realisation, and distribution, along with associated information-flows. Therefore, it means that efficient spare-parts logistics is necessary to be considered [2]. The Block Exemption Regulation (BER) introduced the classification of parts used for vehicle repair, defining sub-categories {O} and {Q} as original spare-parts. The next categories of spare-parts were distinguished in [3] as: (1) spare-parts in the "parts of comparable quality" category (marked with the letter {P}); (2) spare-parts (substitutes), which do not correspond to the previous categories (marked with the letter {Z}). The distribution of alternative {P} spare-parts is carried out by independent distributor in a multi-channel way. They reach the final customer from three sources: (1) directly from the distributor, (2) via the shop, (3) via the workshop. The article concerns the comparative analysis of two preferred models of the system of distributing alternative {P} parts of comparable quality and the option of direct deliveries to workshops. It is done using a simulation method. The latter model was chosen due to its largest market share (83%). The model 1 analysed in this paper is a model of distribution system is the distribution and sale with the use of mobile warehouses. The model 2 is a distribution system using transport via the supplier of goods from the supplier's warehouse or via the delivery company.

The paper is organized as follows. In chapter 2, essential conditions for the functioning of distribution system models selected for the analysis are discussed. Reference, mathematical and simulation models are included there. In chapter 3 the selected results of simulation experiments are presented and simulation models of distribution systems as regards the level of customer service are analysed. And chapter 4 concludes all results obtained in the research. The research process ends with the interpretation of the obtained results. The main aim of the article and the analysis is to identify which of the preferred systems is more effective as regards the order completion time and the level of customer service.

2. MODELS OF SELECTED DISTRIBUTION SYSTEMS

The model of the distribution system based on direct deliveries from the independent distributor's plant branch with the use of "milk run supply" principles is analysed. Standard material-handling system can minimize the total material-handling and inventory holding cost to the extent level [4]. In the considered company, every salesperson has their own customer base. The workers are equipped with GPS navigation system and a program that tracks and monitors the drivers. This indicates how much time the worker spent on the route, how much the worker's rest break last, and, above all, it makes orders from customers easy to view. The sale of products takes place via a chain of 9 branches across Poland, and 5 authorised dealers operate on the same principles as the company's branches and serve an area where no plants are located. Two distribution systems were suggested for the direct distribution model. The first one is a mobile warehouse system, whereas the second one is a distribution system using transport via the supplier of goods from the supplier's warehouse or via the delivery company.

2.1. Reference models of selected distribution systems

IDEF0 is a method designed to model the decisions, actions, and activities of an organisation or system [5]. A modified IDEF0 (Integrated DEFinition Methods) methodology and a "swimlane" concept were used in the reference model. IDEF0 allows to build diagrams reflecting the processes, which may be treated as a documentation of the process and as a model itself. A "swimlane" concept is a mechanism determining the activities of participant co-operating in the system. The mobile warehouse system (model 1) assumes that the goods are distributed from the company's branch and authorised dealers to customers based on van-selling principles (**Figure 1a**). During visiting the customer, the salesperson spends a lot of time on activities connected with the sale, i.e. presenting the offer, preparing an item from the vehicle, and issuing and printing an invoice (**Figure 1a**). Each of the sales representatives is equipped with a light commercial vehicle with a limited capacity of 3.5 tonnes.

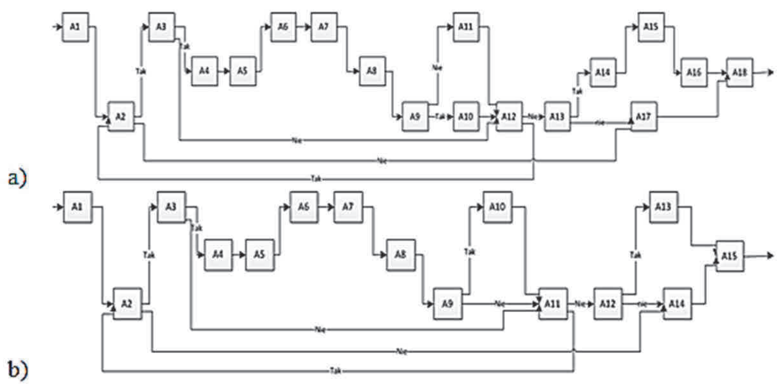

Figure 1 Reference model's: (a) model 1; (b) model 2; own-work

In case of model 1, activity name and their duration time ([min]) are: A1 - greeting and presenting a subject of negotiation (2), A2 - the decision about a need of purchase (1), A3 - verification of direct accessibility (2), A4 - presenting the positions of the parties - active recognition of a customer's needs (3), A5 - developing the argumentation - demonstrating an item in the mobile warehouse (1), A6 - finding a desired item of purchase (2), A7 - presenting the item of purchase (2), A8 - confronting the differences - determining the details concerning the item of purchase (3), A9 - the decision about purchasing the item of purchase (1), A10 - putting aside an item of purchase by a client - acceptance (1), A11 - putting an item of purchase back to a mobile warehouse - resignation (1), A12 - decision about continuing the process - the next item of purchase (1), A13 - decision about continuing a process - determining the conditions of purchase (2), A14 - preparing the printer and connecting an invoicing device (2), A15 - printing an invoice (2), A16 - receiving cash payment (2), A17 - refusal (1), A18 - arranging a date of the next meeting, goodbye (1).

In case of model 2, activity name and their duration time ([min]) are: A1 - greeting and presenting a subject of negotiation (2), A2 - decision about a need of purchase (1), A3 - verification of availability in an on-line catalogue (1), A4 - presenting the positions of the parties - active recognition of the Customer's needs (3), A5 - developing the argumentation - based on the on-line description (1), A6 - finding a desired item of purchase (1), A7 - presenting an item of purchase (1), A8 - confronting the differences - determining details concerning an item of purchase (3), A9 - decision about purchasing an item (1), A10 - confirmation of the order in an on-line system (1), A11 - decision about continuing a process - the next item of purchase (1), A12 - decision about continuing the process - determining the conditions of purchase (2), A13 - on-line order generation (1), A14 - refusal (1).

The salespeople do not play the role of a seller with a mobile warehouse, but of a sales representative. They are equipped with a passenger car and tablets connected to the ERP system supporting the company's functioning. An additional advantage is that a salesperson can monitor the warehouse stocks, knowing if a product of customer's interest is available. The number of operations in relation to the first model is lower (**Figure 1b**). In the delivery system via the supplier of goods from the branch's warehouse (model 2), automatically after receiving an order, order-picking and loading to the means of transport take place. The means of external transport or the appointed courier travel the same route in order to leave the ordered item at the customer's delivery address not later than one day after. Unfortunately, such operations extend the order completion time. Two reference models of distribution systems assumptions are compared in **Table 1**.

Table 1 Comparison distribution systems, source: own-work

Model 1	Model 2
direct access to 646 product indices (on average) located in a mobile warehouse	direct access to 2 500 product indices (on average) located in a branch's warehouse
the number of customers served at the level is 169	the number of customers served at the level is 178
the number of indexes sold at the level is 621 pcs and 817 185 pcs of goods per year	the number of indexes sold at the level is 771 and 890 000 pcs of goods per year
accessibility to the goods offered at the level of 67%	accessibility to all goods offered at the level of 97%
if the item is unavailable and the customer maintains the order, the item is delivered after one week	delivering the ordered item 24h after an order occurring

2.2. Mathematic and simulation models of chosen distribution systems

According to [6] "a simulation model is the multi-modules software that creates a kind of functional simulator with the compatible computer, which allows to generate states of modelled system." The requirements for above definition are fulfilled. Scheme of research procedure in the case of simulation models' constructing are drawn, with slightly changes, after [7]. The simulation models, described in the paper, were developed in accordance to guidelines of Discrete Event System Specification that is precisely defined in [8].

Simulation models e.g. allow conducting experiments and testing "what-if ...?" scenarios, both in the case of already existing systems or - in the case of processes planning - long before implementation. Simulation models that appear in this classification - depending on the characteristics or attributes of models describing the state of the system at the time - can be divided into four types: dynamic, static, stochastic, deterministic [8]. Herein, dynamic simulation models are considered. In the case of dynamic models, the time factor is significant. System's state changes with a simulation time and thus the properties and attributes of the system are dependent on a simulation time. As a simulation result depends on its duration, it is possible to obtain various effects.

There are many software tools that use the mentioned DEVS model. Some of them are: Arena, Dosimis-3, Tecnomatix® Plant Simulation, Flexsim etc. Some of these tools are made especially for simulating some aspects of logistics and production, whereas others can be adapted to achieve the necessary results.

In the research, presented in this paper, Tecnomatix® Plant Simulation 10.1 was used. Tecnomatix® Plant Simulation is a tool for digital numerical simulation models constructing and researching. Mainly, the software is used in simulations of manufacturing processes. According to the entrepreneurs who possess copyrights for Tecnomatix® Plant Simulation, it can be used in most industries [7].

2.3. Simulation model - model 1

As the first one, the simulation model that represents model 1 was prepared. It is based on reference model itself and its main form is given in **Figure 1a**. In the simulation model 40 highly-specialized sales representatives for 5 dealers and 2 sales representatives per one branch are assumed. Total amount of workers considered in the model is 58 persons. That means that assuming 252 working days, 56 items can be sold per one day. The exit strategy for A3 operation that is the verification of the direct accessibility to the goods offered by sales representatives is at the level of 67%. Whereas, for A13 operation (the decision about continuing the process - the next item of purchase) 46.7% or orders are positively realised. For the rest of operations, which need specific exit strategy, it was assumed to consider fifty-fifty strategies. **Figure 2**. presents processing capacity of every *A*-set elements in the case of the model 1. As it can be specified, some operations are in waiting mode in long period of time. In this simulation model, it is because one simulation correspond to one sales representative. She / he cannot realise different activities in the same time. However, some activities are in blocked mode. It means that the adequate activity last too long and other customers and orders are waiting in a queue. Some other results connected to model 2 are given in **Table 2**.

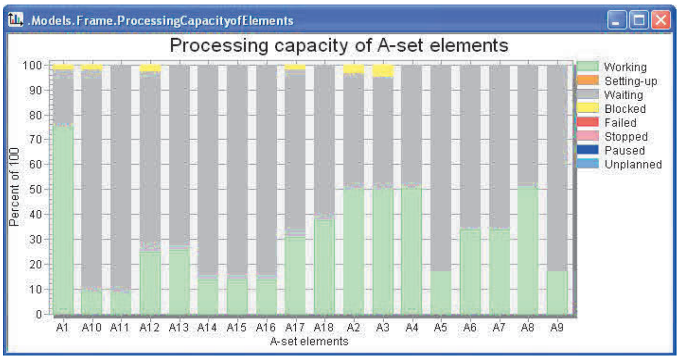

Figure 2 Processing capacity of *A*-set elements in the case of the model 1; source: own-work

Table 2 Selected standard measures the level of customer service in simulation analysis, source: own-work

The percentage of currently unavailable items is 56.8% (in the simulation model it is coded as:	The percentage of the customer's orders carried out completely is 18.5% (this one is coded as):
„Models.Frame.OrdersTime[5,.Models.Frame.Drain.statNumin]:=Num_To_Str((1(.Models.Frame.A5.statNumOut)/(.Models.Frame.Source.statNumOut))*100);"). Trend lines in this case are, as it follows (coefficient of determination R^2 is given after coma):	„Models.Frame.OrdersTime[7,.Models.Frame.Drain.statNumin]:=Num_To_Str(((.Models.Frame.A16.statNumOut)/(.Models.Frame.Source.statNumOut))*100);"). Trend lines in this case are, as it follows (coefficient of determination R^2 is given after coma):
linear: $y = -0.3911x + 77.5350$, $R^2 = 0.6624$,	linear: $y = -0.2006x + 6.6577$, $R^2 = 0.6823$,
logarithmic: $y = -8.3749 \cdot \ln(x) + 92.1640$, $R^2 = 0.9178$,	logarithmic: $y = 4.0223 \ln(x) - 0.0043$, $R^2 = 0.8288$,
polynomial: $y = 0.0118 \cdot x^2 - 1.0628 \cdot x + 84.0280$, $R^2 = 0.7879$.	polynomial: $y = -0.0042 \cdot x^2 + 0.4427 \cdot x + 4.3173$, $R^2 = 0.7462$.
power series: $y = 94.2330 \cdot x^{-0.1157}$, $R^2 = 0.9276$,	
exponential: $y = 77.4410 \cdot e^{-0.0056x}$, $R^2 = 0.7227$,	

The percentage of orders carried out completely from the stock in the warehouse is 100%. And at last, time from the moment of placing the order by the customer to the moment of delivering the ordered goods is 17 min. and 8.52 sec. Simulation time was 2 hours and 29 minutes, which means that sales representatives could serve three times more customers or in other words the number of workers seems to be too plentiful.

2.4. Simulation model - model 2

As the second one, the simulation model that represents the delivery system known here as model 2 was prepared. It is based on reference model in **Figure 1b**. In general, the entrepreneur employs 220 persons: 2 highly-specialized sales representatives per one of 9 branches, who sell items in mobile warehouse system and 40 highly-specialized sales representatives for 5 dealers, which means the rest of workers are hired in branches. That means that assuming 252 working days, 43 orders can be realised per one day. The exit strategy for A3 operation that is the verification of the direct accessibility, accessibility to the goods offered is at the level of 67%. Whereas, for A12 operation (the on-line order generation) 50% of orders are positively realised. For the rest of operations, which needs specific exit strategy, it was assumed to consider fifty-fifty strategies. **Figure 3**. presents processing capacity of every *A*-set elements in the case of the delivery system. As it was specified before, also in the case of second model some operations are in waiting mode in long period of time. In this simulation model, it is caused by the fact that one simulation correspond to one warehouse worker who serves one customer / order. She / he cannot realize different activities in the same time. Herein, only one activity is in blocked mode. It is A3 operation: verification of the availability in the on-line catalogue. It means that the adequate activity last too long. It might occur that it is because of the numerous assortment exposed in the catalogue.

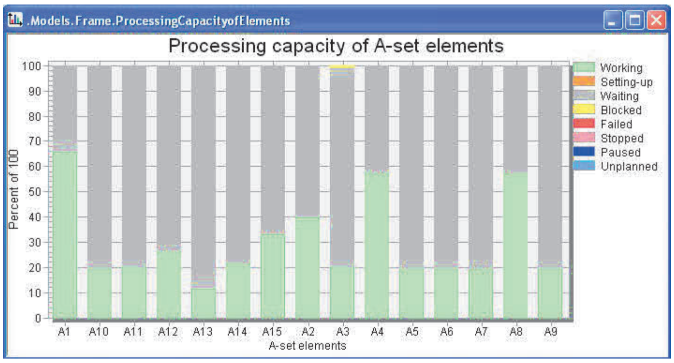

Figure 3 Processing capacity of A-set elements in the case of the model 2; source: own-work

Table 3 Selected standard measures the level of customer service in simulation analysis, source: own-work

The percentage of currently unavailable items is 41.85% (in the simulation model it is coded as:	The percentage of the customer's orders carried out completely is 34.88% (this one is coded as:
„.Models.Frame.OrdersTime[5,.Models.Frame.Drain.statNumin]:=Num_To_Str((1(.Models.Frame.A5.statNumOut)/(.Models.Frame.Source.statNumOut))*100);").Trend lines in this case are, as it follows (coefficient of determination R^2 is given after coma):	„.Models.Frame.OrdersTime[7,.Models.Frame.Drain.statNumin]:=Num_To_Str(((.Models.Frame.A13.statNumOut)/(.Models.Frame.Source.statNumOut))*100);"). Trend lines in this case are, as it follows (coefficient of determination R^2 is given after coma):
linear: $y = -0.5895 \cdot x + 71.6200$, R^2 = 0.5949,	linear: $y = 0.7943 \cdot x + 9.8080$, R^2 = 0.7302,
logarithmic: $y = -10.0260 \cdot \ln(x) + 86.9880$, R^2 = 0.8426,	logarithmic: $y = 12.7610 \cdot \ln(x) - 8.7858$, R^2 = 0.9230,
polynomial: $y = 0.0193 \cdot x^2 - 1.4394 \cdot x + 77.9950$, R^2 = 0.6734,	polynomial: $y = 0.0413 \cdot x^2 + 2.6135 \cdot x + 3.8363$, R^2 = 0.9736.
power series: $y = 89.3040 \cdot x^{-0.1527}$, R^2 = 0.8406,	
exponential: $y = 71.5710 \cdot e^{-0.0096x}$, R^2 = 0.6723.	

The percentage of orders carried out completely from the stock in the warehouse is 100%. And at last, time from the moment of placing the order by the customer to delivering the ordered goods is 15 min. and 34.88 sec. Simulation time was 2 hours and 11 min., which means that warehouse workers could serve three and a half times more customers or in other words the number of workers is too plentiful.

3. THE RESULTS OF SIMULATION EXPERIMENTS AND THE COMPARATIVE ANALYSIS

It should be explained that to check whether two variables describing the state of distribution systems (the percentage of currently unavailable items in simulation time and percentage of the customer's orders carried out completely in simulation time) oscillate around their final values at the end of simulation process, the exact test was introduced. In model 1 the percentage of currently unavailable items in simulation time oscillate around the final value (56.80%). Only 1 element, after plenty of simulation experiments, does not belong to partition 56.80% ± 3σ. The Fisher exact test statistic value is 1. The result is not significant at *p*-level: $p < 0.05$. Variables are independent. Whereas, in model 2, the percentage of currently unavailable items in simulation time oscillate around the final value (41.85%). Only 1 element does not belong to partition 41.85% ± 3σ. Percentage of the customer's orders carried out completely in simulation time is also considered. In this case, the Fisher exact test statistic value is 0.630584. The result is not significant at *p*-level: $p < 0.05$. Variables are independent.

4. CONCLUSION

The main result of this paper is to the comparative analysis concerns, among others, the assessment of the level of customer distribution service. Simulation with using adequate models show that in two distribution systems some organisational change might occur. Simulation results show in the first model that sales representatives could serve at least three times more customers while in the second model even three and a half times more customers. In other words the number of workers might be thought as too plentiful. However, it needs additional research to define adequate conclusions in the last matter. Obviously, it is required into consideration how much time the worker spent on the route, how much the worker's rest break last etc. From a practitioner perspective, the considerable investments in spare-parts availability signify that very small improvements in this area may lead to substantial cost savings. Notwithstanding, introducing of proposed changes would mean some savings for the company. It should be emphasized here that proposed changes tend to reduce the number of employees and increasing the efficiency of their work.

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