The Application of Simulation Methods in the Comparative Analysis of Car Spare Parts Distribution Systems

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Car spare parts are omnipresent in the modern world. They play a major role in business, maintenance and repairs. Car spare parts must be frequently provided in after-sales service. Customers of spare parts have great expectations in terms of their delivery and availability. Most important are short-term orders realisation and flexible services. The main aim of the paper is to consider two different distribution systems that occur at one entrepreneur's. The reason of this consideration is to identify which of the distribution systems is more effective regarding the order completion time and more effective regarding the level of customer service. In case of realising these aims, the simulation models analyses are proposed.

Keywords: Car spare parts, simulation models, distribution systems.

1. INTRODUCTION

Logistics processes serve the purpose of physical relocation of materials or products in a supply chain in order to meet the requirements of customers while maintaining economical principles [1]. A supply chain management is a decision process that not only integrates all of its participants, but also helps to coordinate the basic flows: products/services, information and funds [2], [3]. In [4] Christopher defined the logistics spare parts as : logistics spare parts contains the market-orientated planning, realization, and distribution, along with associated information-flows. Logistics spare parts aims at a demand-driven, cost-minimal provision of the required spare parts for the defective or preventive maintenance of primary products to ensure an optimal level of availability or reliability of the product.

Many authors consider problems of spare parts. As the example paper [27] can be cited. Authors of it propose mathematical model to address the optimal management of infrequent demand spare parts in the automotive industry. Whereas, in [28] spare parts stocking problems are presented to study the feasibility of the analysis using genetic programming.

Therefore, it means that efficient spare-parts logistics is necessary to be considered [4], [5].

Poland is an important manufacturer of automotive parts and accessories in the European Union. In 2003, their value exceeded PLN 59 billion, in 900 Polish factories. The demand for spare parts grows whenever a component fails or requires replacement, and as such it is different from that associated with a 'typical' Stock Keeping Unit (SKU) [6]. Managing spare parts is an important task in modern societies, with tremendous cost implications for the organizations that hold relevant inventories [6], [7].

The Block Exemption Regulation (BER) introduced the classification of parts used for vehicle repairs, defining sub-categories {O} and {Q} as original spare parts. The following categories of spare parts were distinguished in [8] and [9] as :

- original parts: (1) original spare parts with car manufacturer's packaging (marked with the letter {O}); (2) original spare parts without car manufacturer's packaging or markings in the packaging of parts manufacturers (marked with the letter {Q});
- spare parts in the "parts of comparable quality" category (marked with the letter {P});
- spare parts (substitutes), which do not correspond to either "original spare parts" or

"parts of comparable quality" categories (marked with the letter {Z}).

The supply of {P} spare parts strictly depends on customers' needs. The manufacturers of non-original parts start the production when it is economically justified. This requires the fulfilment of the following requirements [10]:

- the car brand and model are sufficiently popular in a regional, continental, or global scale,
- the part is replaced often enough and it is not technically demanding,
- the vehicle model has been produced for several years and therefore car owners start using services of independent repair garages.

The production of {P} spare parts is discontinued when the car model gradually ceases to be used or repaired due to economical reasons.

There are independent distributors of automotive parts and accessories operating in Poland. In 2014, they had over 1,000 wholesale outlets (Fig. 1) [11]. The distribution of alternative {P} spare parts is carried out by independent distributors in a multi-channel way (80% was accounted in accordance to the passenger car segment, whereas 20% to the truck segment). The system of parts distribution and sale includes direct deliveries to garages or automotive shops [11], [12]. They reach the final customer from three sources [10]: (1) directly from the distributor (5%), (2) via the shop (12%), (3) via the garage (83%).
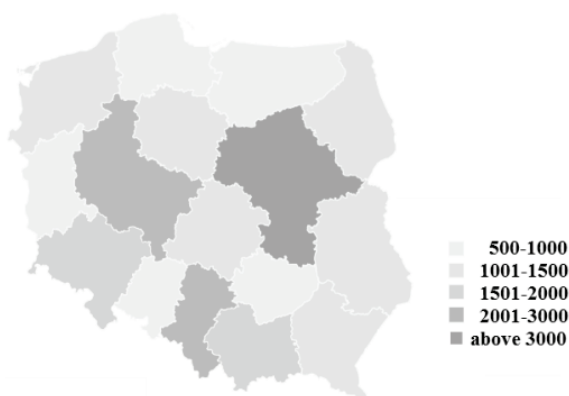

Fig. 1. The number of independent garages in province [11].

The last mentioned ones are carried out with the supplier's transport or via a delivery company. If the parts are available in a country, the delivery takes up to 2 working days. It happens that deliveries are extended in time if the parts are not available in a country. Sometimes the deliveries are not carried out [10].

The article deals with 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 garages. It is done using a simulation method. The latter was chosen due to its largest market share (83%). The first analysed model of a distribution system is the distribution and sale with the use of mobile warehouses. The second model is a distribution system using transport via the supplier of goods from the supplier's warehouse or via the delivery company.

The comparative analysis was divided into four stages:

1. defining the research problem – it will enable determination of the proper scope of research, exclude insignificant elements or aspects and provide minimal requirements for comparison,
2. collecting empirical data – consists in choosing a suitable research method; selection of proper information gathering method plays a crucial role in a study,
3. empirical data processing – consists in preparation of the empirical data,
4. analysis of empirical data – aims at comparison of the data (at this stage, equivalence is especially important).

The research process ends with the interpretation of the results obtained.

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 more effective as regards the level of customer service.

The paper is organized as follows: part II discusses essential conditions for the functioning of distribution system models selected for the analysis. Reference, mathematical and simulation models are included there. In part III the selected results of simulation experiments are presented and simulation models of distribution systems as regards the level of customer service are analysed. And part IV concludes all results obtained in the research.

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. The milk run supply system is also known as the cyclic goods supplying system, where goods are either collected from several suppliers and delivered to certain customers or collected from certain suppliers and delivered to several customers in a cyclic manner. Milk run supply system is secure logistics system which means it reduces transportation-related concerns at an extent level. A standard material-handling system can minimize the total material-handling and inventory holding cost to the extent level [13].

In the considered company, every salesperson has their own customer base, which they take care of and visit once a week. A route according to which the salesperson travels from customer to customer in order to sell goods is scheduled for each day. The daily aim is to visit 15 customers, and half of the visits should end with placing an order. The workers are equipped with GPS and a program that tracks and monitors the drivers. This indicates how much time the worker spent on the route, how long the worker's rest break lasted,

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

Modelling always begins with a so-called mental model. Mental models can be found in a variety of disciplines within the humanities and were first introduced in the field of simulation modelling by Forrester [14]. The historical foundations of modelling formalism were developed in the USA [15], and they resulted the creation of the family of IDEF methods. Until now, over 70 modelling languages have been developed. However, this large variety makes language selection process difficult [16]. IDEF0 is a method designed to model the decisions, actions, and activities of an organization or system [17], [18].
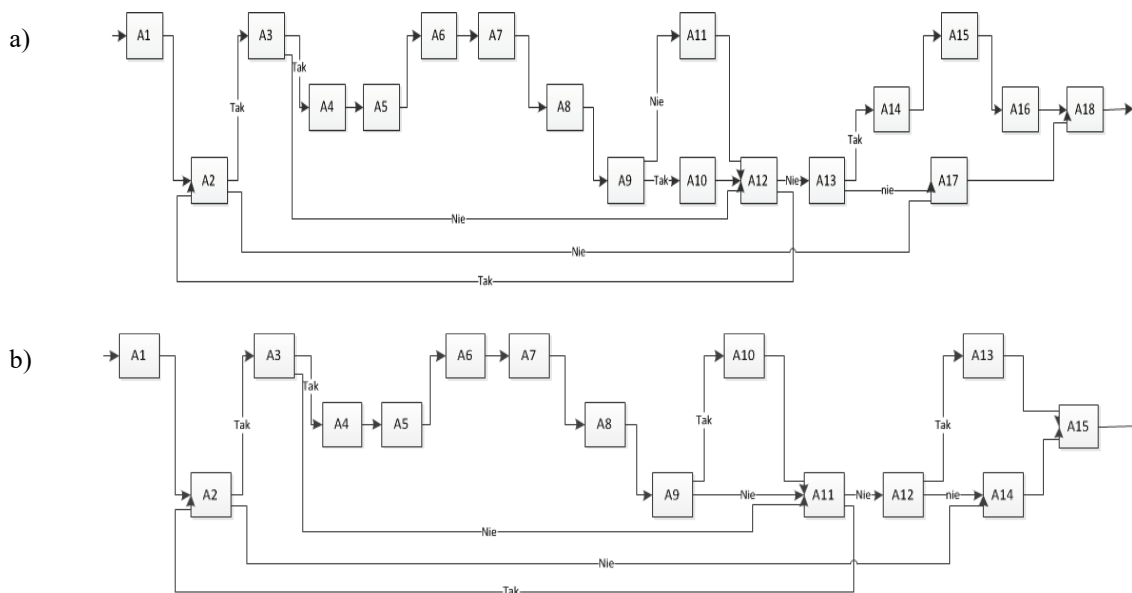

Fig. 2. Reference model for the mobile warehouse system (a); Reference model for the delivery system via the supplier of goods from the branch's warehouse or via the delivery company (b).
Source: own-work.

and, above all, it makes easy to view orders from customers.

The sale of products takes place via:
- a chain of 9 branches across Poland,
- 5 authorized dealers operating on the same principles as the company's branches and serving an area where no plants are located.

A modified IDEF0 (Integrated DEFinition Methods) methodology and a "swim-lane" 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, i.e. a repository of objects with their features and relations that can be tested, reported and improved then. A "swim-lane" concept is a mechanism determining the activities of participant

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co-operating in the system. It presents visually separated categories reflecting different functional responsibilities and competences.

The mobile warehouse system assumes that the goods are distributed from the company's branch and authorized dealers to customers based on van-selling principles (Fig. 2a and adequate Table I).

The mobile warehouse system provides:

- direct access to 646 product indices (on average) located in a mobile warehouse, the so-called general cargo, from 2 500 available from the branch's warehouse,

- accessibility to the goods offered at the level of 67% (the accessibility test showed that 73% customers were not satisfied with the accessibility of the goods, whereas 10% customers assessed the accessibility as good),
- if the item is in the mobile warehouse, it is readily available,
- if the item is unavailable and the customer maintains the order, the item is delivered after one week.

Table 1. Activities for the reference model of the mobile warehouse system.

ID	Activity name (duration, [min])	I entrance	O exit	ID next	ID prev
A1	Greeting and presenting a subject of negotiation (2)	I1	I2	A2	--
A2	The decision about a need of purchase (1)	I2, I15	I3, I22	A3, A17	A1
A3	Verification of direct accessibility (2)	I3	I4, I14	A4, A12	A2
A4	Presenting the positions of the parties - active recognition of a customer's needs (3)	I4	I5	A5	A3
A5	Developing the argumentation - demonstrating an item in the mobile ware-house (1)	I5	I6	A6	A4
A6	Finding a desired item of purchase (2)	I6	I7	A7	A5
A7	Presenting the item of purchase (2)	I7	I8	A8	A6
A8	Confronting the differences - determining the details concerning the item of purchase (3)	I8	I9	A9	A7
A9	The decision about purchasing the item of purchase (1)	I9	I10, I11	A10, A11	A8
A10	Putting aside an item of purchase by a client – acceptance (1)	I10	I12	A12	A9
A11	Putting an item of purchase back to a mobile warehouse – resignation (1)	I11	I13	A12	A9
A12	Decision about continuing the process - the next item of purchase (1)	I12, I13, I14	I15, I16	A2, A13	A3, A10, A11
A13	Decision about continuing a process - determining the conditions of purchase (2)	I16	I17, I18	A14, A17	A12
A14	Preparing the printer and connecting an invoicing device (2)	I17	I19	A15	A13
A15	Printing an invoice (2)	I19	I20	A16	A14
A16	Receiving cash payment (2|)	I20	I21	A18	A15
A17	Refusal (1)	I18, I22	I23	A18	A2, A13
A18	Arranging a date of the next meeting, goodbye (1)	I21, I23	I24	--	A16, A17

Source: own-work.

- serving 15 customers (on average) per working day, assumed that 7 customers will place an order,
- dealers employ 40 highly-specialized sales representatives, who sell items in mobile warehouse system,
- the number of customers served at the level is 169 customers,
- the number of indices sold at the level is 621 pcs,
- the sale is 817 185 pcs of goods per year,

During visiting the customer, the salesperson spends a lot of time on activities connected with the sale, i.e. presenting the offer, completing sales transaction, preparing an item from the vehicle, and issuing and printing an invoice (Fig. 2(a), Table I).

Each of the sales representatives is equipped with a light commercial vehicle with a limited capacity of 3.5 tonnes. A purchased item becomes property of a customer in the moment of purchase. If a customer wants to make a purchase different

than provided by a mobile warehouse, a customer is referred to the company's branch. A troublesome situation occurs when selected item is not available in a vehicle, let alone in the branch's warehouse.

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

Table 2. Activities for the reference model for the delivery system via the supplier of goods from the branch's warehouse or via the delivery company.

ID	Activity name (duration, [min])	I entrance	O exit	ID next	ID prev
A1	Greeting and presenting a subject of negotiation (2)	I1	I2	A2	--
A2	Decision about a need of purchase (1)	I2, I14	I3, I18	A3, A13	A1
A3	Verification of availability in an on-line catalogue (1)	I3	I4, I13	A4	A2
A4	Presenting the positions of the parties - active recognition of the Customer's needs (3)	I4	I5	A5	A3
A5	Developing the argumentation - based on the on-line description (1)	I5	I6	A6	A4
A6	Finding a desired item of purchase (1)	I6	I7	A7	A5
A7	Presenting an item of purchase (1)	I7	I8	A8	A6
A8	Confronting the differences - determining details concerning an item of purchase (3)	I8	I9	A9	A7
A9	The decision about purchasing an item (1)	I9	I10, I11	A10, A11	A8
A10	Confirmation of the order in an on-line system (1)	I10	I12	A11	A9
A11	Decision about continuing a process - the next item of purchase (1)	I11, I12, I13	I14, I15	A2, A12	A3, A9, A10
A12	Decision about continuing the process - determining the conditions of purchase (2)	I15	I16, I17	A13, A14	A11
A13	On-line order generation (1)	I16	I19	A15	A12
A14	Refusal (1)	I17, I18	I20	A15	A2, A12

Source: own-work.

The distribution system using transport via the supplier of goods from the supplier's warehouse or via the delivery company (Fig. 2b and adequate Table II) assumes:

- direct access to 2,500 product indices (on average) located in a branch's warehouse,
- serving 17 customers (on average) per working day, assumed that half of customers will place an order,
- employ 2 per 1 of 9 branches highly-specialized sales representatives, who sell items in a mobile warehouse system,
- the number of customers served at the level is 178,
- the number of indexes sold at the level is 771,
- the sale is 890,000 pcs of goods per year,
- accessibility to all goods offered at the level of 97%,
- monitoring the accessibility of stock in a branch's warehouse,
- delivering the ordered item 24h after an order occurring.

supporting the company's functioning. Thanks to this, the representative travelling to the customer according to the determined route and the schedule offers a range of goods amounting to 2 500 items. An additional advantage is that the 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 (Fig. 2b, Table II).

In the delivery system via the supplier of goods from the branch's warehouse, 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.

2.2. MATHEMATIC AND SIMULATION MODELS OF CHOSEN DISTRIBUTION SYSTEMS

According to [19] "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 [20].

The simulation models, described in the paper, were developed in accordance to guidelines of Discrete Event System Specification that is precisely defined in [21], [22]. The formalism of its structure consists of septuplet, given as it follows:

$$M^{DEVS} = \langle X, S, Y, \delta_{int}, \delta_{ext}, \lambda, t \rangle \qquad (1)$$

where:
X – the set of inputs,
S – the set of states,
Y – the set of outputs,
δ_{int} – the internal transition function,
$\delta_{int} : S \rightarrow S$,
δ_{ext} – the external transition function,
$\delta_{ext} : Q \times X \rightarrow S$ where Q is the total states set,
$Q = \{(s,e) | s \in S, 0 \le e \le t(s)\}$ and e is the time elapsed since last transition,
λ – the output function, $\lambda : S \rightarrow Y$,
t – the time advanced function $t : S \rightarrow R^+$.

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.

Methodology of approach to the models of systems and processes constructing is indicated in [23]. 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 [21], [22].

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 in their simulation process-making structure. Some of them are (products names are given only as examples, without comparison of theirs unique possibilities): Arena, Dosimis-3, Promodel, Witness, Tecnomatix® Plant Simulation, Flexsim etc. Various simulation and programming tools are commercially available to aid the logistics, transport and other kind of processes modelling. 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. Simulation models can be also realized e.g. in Matlab® or even Visual Basic Application in MS Excel. That kind of modelling can be much cheaper than using dedicated tooling software in such a situation. However, it is more work-consuming.

In the research, presented in this paper, Tecnomatix® Plant Simulation 10.1 was used (it was also known as Simple++, as well as eM-Plant before; more to be read in [23, 24]). Last year Tecnomatix® Plant Simulation is applied wider in research and industrial studies.

Tecnomatix® Plant Simulation is a tool for digital numerical simulation models constructing and researching. Mainly, the software is used in simulations of manufacturing processes. Generally, according to the entrepreneurs who possess copyrights for Tecnomatix® Plant Simulation, it can be used in most industries, e.g. automotive industry, aerospace, mechanical engineering, process industry, electronics industry, consumer packaged goods industry, airports, logistics companies, which include transport logistics, plant manufacturing and production logistics and last but not the least storage logistics [20].

The choice of these tools from a range of other simulation tools was dictated by the nature of object-oriented software, accessible language programming, ability to implement multi-faceted issues of process and prosaic reality of the first author's direct experience working with the tool and working together with its developers years ago. Its first application of one of paper's authors were in 2007.

2.3. SIMULATION MODEL IN THE CASE OF THE MOBILE WAREHOUSES SYSTEM

As the first one, the simulation model that represents mobile warehouse system was prepared. It is based on reference model itself and its main form is given in Fig. 3a.

In the simulation model 40 highly-specialized sales representatives for 5 dealers are assumed and 2 sales representatives per one branch. Total amount of workers considered in the model is 58 people.

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. 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.

In Fig. 4 quantities of items, in their distribution process, ordered to specific operations, are given. By the name of operations the activities (elements of A-set described in Table I) are understood.

(.Models.Frame.A5.statNumOut)/(.Models.Frame. Source.statNumOut))*100);"). In the whole simulation process, it changes as it can be seen in Fig. 6. Trend lines in this case are, as it follows (coefficient of determination R^2 is given after coma):

- linear: $y = -0.3911 \cdot x + 77.5350$, $R^2 = 0.6624$,
- logarithmic: $y = -8.3749 \cdot \ln(x) + 92.1640$, $R^2 = 0.9178$,
- polynomial: $y = 0.0118 \cdot x^2 - 1.0628 \cdot x + 84.0280$, $R^2 = 0.7879$,
- power series: $y = 94.2330 \cdot x^{-0.1157}$, $R^2 = 0.9276$,
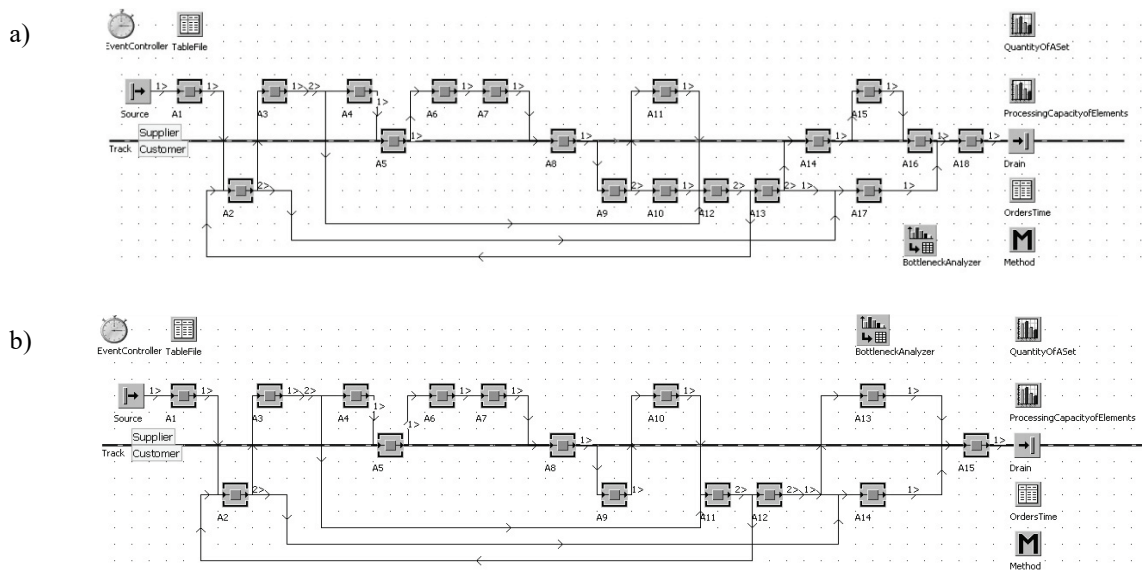- exponential: $y = 77.4410 \cdot e^{-0.0056x}$, $R^2 = 0.7227$.

Fig. 3. Simulation model's main form in the case of: a) the mobile warehouses system, b) the delivery system via the supplier of goods from the branch's warehouse or via the delivery company.
Source: own-work with using Tecnomatix® Plant Simulation.

More interesting is chart given in Fig. 5. It presents processing capacity of every A-set elements in the case of the mobile warehouses system. 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.

The following selected standard measures the level of customer service are obtained in simulation analysis.

The percentage of currently unavailable items is 56.8% (in the simulation model it is coded as: *„.Models.Frame.OrdersTime[5,.Models.Frame.Dr ain.statNumin]:=Num_To_Str((1-*

Meanwhile, the percentage of the customer's orders carried out completely is 18.5% (this one is coded as: *„Models.Frame.OrdersTime[7,.Models.Frame.Dra in.statNumin]:=Num_To_Str(((.Models.Frame.A1 6.statNumOut)/(.Models.Frame.Source.statNumOu t))*100);"*). Trend lines in this case are, as it follows (coefficient of determination R^2 is given after coma):

- linear: $y = -0.2006 \cdot x + 6.6577$, $R^2 = 0.6823$,
- logarithmic: $y = 4.0223 \cdot \ln(x) - 0,0043$, $R^2 = 0.8288$,
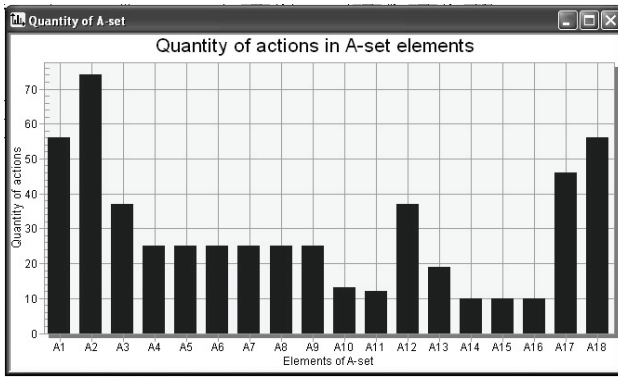- polynomial: $y = -0.0042 \cdot x^2 + 0.4427 \cdot x + 4.3173$, $R^2 = 0.7462$.

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Fig. 4. Quantities of items in its distribution process arranged in order by specific operations in the case of the mobile warehouses system.
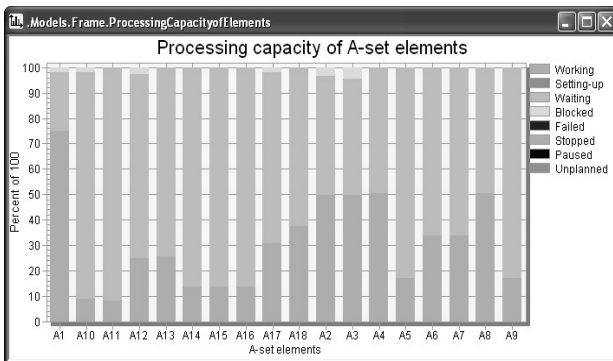Source: own-work, using Tecnomatix® Plant Simulation.

Fig. 5. Processing capacity of A-set elements in the case of the mobile warehouses system.
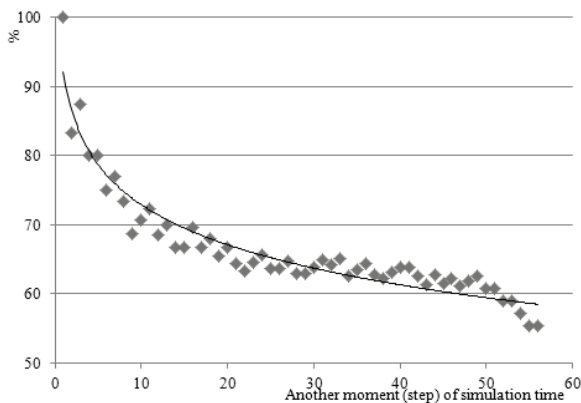Source: own-work, using Tecnomatix® Plant Simulation.

Fig. 6. Changes of the percentage of currently unavailable items in simulation time (logarithmic trend line adjusted) in the case of the mobile warehouses system.
Source: own-work, using Mac Pro Numbers.

As far as the percentage of the customer's orders carried out without damage shortage (reliability) is concerned, it cannot be analysed because of lack of data. 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 minutes and 8.5174 seconds. 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 THAT REPRESENTS THE DELIVERY SYSTEM, VIA THE SUPPLIER OF GOODS FROM THE BRANCH'S WAREHOUSE OR VIA THE DELIVERY COMPANY

As the second one, the simulation model that represents the delivery system, via the supplier of goods from the branch's warehouse or via the delivery company, was prepared. It is based on reference model described before and its main form is given in Fig. 3b.

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 (18 per one branch, assuming that 50% of workers are hired in managing position, the simulation model is computed for 9 warehouse workers per branch).

That means that assuming 252 working days, 43 orders can be realized 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 realized. For the rest of operations, which needs specific exit strategy, it was assumed to consider fifty-fifty strategies.

In Fig. 7, quantities of items in the distribution process in the case of this delivery service, ordered to specific operations, are given. As in the case of the first model, also here by the name of operations, the activities (elements of A-set described in Table II) are understood. Again, more interesting is chart given in Fig. 8. It 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 at 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 (2 500 items).

The following selected standard measures of the level of customer service are obtained in simulation analysis.

The percentage of currently unavailable items is 41.85% (in the simulation model it is coded as: „*.Models.Frame.OrdersTime[5,.Models.Frame.Dr ain.statNumin]:=Num_To_Str((1-(.Models.Frame.A5.statNumOut)/(.Models.Frame. Source.statNumOut))*100);"*). In the whole simulation process it changes as it can be seen in Fig. 9. Trend lines in this case are as it follows (coefficient of determination R^2 is given after coma):

- linear: $y = -0.5895 \cdot x + 71.6200$, $R^2 = 0.5949$,
- logarithmic: $y = -10.0260 \cdot \ln(x) + 86.9880$, $R^2 = 0.8426$,
- polynomial: $y = 0.0193 \cdot x^2 - 1.4394 \cdot x + 77.9950$, $R^2 = 0.6734$,
- power series: $y = 89.3040 \cdot x^{-0.1527}$, $R^2 = 0.8406$,
- exponential: $y = 71.5710 \cdot e^{-0.0096x}$, $R^2 = 0.6723$.

Meanwhile, the percentage of the customer's orders carried out completely is 34.88% (this one is coded as: „*.Models.Frame.OrdersTime[7,.Models.Frame.Dr ain.statNumin]:=Num_To_Str(((.Models.Frame.A 13.statNumOut)/(.Models.Frame.Source.statNumO ut))*100);"*). In the whole simulation process it changes as it can be seen in Fig. 13.

Trend lines in this case are as it follows (coefficient of determination R^2 is given after coma):

- linear: $y = 0.7943 \cdot x + 9.8080$, $R^2 = 0.7302$,
- logarithmic: $y = 12.7610 \cdot \ln(x) - 8,7858$, $R^2 = 0.9230$,
- polynomial: $y = 0.0413 \cdot x^2 + 2.6135 \cdot x + 3.8363$, $R^2 = 0.9736$.
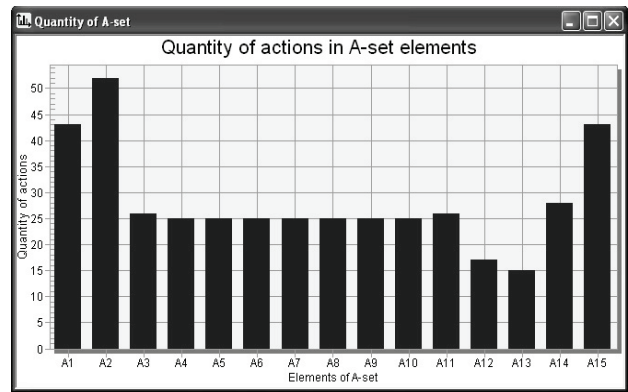

Fig. 7. Quantities of items in its distribution process arrange in order by specific operations in the case of the delivery system via the supplier of goods from the branch's warehouse or via the delivery company.
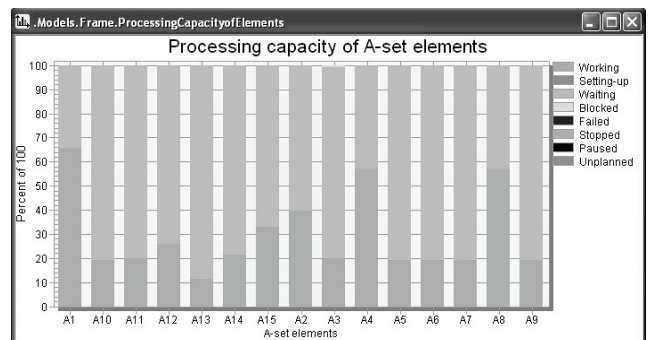Source: own-work, using Tecnomatix® Plant Simulation.

Fig. 8. Processing capacity of A-set elements in the case of the delivery system via the supplier of goods from the branch's warehouse or via the delivery company.
Source: own-work, using Tecnomatix® Plant Simulation.

As far as the percentage of the customer's orders carried out without damage shortage (reliability) is concerned, it cannot be analysed because of lack of data. 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 minutes and 34.8837 seconds. Simulation time was 2 hours and 11 minutes, 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.
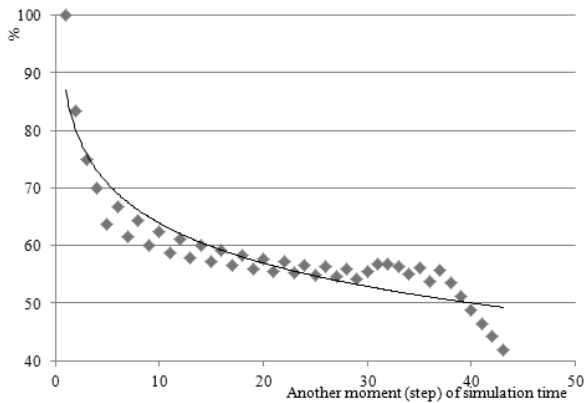
13

Fig. 9. Changes of the percentage of currently unavailable items in simulation time (logarithmic trend line adjusted) in the case of the delivery system via the supplier of goods from the branch's warehouse or via the delivery company.
Source: own-work, using Mac Pro Numbers.

3. THE RESULTS OF SIMULATION EXPERIMENTS AND THE COMPARATIVE ANALYSIS OF DISTRIBUTION SYSTEM SIMULATION MODELS

The comparative analysis concerns, among others, the assessment of the level of customer distribution service. This level determines the capability of the logistics system of satisfying the customers' needs as regards: time, reliability, quality and comfort. The analysis included only two components determining the level of customer service, namely: order completion cycle and the accessibility of the item from the stock.

Order completion cycle is the sum of times devoted to complete the customer's order. Order completion time includes:

- order processing time – it is dependent on the way of work organization and the number of activities carried out. They are included in the reference models and the tables describing ones.
- order placement time – it is necessary for transferring the customer's order. In the case of the mobile warehouse system, this time amounts to 0 min., whereas in the delivery system via the supplier of goods from the branch's warehouse this time is estimated to be approx. 2 min.
- shipment preparation time – in the mobile warehouse system this time amounts to 0 min., whereas in the delivery system via the supplier of goods from the branch's warehouse this time includes, among other,

activities such as: collecting the item from the shelf, picking, packing and loading the item to the means of transport.

- delivery (transport) time – it is counted from the moment of completing loading the item to the means of transport to the moment of delivering the item at the destination. It depends on the means of transport used and the distance from the customer. In the mobile warehouse system this time amounts to 0 min., whereas in the delivery system via the supplier of goods from the branch's warehouse this time is determined on the basis of estimated activity times.

The accessibility of the item from the stock determines the number of orders carried out from the stock kept in the warehouse. They may be also understood as the readiness to release the item from the stock immediately.

At least, 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 Fisher's exact test was introduced. In the Table III. (for percentage of currently unavailable items in simulation time) category for model 1 stands for quantity of elements in model 1 sample in case of the percentage of currently unavailable items in simulation time which oscillate around the final value (56,80%). Only 1 element does not belong to partition $56,80\% \pm 3\sigma$. Whereas, category for model 2 stands for quantity of elements in model 1 sample in case of the percentage of currently unavailable items in simulation time which oscillate around the final value (41,85%). Only 1 element does not belong to partition $41,85\% \pm 3\sigma$.

Table 3. Fisher's Exact Test Elements (Percentage Of Currently Unavailable Items In Simulation Time).

Results			
	Category for model 1	Category for model 2	*Marginal Row Totals*
Group 1 (YES)	42	55	97
Group 2 (NO)	1	1	2
Marginal Column Totals	43	56	99 (Grand Total)

Source: Own-Work.

Table 4. Fisher's exact test elements (percentage of the customer's orders carried out completely in simulation time).

Results			
	Category for model 1	Category for model 2	*Marginal Row Totals*
Group 1 (YES)	42	53	97
Group 2 (NO)	1	3	2
Marginal Column Totals	43	56	99 (Grand Total)

Source: Own-Work.

The Fisher exact test statistic value is 1. The result is not significant at p-level: $p < 0.05$. Variables are independent.

In the Table IV. percentage of the customer's orders carried out completely in simulation time is considered.

The Fisher exact test statistic value is 0.630584. The result is not significant at p-level: $p < 0.05$. Variables are independent.

4. CONCLUSIONS

The car spare parts distribution systems has some common points with the logistics of general goods. Fundamental logistics operations *include information processing, purchasing, warehouse management, transportation and distribution management*. The car spare parts distribution systems are different from the logistics of general goods. The reason is that the logistics activity of automotive spare parts serves for the after-sale service [26].

The paper presents the results of a practical project based on some basic results obtained in research work. 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 organizational 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, additional research is needed to define adequate conclusions in the last matter. Obviously, it is should be considered how much time the worker spent on the route, how long the worker's rest break lasted etc. The implemented models do not deal with such thing as physiological human needs etc.

From a practitioner's perspective, the considerable investments in spare parts availability signify that very small improvements in this area may lead to substantial cost savings. Notwithstanding, introducing the 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 increase the efficiency of their work (that is mentioned in previous indentation).

Despite all these facts, according to the results, the second distribution system is a more effective one. The decision of choosing the second distribution system is based on experts method.

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