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Integrated Simulation and Regression Framework for Delivery Management in E-commerce

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Problems with commodities and the delivery of products have accompanied trade since its beginnings. It is not possible to stock up, as there will always be limitations – of storage space, resources or financial resources. The e-commerce sector in the age of Industry 4.0 era faces its own specific problems: on the one hand, customers want customised products fast, on the other hand, shops have to lower storage costs and efficiently manage the supply chain. The paper proposes a framework of simulation modelling with a regression module for shops operating in the e-commerce sector; it is a tool for decision-makers that simulates the ordering and delivering process with a varying number of products, suppliers and a varying demand. The aim is to define a novel approach where computer simulation and regression models are integrated and combined in order to provide decision-makers with information about the average delivery time to customers ordering online products and possible delays. The results of analyses show 90% reliability of the regression model in terms of changes in the average delivery time depending on number of products sold by the shop, demand fluctuation, the number of distributors and the average delivery time of products from the distributor.

Keywords: delivery management, simulation modelling, regression analysis, e-commerce, supply chain

Wykorzystanie połączenia symulacji i regresji dla problemu zarządzania dostawami w sektorze e-commerce

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Problemy z zapasami i dostawą produktów towarzyszyły handlowi od początku jego istnienia. Nie jest możliwe utrzymanie cały czas wysokiego stanu zapasów, ponieważ zawsze będą istniały ograniczenia – powierzchni magazynowej, zasobów materialnych lub zasobów finansowych. Sektor e-commerce w dobie Przemysłu 4.0 boryka się z własnymi specyficznymi problemami: z jednej strony klienci chcą szybko dostać dostosowane do swoich potrzeb produkty, z drugiej zaś – sklepy muszą obniżyć koszty magazynowania i efektywnie zarządzać łańcuchem dostaw. W artykule proponuje się połączenie modelowania symulacyjnego z modułem regresji dla sklepów działających w sektorze handlu elektronicznego; jest to narzędzie dla decydentów, które symuluje proces zamawiania i dostarczania dla różnej liczby produktów, dostawców i zróżnicowanego popytu. Celem artykułu jest zdefiniowanie nowego podejścia, w którym symulacja komputerowa i modele regresji są zintegrowane i połączone w celu dostarczenia decydentom informacji o średnim czasie dostawy i ewentualnych opóźnieniach do klientów zamawiających

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produkty online. Wyniki analiz modelu regresji pokazują iż 90% zmian średniego czasu dostawy zależy od liczby produktów sprzedawanych przez sklep, wahań popytu, liczby dystrybutorów oraz średniego czasu dostawy produktów od dystrybutora.

Słowa kluczowe: zarządzanie dostawami, modelowanie symulacyjne, analiza regresji, handel elektroniczny, łańcuch dostaw.

JEL: L8, L81

1. Introduction

E-commerce has experienced steady growth over the past decade. This growth has generated significant demand for dedicated delivery services to end consumers. While safe, secure and timely delivery has always been a priority for the post and courier companies, delivery has never been as essential to the bottom line as it is today. Efficient supply chain and inventory management is becoming an increasingly critical task for e-commerce companies in the era of Industry 4.0. Two-thirds (66 percent) of consumers chose online sellers on the basis of delivery options (MetaPack, 2015). Most alarming of all is the decision moment, when due to dissatisfaction with delivery options, 68 percent of customers abandon their shopping carts before submitting their order (International Postal Corporation, 2014).

All entrepreneurs strive to increase their profits and optimise costs. Although this applies to the majority of department within a company, it is most evident in logistics. What are the main costs generated by warehouses? All depends on the industry and the specific nature of the company's operations, but in e-commerce, expenses are largely similar. At the planning stage, managers have to remember about such financial outlays as:

- rental or construction of a warehouse and the subsequent maintenance costs,
- service costs – mainly due to the inspection and repair of storage racks, the efficiency of equipment, lighting, etc.,
- storage costs – electricity, gas, heating,
- rental of equipment, disposal of old equipment or consumables.

In contrast, modern customers expect a fast and efficient service from e-shops and brick-and-mortar shops alike. Goods that are not imported on request should be available and in stock, while employees are expected to be reliable and competent.

Therefore, inventory and delivery management are becoming increasingly important issues. On the one hand, we want to reduce warehousing costs by keeping goods in warehouses for as short a period as possible, but on the other hand, we want to ensure quick deliveries to customers. Therefore, it becomes important to know which factors influence the timeliness of deliveries to customers, especially when we take into account random factors

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that may affect delivery times, such as failures of means of transport, road incidents, etc.

The aim of this article is to define a novel approach where computer simulation and regression models are integrated and combined in order to provide decision-makers with information that will help them precisely define delivery times to their customers. It is equally important to understand which elements of the supply chain have the greatest impact on delivery times and delays.

2. The supply chain and inventory management in e-commerce

Efficient inventory management means keeping an optimum amount of stock and involves purchase and sale processes. The difficulty lies in the fact that stock control requires different parts of the supply chain to be taken into account. Stock management is affected by the nature of demand, which is very often either unknown or known (projected), but with a degree of probabilistic uncertainty (Narmadha & Selladurai, 2009). In most cases, supply chains are characterized with demand uncertainty, which means that security stocks have to be accepted in order to prevent a complete shortage of goods. The aim of managing uncertainty should, therefore, be to minimise inventory levels and to meet customer expectations. There are two strategic decisions that companies face in managing their supply chain: delivery times and inventory levels (Kristianto, 2011). In order to increase responsiveness and reduce inventory costs, four types of cooperation can be resorted to, classified according to their integration level, ability to integrate supply chain planning, forecasting and replenishment (Christiansen, Kotzab & Mikkola, 2007).

Consequently, product distribution challenges in e-commerce are greater, with direct effects on logistics systems in urban and suburban areas, where traffic congestion and accessibility are crucial factors (Morganti, Dablanc & Fortin, 2014). In the case of the business-to-consumer market (B2C), home deliveries are most problematic in terms of service costs and organization (Song, Cherrett, McLeod & Wei, 2009).

E-shops provide information about the availability of each product. For customers, it is one of the most important pieces of information regarding a product: they know when to expect the processing of their order to commence. It is assumed that delivery time encompasses the packing of goods and the delivery of the product to the customer. It is usually 24h–48h in the case of courier deliveries and a few days if the parcel is sent by post. Obviously, it always depends on many external factors and companies have no influence over many of them.

Reasons of delays in deliveries to customers are manifold:

- lack of goods in stock and incorrect information in the product data sheet,

- the shop orders goods from the distributor and receives them only upon the payment of the the invoice,
- drop shiping and delays that may result from it – this solution has its advantages, as it does not require the shop to keep goods in stock,
- delivery and supply problems,
- poorly prepared promotional sales.

Deliveries in e-commerce have been discussed in literature from different perspectives. Customer service, and specifically logistics customer service, has become a critical aspect of online consumer interactions. Research Mentzer (2007) shows that customers expect value to be created through both their online purchase experience and the actual product delivery. The product must arrive in a timely manner and in good condition. When it comes to online shopping experience, a great deal of emphasis is placed on timely delivery and the superior condition of the delivered product. The paper (Kadłubek, 2015) presents selected areas of logistics based on information technology solutions, supporting logistics processes using ICT systems and tools, and the Internet. Author concludes that the use of modern information and communication technologies to support logistics management of the company brings positive results across the board. Studies performed to identify city logistics measures propose solutions that can be implemented to solve several complicated problems related to urban freight connected with online shopping (Russo & Comi, 2010, Teoa, Taniguchia & Qureshia, 2012). Morganti et al. (2014) document the recent development of alternative parcel delivery services available to e-shoppers in Europe, particularly in France. They describe how operators have organized their network of pickup points, identifying the main variables and constraints. Another article (Xianglian & Hua, 2013) presenting research on the logistics of domestic and international e-commerce analyses the characteristics of e-commerce logistics in the light of the current situation and problems in China. Its authors argue that the development trend of e-commerce logistics system information technology in China is the integration of logistics and purchasing. In the paper by Yu, Wang, Zhong and Huang (2016), e-commerce logistics in supply chain management is examined from the practical perspective. Due to the fast development and the strong influence of e-commerce, logistics have greatly changed over the past decades. The paper highlights logistics models and supporting techniques that have significantly improved e-commerce logistics. Implementation in North America, Europe, and South-East Asia is discussed.

3. Use of simulation modelling and regression analysis of delivery management problem

In the era of global competition, fast reaction to changing customer needs and the application of modern technologies and information systems

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to support management are of utmost importance (Kadłubek, 2015). In e-commerce, transactional elements of logistics are crucial, particularly the availability of products and services, rapidity of communication between contractors, the lead time, the scope of activity, the flexibility and reliability of supply. Uninhibited use of inventory and delivery control models, especially those that are more complex, requires a thorough knowledge of statistics, econometrics and operational research, as well as access to advanced systems incorporating appropriate algorithms. Managers controlling inventories and deliveries, especially in small and medium-sized enterprises, often limit themselves to basic quantitative models, in many cases making decisions based on common sense. However, in order to respond to the needs of customers, suppliers and partners, while reducing costs and increasing revenue, it is advisable to use specialized software.

One of the possible solutions is to use simulation modeling software to make simulations, and even to optimize inventory control under conditions of uncertainty. Simulation modeling is used when it is difficult or impossible to accurately analyze complex systems using constructed mathematical models. Observation of real objects that form part of complex systems, such as supply chains, proves that they are influenced by numerous random factors (Thierry, Narahari & Thomas, 2010). Simulation modelling allows the assessment of operating parameters prior to system implementation. Managers can perform useful "what-if" analyses that allow them to make better planning decisions. Some authors use simulations for modelling supply chains with delivery and inventory management problems. Duong et al. (2015) proposes model support to analyze relationships between input factors such as lifetime, lead time, and substitution ratio to provide better understanding of inventory management in the multi-echelon model for perishable and substitutable products. In the study by Torkul, Yılmaz, Selvi, and Cesur (2016), a simulation experiment is conducted to understand real-time delivery and inventory management model, and compare it to the re-order point inventory model. Ding, Benyoucef, Xie, Hans, and Schumacher (2004) have developed a simulation-based, optimised tool to design, improve, and support supply chain decision making. Berger, Tortorella, Frazzon (2018) analyse different delivery and inventory management strategies for finished products in the supplier-customer relationship. In order to perform this analysis, a computational simulation was used to model four different strategies. Results were measured on the basis of the lead time and service level indicators in four different configurations considering stochastic behaviours in the supplier and customer production processes.

Several papers describe the use of regression analysis in supply chain management. Nguegan and Mafini (2017) use regression analysis as a tool for supply chain management and business performance in the food processing industry. Benkachcha, Benhra and El Hassani (2014) resort to regression modelling to predict future sales of a product based on amounts invested in advertising, promotion expenses, and quarterly sales of the main competitor. No articles connect simulation modelling, regression analysis and the e-commerce market.

The majority of studies focus on inventory problems. There is a shortage of extensive research into delays in delivery to customers, their causes and effects, even though the speed of order completion, the availability of products and their wide selection, punctuality and low delivery costs are, in addition to price, crucial factors for customers, especially in e-commerce. Understanding what affects delivery delays and identifying elements of the logistics process that have the greatest impact are key element of store management – after all, shops want the customer to return.

We propose a framework for the use of computer simulation with a general regression module for identification purposes (Figure 1). It is intended to show which elements affect delivery delays and what their impact it.

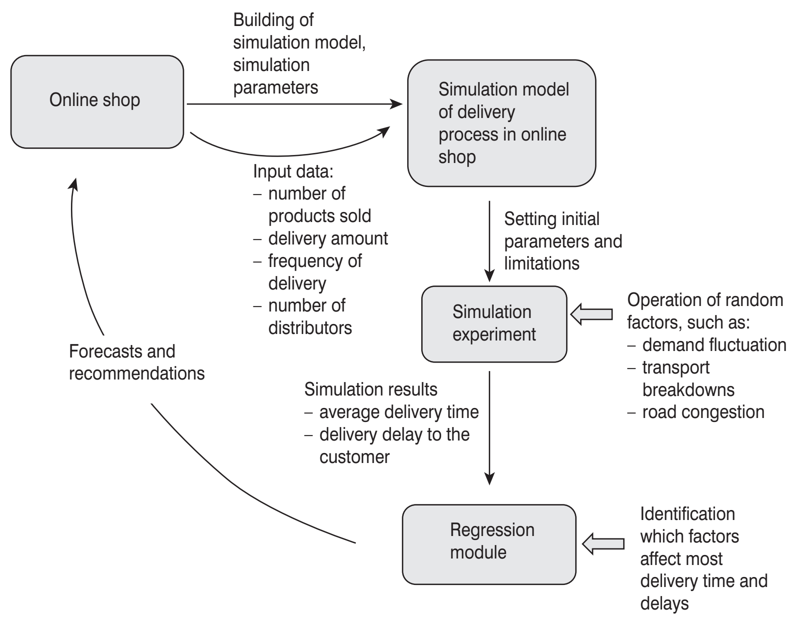

Fig. 1. Conceptual framework scheme of simulation modelling with a regression module for online shops

Online shops usually provide approximate delivery dates for each product; sometimes, a time range is given. Shops define delivery dates based on their experience or recent data. For several reasons, this is not the right approach. First of all, delivery times are affected by the seasonality of

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sales, e.g. busy periods before holidays or due to seasonal promotions. In addition, random factors such as breakdowns, or those affecting employees (drivers) (sick leave, road congestion) have an impact on the actual time of delivery to the customer.

Dealers usually do not have access to data from the entire supply chain, but sometimes they can obtain such data from their suppliers or measure the time themselves. This data, together with the number of suppliers and the number of products that are always in stock, would help generate likely scenarios in which delivery times to customers could be predicted using the simulation model. In addition, the regression module could be used to identify major factors affecting delivery times and delays. Ordinary linear regression can be used to forecast the expected value of a given unknown quantity (the response variable) as a linear combination of a set of observed values. We propose to use generalized linear models allowing for response variables with arbitrary distributions (rather than normal distributions), and for an arbitrary function of the response variable to vary linearly with the predicted values (rather than assuming that the response itself must vary linearly).

Businesses would have access to more reliable data, which they could provide to customers based on specific calculations from the entire supply chain, and not solely on their observations. Customers would appreciate such precise information about deliveries, for example, the average and the maximum waiting time for a given type of product.

4. Case study – identifying delays in online store

In logistics chains, especially in e-commerce, the timeliness of deliveries to customers plays a crucial role. Late delivery of goods from suppliers and other factors related to warehouse inventory management translate into delays in shipment to end customers, which has a negative impact on the quality of customer service.

In the analyzed example of online shop sales, the aim was to investigate delayed deliveries to the end customer in the supply chain. Methodology based on computer simulation together with the regression module was used to analyze more than 1,300 different cases of simulation models (different numbers of suppliers and products, variable demand, etc.). Arena software from Rockwell Software was used to build a simulation model of the delivery process in an online shop, with special blocks and methods dedicated to logistics processes. The regression module in this methodology allows the identification of factors that affect delivery delays and their impact.

When analyzing real phenomena and processes, even in relatively simple situations, we are not always able to thoroughly explain them. Therefore, we tend to use simplified models of real interdependencies. In the process of building a model, it is necessary to find a compromise between oversimplification of reality and the desire to include excessively detailed data.

In this paper, the regression analysis is used to explain the impact of changes in independent variables (from x_1 to x_5) on dependent variables (y_1 and y_2).

Dependent variables (outputs from simulation experiments):

y_1 – average delivery time to the customer

y_2 – delay in delivery to the customer

Independent variables (inputs in the simulation model):

x_1 – the number of products sold by the shop (between 20 and 200 different products in simulated scenarios)

x_2 – the percentage of products that are always in stock (between 20% to 35% in simulated scenarios)

x_3 – demand fluctuation expressed as a standard deviation (percentage) of the average demand for products (between 5% to 15% in simulated scenarios)

x_4 – the number of distributors (simulated scenarios contained between 5 to 25 different distributors in simulated scenarios)

x_5 – average time of delivery from the distributor (this variable changes in simulated scenarios as a result of a variety of random circumstances related to deliveries, such as traffic jams, transport failure, etc.)

Research began with a comprehensive model containing all potential factors affecting the examined phenomenon that were subject to testing. Then the components of the initial extensive model were tested to identify less extensive sub-models that adequately explain the investigated phenomenon. Finally, among these potential sub-models, the simplest one was selected as "the best" when it comes to describing the studied phenomenon.

The backward stepwise regression method was used to simplify the model. Simple models are preferred for practical reasons: they are easier to retest, less expensive to implement and easier to understand.

Two analyzes were carried out, separately for each dependent variable (y_1 – average delivery time to the customer, and y_2 – delay in delivery to the customer). For y_1 backward stepwise regression was performed and, after 2 steps 4, independent variables were left: x_1, x_3, x_4, x_5. Table 1 presents significance tests with effect sizes, *p*-value and *t*-test for y_1 – average delivery time to the customer.

As can be seen from Table 1, all 4 variables left after stepwise regression are statistically significant – the *p*-values are distinctly less than 0.05. Additionally, an assessment of the significance of structural parameters was carried out. To check the significance of structural parameters b_0, b_1, …, b_n, *t*-test was used, where *t* statistic has *t*-test distribution with *n-k-1* degrees of freedom.

 DOI 10.7172/1644-9584.82.11

	Sum of squares	**Mean Square**	***F***	***p*-value**	***t*-test**
x_1 – number of products	27747.8	27747.8	102.5144	<0.0001	10.12494
x_3 – demand fluctuation	198073.1	198073.1	731.7818	<0.0001	27.05147
x_4 – number of distributors	106.788	106.788	24.309	<0.0001	–4.9305
x_5 – delivery time from distributor	9302.5	9302.5	34.3683	0.01081	5.86244

Tab. 1. Significance tests for the average delivery time to the customer

Null and alternative hypotheses:
H_0: $b_i = 0$ (no linear relationship)
H_1: $b_i \neq 0$ (linear relationship does exist)
The critical region is two-sided, with the critical value from *t*-test distribution for a fixed level of significance a and *n-k-1* degrees of freedom. If the value of *t* is in the critical region (calculated value of $t >$ value of *t* from table), we have to reject H_0 in favor of H_1. Otherwise, there is no basis for rejecting H_0. In the case of structural parameters from Table 1, all values of *t* are in the critical region, and therefore the correlation does exist.

The regression model for y_1 – average delivery time to the customer is as follows:

$$y_1 = 4.73 + 0.08\, x_1 + 2.98\, x_3 - 0.19\, x_4 + 0.19\, x_5$$

A similar situation can be seen in Table 2, where significance tests are presented with effect sizes for the second dependent variable y_2 – delay in delivery to the customer. In this case, the backward stepwise regression was performed; after the 2 steps, 4 independent variables were left: x_1, x_2, x_3, x_5.

	Sum of squares	**Mean Square**	***F***	***p*-value**	***t*-test**
x_1 – number of products	2227.83	2227.833	175.5871	<0.0001	–5.3442
x_2 – number of products that are always in stock	6311.202	6311.202	11.37535	0.00784	–3.3724
x_3 – demand fluctuation	3696.50	3696.499	291.3405	<0.0001	9.86121
x_5 – delivery time from distributor	2401.98	2401.98	43.29350	<0.0001	6.57978

Tab. 2. Significance tests for the delay in delivery to the customer

According to Table 2, all variables left after the 2 steps of stepwise regression are statistically significant, with *p*-values distinctly lower than

0.05. In order to check the significance of structural parameters, we can also refer to *t*-test values in the Table; in each case they are in a critical region, which means that the relationship does exist.

The regression model for y_2 – delay in delivery to the customer:

$$y_2 = 0.84 + 0.02\ x_1 - 0.04\ x_2 + 0.41\ x_3 + 0.91\ x_5$$

Furthermore, the model has been verified to check whether regression models are acceptable. The properties of standard deviations have been examined and it has been verified whether the assessment of the model fits with the empirical data. A number of indicators have been calculated to verify the presented regression models:

- The Coefficient of Determination, R^2 – is the portion of the total variation in the dependent variable that is explained by the variation in the independent variable, $0 \leq R^2 \leq 1$
- The Standard Error of Estimate, s_ε – the standard deviation of the variation of observations around the regression line
- The Coefficient of variation Vs_ε – a standardized measure of dispersion of probability distribution or frequency distribution. The lower the value of this coefficient, the better model.

	R^2	s_ε	Vs_ε
y_1 – average delivery time to the customer	0.9078	5.08	15.24%
y_2 – delay in delivery to the customer	0.7079	1.14	19.94%

Tab. 3. Verification of regression models

In Table 3, the R^2 parameter shows that 90.78% of changes in the average delivery time are explained by the change in the set of independent variables (x_1, x_3, x_4, x_5). In the case of delays in delivery the result is slightly worse, but also acceptable: 70.79% changes in delivery delays are explained by the change in the set of independent variables (x_1, x_2, x_3, x_5). The s_ε parameter indicates that the estimated values of average delivery time and delay in delivery to the customer differ from real values by 5.08 and 1.14 respectively.

Summing up these results and the *t*-test value from Tables 1 and 2, it transpires that both regression models are statistically significant, with a slightly better value obtained in the model created to calculate the average delivery time to the customer, especially the R^2 parameter, which explains as much as 90% of the variance of the model.

5. Conclusion

Logistics in e-commerce are a complex issue. Inventory management in the supply chain in the era of Industry 4.0 is becoming an increasingly

 DOI 10.7172/1644-9584.82.11

important problem for the sector. The number of factors that affect the timeliness of orders is such that one small mistake at a certain point of order completion may trigger a problem that will discourage customers from placing further orders. In order to avoid such situations, it is necessary to accurately examine the ordering process and improve each of its stages. This requires the identification of factors that affect delays in delivery to the customer and their precise impact on the process.

The paper proposes a simulation modelling framework with a regression module for online shops. It is a tool that can be used by decision-makers to simulate the process of placing orders and delivering products to customers of an e-store, taking into account different numbers of products and suppliers, as well as demand variability.

The example examined in the paper proves that the use of an additional regression module allowed us to ascertain that the average time of delivery to customers is affected by the following: the number of products sold, the variability of demand, the number of distributors and the average delivery time from the distributor – changes due to various random circumstances related to deliveries, such as traffic jams, transport failure etc. Over 90% of changes in the average delivery time are explained by changes in the above factors. In addition, over 70% of changes in delivery delays are explained by changes in the number of products sold by the shop, the percentage of products that are always in stock, demand variability, the average delivery time from the distributor – changes due to various random circumstances related to deliveries, such as traffic jams, transport failure etc.

Decision-makers can use computer simulation to get concrete results from a variety of case studies, and to set target, e.g. increasing or decreasing the number of products sold or the number of distributors. Secondly, using the methodology presented in the paper, a combination of computer simulation with a regression model, decision-makers can calculate (from the obtained formula) the average delivery time and the estimated delay in delivery. This allows them to provide customers with more precise information about the delivery of products they have ordered.

6. Limitations and suggestions for further research

Some limitations of this study should be highlighted so that they can be addressed in future. The study is limited, as in the case of simulation modelling, the model is always only a fragment of reality. This means that other unforeseen factors not included in the model can affect the delivery time. In the simulation model, certain limits must be imposed, e.g. 200 products in a shop.

The study has several implications for future research. First, the presented methodology is universal and can be used not only in e-commerce, but also with respect to traditional businesses. Second, in order to improve the quality of information (estimated average delivery time and delivery delay), another method, such as artificial neural networks, can be used instead of regression analysis.

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