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MODELLING THE COSTS OF POSTAL COMPANIES FOR THE DELIVERY OF GOODS TO CONSUMERS WITHIN THE LAST MILE

Summary. The aim of this paper is to design a methodological procedure for determining the costs of companies in the process of travelling the last mile in the context of changing the business model. At present, traditional services such as delivery by post or by courier to a particular consumer's place of residence are still used to deliver consignments to consumers. In recent years, however, new delivery methods have begun to be used, such as ParcelShops, lockers located at specific locations, or dispensing points where the consumer comes to pick up the shipment. In order for each of these methods of delivering goods to consumers to work as efficiently as possible, it is necessary to incur certain costs. The results of this paper contain a mathematical relationship for calculating the total costs that a postal company has to incur in order to deliver goods to consumers within the last mile using the available delivery options.

1. INTRODUCTION

Last mile logistics reflects a company's consumer orientation. In the era of e-commerce, last mile logistics for product delivery has become the focus of attention of individual institutions [1]. Current technological advances are also blurring the line between the supply of physical and electronic means [2]. Last mile logistics has been a serious issue in recent years, as consumers expect their orders to be delivered quickly and reliably, regardless of where they place their orders from. In addition to the delivery time of the order, expectations are also increasing concerning communication and the tracking of e-commerce orders [3]. Consumer satisfaction has received a great deal of attention in the services sector, and improving service quality and maintaining consumer loyalty have become central concerns, especially in highly competitive markets [4]. Consumers are often unaware of how many different processes and procedures need to be performed before the ordered product or service reaches them [5].

The term "last mile" refers to a short geographical segment of the provision of communication and media services to consumers or the supply of products to consumers. Last mile logistics is complex and a source of high costs for providers of specific goods and services in certain geographical areas [6].

The last mile represents the last part of the transit in the supply chains, within which goods are delivered from the last place of transit to the destination, which is usually a specific consumer. This part of logistics plays a key role in ensuring that specific products ordered by consumers are delivered on time, in the right quantity, and to a pre-determined place [7].

Businesses have to consider distribution and business models that can operate in different dimensions. Such dimensions include cost-effectiveness, innovativeness, consumer satisfaction, and sustainability. Only with such models can they respond to the challenges associated with accomplishing last mile e-commerce delivery [8].

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The business model is a central element of any company. It expresses how the company will spend its resources and exert its capabilities to create economic value. It also highlights how the company acquires and uses various forms of capital to create value. Osterwalder and Pigneur defined the term "business model" as follows: A business model describes the reasons why a company creates, delivers and captures value [9, 10]. Osterwalder and Pigneur further stated that the Canvas business model is a strategy that needs to be implemented through organizational structures, processes, and systems. Nine basic building blocks or key business areas form the main business model structure. They show the logic underlying businesses' desires to make money and cover the four main areas of business, which are customers, supply, infrastructure, and financial viability [10, 11].

The logistics industry is facing many challenges simultaneously, thereby forcing the industry to develop innovations to address things in new ways. Logistics service innovations apply to basic and complex logistics services. Specific examples of logistics innovations in recent decades include electronic data interchange, cross-docking, radio frequency identification and joint planning, forecasting, and supplementation. However, innovations, models, or concepts are also being implemented within the last mile. The development of low-fuel, high-efficiency urban logistics vehicles is expected. In addition, the ever-increasing volume of packages that need to be delivered to final consumers every day has led to the introduction of many new last mile solutions in recent years. Moreover, increasing numbers of orders have a negative impact on the environment and safety, as more and more vans are needed to cover the last mile. New last mile concepts include deliveries using drones or small ground-based autonomous robots launched from trucks, the distribution of goods by electric vehicles, deliveries to the trunks of parked cars, the combined distribution of freight with public and private vehicles, reverse logistics, supply crowdsourcing or mobile lockable cabinets, and collection via automated parcel stations. With the growing digitalization of the logistics industry, companies are also increasingly adopting artificial intelligence. They use artificial intelligence in their logistics and supply chains to reduce the amount of time and money spent finding out how, when, and where goods or services need to be delivered [12-15].

The last mile distribution process is challenging, but there are several ways in which goods can be delivered to customers. Companies operating e-shops have implemented various new trends in the field of shipment delivery into their business models. These include lockable parcel boxes, parcel machines, a network of dispensing points, courier services, and, in some countries, autonomous vehicles or drones [16-18]. The most important factor that influences the total cost of mail and parcel services is the costs connected with the transportation of postal shipment [19].

New technologies used in the delivery process determine cost changes. A company's choice of technologies to adopt is linked to key questions, related to whether it is appropriate to use the new delivery technologies, the costs associated with these technologies, and how the customer might perceive new delivery options. Each new way of delivering shipments affects the total cost of delivery. These cost changes affect all stakeholders (i.e., trade companies, postal companies, and the customer). Such changes currently require the interconnection of individual processes, and changes in processes immediately cause changes in costs. Therefore, it is necessary to pay attention to the cost structure of individual methods of delivering goods. The aim of this paper is to present the process of modelling the total cost of delivering goods to customers.

2. METHODOLOGICAL FRAMEWORK OF THE COST STRUCTURE FOR INDIVIDUAL METHODS OF GOODS DELIVERY BY POSTAL COMPANIES

Postal companies have to incur significant costs when delivering goods to consumers. These costs are directly related to the transport of goods purchased from a certain e-shop and their delivery to the consumer. Shipment delivery methods affect all parts of the business model. This matter is related to not only distribution channels but also key resources, activities, partners, customer relationships, and, especially, the value created for and perceived by the customer. At the same time, the effects of individual delivery technologies on the environmental and social levels of the business model must be considered very closely.

The main components of the cost structure reflect the cost classification, which reflects the calculation, type, and purpose breakdown of costs [20]. Fig. 1 summarizes the comprehensive cost structure for each method of delivering goods.

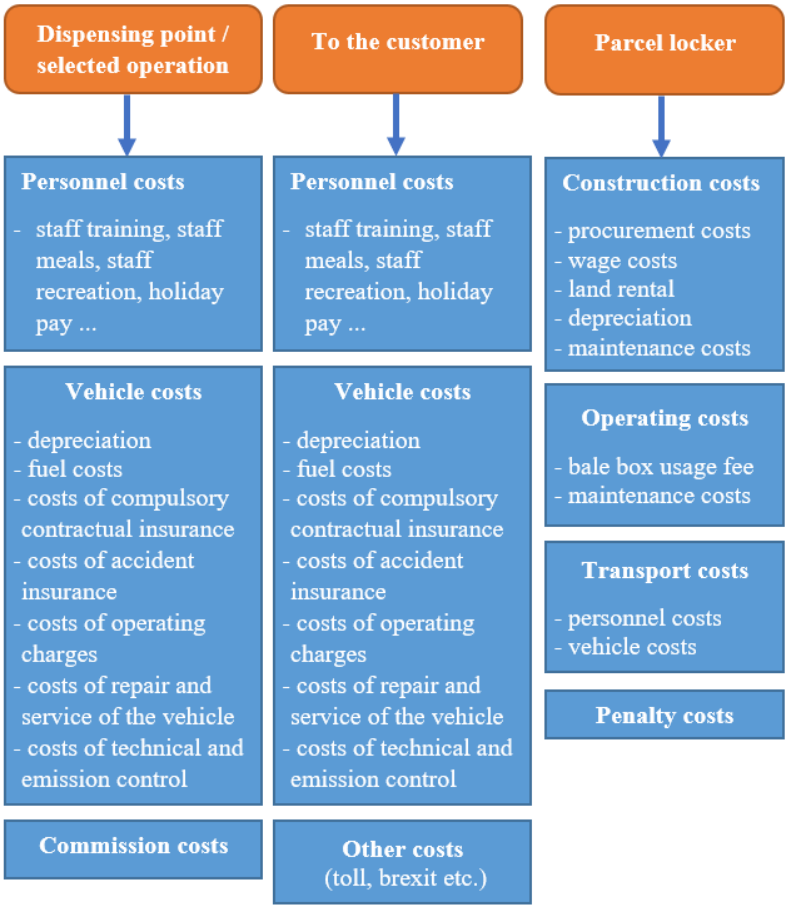

Fig. 1. Cost structure of individual methods of goods delivery by postal companies

Most postal companies deliver goods directly to consumers' homes. Some postal companies have also started to make greater use of parcel lockers. An example of such a postal company in Slovakia is Slovak Post, which has its own parcel lockers called BalíkoBOX. Packeta, which is widespread in Slovakia and uses a network of branches of various small shops and stores of goods and services through which goods are delivered, is expanding its network of packing machines. All postal companies try to respond to the preferences of e-shop customers when offering delivery methods.

3. CALCULATION MODELS OF INDIVIDUAL COSTS

Fig. 1 shows the basic structure of the cost calculation model of the various methods of delivering goods to customers. This structure is the starting point for determining the overall cost model. The approaches to the model reflect the direct cost related to different methods of goods delivery and are based on the static layout configuration.

3.1. Personnel costs

In Slovakia, personnel costs include the total cost of the employee's labour, which consists of wage costs for the employees of a postal company who transport goods and make contributions to social and health insurance companies. This also includes the cost of staff training, staff meals, staff recreation,

holiday pay, levies paid by the employer from the employee's salary, income compensation during an incapacity for work, and the employer's compulsory allocation to the social fund.

The formula for calculating personnel costs is as follows:

$$CPEN = \sum_{i \in I} \left(\frac{MZOD+NMZD+NMZS+ODMZ+NPPN+PNS+PNR+NŠ+PPSF}{M} \right)_i , \quad (1)$$

where:

- CPEN - total personnel costs;
- I = {i = 1,2,3,…, n} - set of employees i;
- MZOD - employee's salary for days worked;
- NMZS - holiday pay;
- ODMZ - levies on employee wages;
- NPPN - compensation of income during the incapacity for work of the employee;
- PNS - meal allowance;
- PNR - recreation allowance;
- NS - employee training costs;
- PPSF - compulsory allocation to the social fund;
- M - time (year, half a year, months).

Sample of personnel costs:

- salary for days worked – salary paid for the number of days in a year (or in a month) and the number of hours that the employee worked on these days (e.g., 221 days for eight hours at 6 €/hour = 1,768 hours * 6 €/hour = 10,608 €),
- wage compensation for vacation – wage compensation paid in full for vacation days based on the number of hours spent working on a normal working day (e.g., 25 days at eight hours = 200 hours at €6/hour = €1,200),
- wage compensation for a holiday – wage compensation paid in full for the days of the holiday based on the number of hours worked on normal working days (e.g., 10 days for eight hours = 80 hours at 6 €/hour = 480 €),
- contributions paid by the employer from the employee's salary – contributions to the health insurance company at the amount of 10% of the employee's salary and to the social insurance at the amount of 25.2% of the employee's salary such that the total amount of contributions is 35.2% of the employee's salary (e.g., 35.2% of (€10,608 + €1,200 + €480) = €4,325.37),
- compensation of income during the incapacity for work – compensation of the income of an employee who cannot perform work activities due to an adverse health condition and who is recognized by a doctor as temporarily unable to work (PN); the daily assessment base for the purpose of determining income compensation in case of a temporary incapacity for work is calculated as a share of the sum of the assessment bases for paying insurance premiums for sickness insurance reached in the decisive period and the number of days of the decisive period (e.g., three days at 25% of €48 + two days at 55% of €48 = €88.80),
- allowance for meals – an allowance that the employer is obliged to provide to employees who have worked more than four hours in a work shift, which must be at least 55% of the price of the meal (e.g., 221 days worked * contribution in the amount of €2.11 = €466.31),
- recreation allowance – the employer's contribution to the employee's recreation to the maximum legal amount of €275,
- training costs – the amount spent by the employer to ensure training related to the employee's work, the amount of which depends on the price of the specific training,
- mandatory allocation of the employer to the social fund – an obligation concerning each employer that is set to the amount of 0.6% to 1% of the base, which represents the sum of the gross wages or salaries of settled employees for payment for the current year (e.g., €18.58/month for 10 employees; per employee, it is €18.58/10 employees per year * 12 months = €22.30 annually).

3.2. Vehicle costs

Vehicle costs include vehicle acquisition costs, motor vehicle tax, the depreciation cost of vehicles, fuel costs, compulsory contractual insurance costs, accident insurance costs, operating costs, vehicle repair and servicing costs, vehicle technical and emission control costs, and other occasional costs arising from the use of vehicles.

The relationship for the calculation of vehicle costs is similar to the relationship for personnel costs and is formulated as follows:

$$NA = \frac{OC}{M} + \frac{PZP}{12} + \frac{HP}{12} + \frac{PHM*SA*km}{100} + \frac{PN}{M} + \frac{DZ}{M} + ON, \quad (2)$$

where:

- NA - monthly vehicle costs;
- $\frac{OC}{M}$ - depreciation;
- OC - purchase price of the vehicle;
- M - time (year, half a year, months);
- PZP - compulsory contractual insurance (paid annually);
- HP - accident insurance (paid annually);
- $\frac{PHM*SA*km}{100}$ - fuel costs;
- PHM - fuel price per 1 litre;
- SA - vehicle consumption;
- km - number of kilometres driven per month.
- PN - price of operating charges;
- $\frac{PN}{M}$ - monthly costs for operating charges;
- DZ - highway stamp price;
- $\frac{DZ}{M}$ - monthly costs for motorway stamps;
- ON - other costs in a given month (service, tire change, MOT, etc.).

An example of calculating regular monthly vehicle costs is given below.

A postal company owns a Peugeot BOXER FURGON Euro 6.3 (L1H1 – diesel) vehicle. Its purchase price was €19,600. The vehicle is included in depreciation group 1, and the depreciation period is four years. PZP and HP are paid by the insurance company UNIQA. PZP costs €169.56 per year, and HP costs €1,238.44 per year (the amount of PZP and HP for the mentioned type of vehicle was found at klik.sk). The combined consumption of the vehicle is 5.9 litres per 100 km. According to the statistical office, the average price of diesel for 2021 is €1,240. It is assumed that the vehicle will cover a distance of approximately 5,000 km per month. The costs of the operating refills were determined as follows: AD Blue at a price of €10.70 and washer fluid at a price of €6.50. The prices of operating fillings were taken from autodielygafa.sk. It is estimated that operational refills are purchased approximately once every two months. The cost of the highway stamp was €50, as an annual highway stamp was purchased. Additional costs are not taken into account in a specific month.

The calculation of monthly costs supplemented with the above numbers is as follows:

$$NA = \frac{19{,}600}{48} + \frac{169.56}{12} + \frac{1{,}238.44}{12} + \frac{1{,}240 * 5.9 * 5{,}000}{100} + \frac{10.70 + 6.50}{2} + \frac{50}{12} + 0$$

$$NA = 408.33 + 14.13 + 103.20 + 365.80 + 8.60 + 4.17 + 0$$

$$NA = 904.23$$

The annual cost of the vehicle would be €10,850.76.

3.3. Costs of delivery of goods to partner establishments and dispensing points

When goods ordered by consumers are delivered to dispensing points, which are various establishments that have entered into a partnership with a postal undertaking, such a postal undertaking incurs commission costs that the company must pay to such establishments for each order placed. In

such a case, the postal company, such as Packeta in Slovakia, also incurs the costs of procuring the necessary equipment (thermal printer, reader) for each new partner operation. However, the specific amount is deducted from the commissions paid to the partner operation.

The monthly costs of a postal company that uses partner establishments as outlets are calculated as follows:

$$N = CMN + CNA + PR, \tag{3}$$

where:

- N - total monthly costs of the postal undertaking;
- CMN - total monthly personnel costs;
- CNA - total monthly vehicle costs;
- PR - monthly commission costs;

PR is calculated as follows:

$$PR = \sum_{k\in K} \sum_{l\in L} VP\, MT_{kl}, \tag{4}$$

where:

- K = {k = 1,2,3,…, o} - set of operations k;
- L = {l = 1,2,3,…, p} - set of consumers l;
- VP - amount of commission;
- MT_{kl} - quantity of goods picked up by the customer in operation.

3.4. Parcel locker costs

The individual cost items are listed in a two-level programming model which was developed to identify the optimal locations for packages while considering the benefits for consumers and the logistics-planning department. The top-level model should determine the optimal position by minimizing the costs of the planners. These costs consist of transport costs (line transport and pick-up and delivery costs) and the investment costs of the equipment. The lower-level model, in turn, provides a balanced distribution of demand by minimizing the cost to consumers of picking up a shipment. Parcel locker costs include the costs of opening and running the parcel locker, operating costs, and penalty costs [21, 22].

The formula for calculating parcel locker costs could appear as follows:

$$NB = ST + \sum_{b\in B} \sum_{l\in L} PNB_b\, PS_{bl} + \sum_{b\in B} \sum_{l\in L} f\, F(PS_{bl}), \tag{5}$$

where:

- ST - construction costs for one parcel locker;
- B = {b = 1,2,3,…, r} - set of bale boxes b;
- L = {l = 1,2,3,…, p} - set of consumers l;
- PNB_b- operating costs per one bale box;
- PS_{bl} - number of products selected by consumers from the bale boxes.
- f - penalty costs per package (EUR);
- $F(x_{bl})$ - the cost of sanctions that a particular company must pay;

An example with specific numbers is given below.

The example is focused on one particular parcel machine, which would have 20 mailboxes. We assume that its estimated maximum capacity is used. A parcel machine with 20 boxes should handle around 4,000 parcels per year. The operating cost for one box of the parcel machine is €0.73. The construction cost for one box of the parcel machine is €1,091.96, and the cost for the entire parcel machine is €21,839.20. Eleven packages are stored in the parcel machine every day. Packages are delivered 365 days a year. Thus, 4,015 packages are delivered to consumers per year. Since its maximum capacity is not used on individual days, penalty costs are €0. Annual operational costs are €2,930.95, and the annual transport cost is €7,216.92. According to the above example, the overall annual cost of a parcel machine is approximately €31,987.07.

3.5. Hardware and software costs

Last mile delivery costs also include hardware and software costs. Today, most customers prefer card payments. This trend deepened during the COVID-19 pandemic, when companies themselves (companies in general, not just postal companies) preferred card payments. Many businesses did not even accept other forms of payment. For this reason, it is necessary, for example, to ensure that couriers and postal couriers have card terminals through which the consumer can pay for their goods by card directly from the courier.

Various applications can also be used to deliver goods to customers within the last mile. An example is vehicle routing optimization, which aims to design the lowest-cost routes to meet customer requirements, including solving the shortest route problem, the business traveller problem, and the driving problem. Many applications, such as Workwave and Upper, represent NRA [23, 24].

The following relationships express the hardware and software costs calculation:

$$CHSW = \sum_{h \in H} HSW_h, \tag{6}$$

where:

- H = {h = 1,2,3,…, z} – the set of hardware and software, as well as the software upgrade h;
- HSW - the price of hardware or software, as well as the software upgrade.

When calculating the cost of hardware and software, it is also necessary to identify the possibilities of interconnection and agreement between the postal company and e-shops in terms of tracking and payment for goods, as well as customers' preferred delivery methods and payment methods. Thus, the change in the hardware and software of the postal company evokes changes on the part of both the e-shop and the consignee. Conversely, changes required by the e-shop from the postal company trigger software updates or the addition of a hardware solution.

4. THE POSTAL COMPANY'S COST MODEL OF GOODS DELIVERY

The postal company's total direct costs of delivering goods to the consumer within the last mile include personnel costs, vehicle costs, costs of documents required to transport the goods abroad, for example, and—finally but importantly—costs related to specific methods of delivery. These costs include, for example, transport costs to partner establishments, which serve as the post office's outlets, costs for the construction and operation of parcel machines, or the cost of a new way to deliver goods within the last mile.

We can formulate a total cost model using Formulas (1-6) as follows:

$$CN = \sum_{i \in I} PENM_i + \sum_{j \in J} NA_j + NDP + \sum_{k \in K} \sum_{l \in L} VP\,MT_{kl} + \sum_{a \in A} NB_a + \sum_{h \in H} HSW_h + OT. \tag{7}$$

A detailed formula with all items is presented below:

$$CN = \sum_{i \in I} PENM_i + \sum_{j \in J} \left(\frac{OC}{M} + \frac{PZP}{12} + \frac{HP}{12} + \frac{PHM * SA * km}{100} + \frac{PN}{M} + \frac{DZ}{M} + ON \right)_j + NDP + \sum_{k \in K} \sum_{l \in L} VP\,MT_{kl} + \sum_{a \in A} (ST + \sum_{b \in B} \sum_{l \in L} PNB_b\,PS_{bl} + \sum_{b \in B} \sum_{l \in L} f\,F(PS_{bl}))_a + \sum_{h \in H} HSW_h + OT, \tag{8}$$

where:

- I = {i = 1,2,3,…, n} - set of employees i;
- $PENM_i$ - monthly personnel costs per employee;
- NA - monthly cost per vehicle;
- J = {j = 1,2,3,…, m} - set of vehicles j;
- $\frac{OC}{M}$- depreciation;
- OC - purchase price of the vehicle;
- M - time (year, half a year, months);
- PZP - compulsory contractual insurance (paid annually);
- HP - accident insurance (paid annually);
- $\frac{PHM * SA * km}{100}$ – fuel costs;
- PHM - fuel price per 1 litre;

- SA - vehicle consumption;
- km - number of kilometres driven per month;
- PN - price of operating charges;
- $\frac{PN}{M}$- monthly costs for operating charges;
- DZ - highway stamp price;
- $\frac{DZ}{M}$- monthly costs for motorway stamps;
- ON - other costs in the given month (service, tire change, MOT, etc.)
- K = {k = 1,2,3,…, o} - set of operations k;
- L = {l = 1,2,3,…, p} - set of consumers l;
- VP - commission amount;
- MT_{kl}- quantity of goods picked up by the customer in operation;
- NB_a- costs of the construction and operation of the package;
- A = {a = 1,2,3,…, q} - set of parcel lockers a;
- B = {b = 1,2,3,…, r} - set of bale boxes b;
- D = {d = 1,2,3,…, t} - set of months d;
- PNB_b- operating costs per bale box;
- PS_{bl} - number of products selected by consumers from the bale boxes;
- f - penalty costs per package (EUR);
- $F(PS_{bl})$- the cost of sanctions that a particular company must pay;
- H = {h = 1,2,3,…, z} - set of hardware and software h;
- HSW - price of hardware or software;
- OT - other technologies and methods used in the delivery of goods within the last mile.

After substituting specific data for the variables, the postal company could calculate the total costs it has to bear to deliver goods to consumers within the last mile. The relationship includes cost calculations for individual methods of goods delivery that are currently used, and it is possible to add other delivery methods in the future.

5. CONCLUSION

In the case of postal companies, the last mile cost structure depends mainly on the delivery method used. At present, most postal companies offer customers more than one way of delivering goods based on their needs. Whether a postal company pays to implement new delivery methods in its services depends on several factors, one of which is the cost incurred for a particular delivery method.

In the case of innovations to a business model, postal companies have to quantify the costs of introducing a new method of delivery to consumers in the last mile for the specific delivery method it wants to start using. For this to be possible, the postal company must rely on real, attainable numbers. For this purpose, this article elaborates on the cost models in the form of formulas that can be used to calculate these numbers, as well as the individual cost items that the postal company has to include in calculations when quantifying the costs of a particular delivery method. Based on such preliminary cost calculations, as well as possible expected revenues as determined from consumers' preferences in relation to the delivery methods and their comparison, the postal company can determine whether it is worthwhile to introduce a new last mile delivery method. However, the results will always be indicative only, and the results may be different in reality because of the influence of other factors (e.g., the population density in a particular service area, the age of the consumers, and the impact of the COVID-19 pandemic).

The proposed methodological procedure for determining costs and the proposed model, as well as the formulas used to calculate them, should serve as a basis for companies to ensure the delivery of goods to consumers within the last mile when creating a new business model. The formulas provided enable the calculation of the costs of all hitherto used methods of goods delivery in the last mile. Calculations carried out using the proposed relationships can also help companies decide whether it is worthwhile to create a new business model related to the introduction of a new way of delivering goods

within the last mile. The above cost structure also indicates whether, as part of the innovation of the postal company's business model concerning delivery methods, it is more advantageous to address delivery through its own key activities and resources or to identify key partners in last mile processes and enter into partnership agreements.

The models presented in this article have several limitations that need to be studied. The main limitation is related to the focus on the Slovak postal market and the operators of this market. The formulated models and formulas may differ between countries according to the ways in which postal markets are regulated, as well as because of previous developments in these markets. Therefore, it is necessary to test the models and adapt them to national regulations. Another limitation of the solution is that the methods of goods delivery and cultural differences could affect the preferences of e-shop customers and their perceptions of individual methods of delivery. This means that a sufficient amount of representative data on changes in the behaviour of e-shop customers is needed when planning changes to the postal business model in delivery methods. Other limitations include a static view of individual cost items, the carryover effect, the assurance of service quality, different types of postal companies in the market, the effects of marketing decisions, and the performance of postal companies. Finally, yet importantly, several external influences affect postal companies and their decisions. These limitations affect the further development of the models, particularly regarding environmental and social sustainability.

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