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OPTIMIZATION OF COLLECTION ROUTES USING THE CENTRE OF GRAVITY METHOD: A CASE STUDY

Summary. The paper deals with the implementation of research concerning the collection routes of a selected company and subsequent streamlining processes in the field of distribution logistics. Specifically, the paper is focused on the optimization of collection routes of textile waste for the customer, i.e., a contractual partner of the company under investigation. The objective of the paper is to analyse step by step the current state of logistics of supplying a specific warehouse, followed by the application of the centre of gravity method for proposing a warehouse relocation. Finally, the individual routes to collection points are optimized. In general, optimization is done for two basic reasons: profit maximization and logistics costs minimization, which ultimately has a positive impact on earnings. The outcome is to determine the optimal routes with respect to

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costs and traffic while considering complications that may occur in a given transport territory.

Keywords: distribution logistics, optimization, waste collection route, centre of gravity method

1. INTRODUCTION

The current corporate environment is characterized by strong competition and instability, both on the side of potential customers and suppliers as well as employees in numerous instances. A highly competitive environment encourages companies to continuously improve, which is directly related to prompt responses to market changes and prompt decision-making. The fundamental prerequisite for the success of the company is its ability to adapt to the changing market environment.

A key aspect of a company's success is clearly quality management. Ensuring the prosperity of the company is a task that requires increased effort, thorough analysis, planning, solving existing problems, and preventing potential problems. Companies can influence their success in the market by actively seeking out their weaknesses that prevent them from achieving higher productivity.

Optimization of waste collection routes encompasses performing the collection of waste material as quickly and efficiently as possible by deploying a collection vehicle. Reducing the distance traveled to perform a collection route represents an important method to diminish greenhouse gas emissions as well as minimize the logistics costs of an enterprise. This part of corporate logistics is very challenging and topical and requires excellently coordinated corporate organizational approaches and systems. Once it is adequately optimized, an enterprise can utilise the benefits of pros and efficiencies, transforming its costs and enhancing fleet management as a whole [3].

A wide range of approaches, methods [17], and route planner applications can help towards such an optimization in terms of managing waste collection routes [21]. One of the options for doing so is discussed in this case study. As a novelty of this research, the centre of gravity method, which is usually used for other logistics-related assignments, is applied to suggest a new warehouse location .

2. LITERATURE REVIEW

In the preparation of this case study, there were several publications related directly or indirectly to the presented study. The applied analysis of independent components is presented in detail in studies dealing with the evaluation of independent components in solving decision-making problems [18]. Research in the given field is also based on a specific study dealing with the application of automatic identification systems [20] and RFID technology in logistics companies operating in EU countries [2].

For the purposes of the study, it is also necessary to perform the analysis of vehicle repair costs at a selected transport company, as described in [10]. The application section of the manuscript was prepared on the basis of scientific publications [5,13], which provide a detailed description of research findings concerning the model evaluation of suppliers in terms of factors in a real company and the selection of locations suitable for the allocation of a specific company. The case studies [7,9] focused on maritime transport deal with the optimization of logistics processes in transportation in terms of the deployment of transhipment points and terminals in a specific territory. The paper [14] also deals with the identification of objects during the transhipment of intermodal transport units, which has greatly influenced the insight into the given research issue.

The logistics network in relation to resource harmonization is closely related to the subject under our investigation. It is also addressed in [23]. The case study [25] presents the optimization of 50 transport routes. The authors use an accounting of the transit service abilities of individual railway stations to predict the two best routes. This approach represents another alternative solution to the problem. A different perspective is described in [1], where the problem of warehouse location is addressed using Operations research techniques. The authors Hornstra et al. discuss a similar problem of vehicle routing (hereinafter referred to as VRP), which is directly related to the research analysed in the presented paper [8]. The paper [15] highlights the characteristics of transporting goods in batches, which is an important aspect of flexibility in the logistics supply process, as addressed in this case study. The objective of the work [16] is to search for the most suitable locations for multiple logistics objects, allocate clients to these objects, as well as determine the optimal routes to be executed by several delivery vehicles in order to minimise the overall transport costs when using the bi-objective periodic location routing problem with simultaneous pickup, delivery, and time windows.

Another issue closely related to the topic addressed in the presented research is that of VRP with regard to perishable goods. This issue is addressed in [24] and represents another problem concerning distribution (serviceability) that needs to be regarded as an important variable in the temporal aspects of the research. The assignment of time windows in distribution and supply [26] as well as the specification of the daily movement of the vehicle with respect to passenger transportation [11] are other relevant aspects emphasized and thus goals to be achieved.

Sadati et al. address a bi-level optimization task aimed at identifying the most crucial warehouses in terms of vehicle routing issues by implementing Stackelberg game from an adversary agents perspective, with the objective of generating maximum disruption on a given territory, commonly referred to as selective r-interdiction multi-depot VRP.

As for the research presented, the technologies "Just-in-time" (JIT) and "Just-in-sequence" (JIS) represent other important concepts related to smooth collection or distribution systems; the original transport routes could thus be replaced with new routes that will be optimized using the centre of gravity method, which will have a positive impact on the financial situation of the company and, on a societal scale, on the reduction of emissions in an area under study [4].

3. MATERIALS AND METHODS

The centre of gravity method is a method to address the issue of the warehouse/logistics centre location. It is applied mainly in proposals for warehouse location. The centre of gravity method is based on locating warehouses approximately in the middle, between production and consumption. This method is also referred to as a method of coordinates, and its application is suitable for determining the optimal spatial location of a central warehouse that cooperates with other objects already located in the given area [22]. The centre of gravity method consists in the optimal location of a warehouse in the centre of gravity of a rectangular coordinate system, which is formed by other existing objects. For the already existing objects, it is necessary to determine a point T from which the sum of the given distances is the minimum [12].

The X and Y coordinates of the centre of gravity (T) are calculated as follows (see *Equations 1 and 2*) [12]:

$$X = \frac{\sum xi * qi}{\sum qi} \tag{1}$$

$$Y = \frac{\sum yi * qi}{\sum qi} \tag{2}$$

Where: x_i,y_i – the coordinates of the i-th object located, q_i – transport volumes (kg) of the i-th object located per given unit of time.

The calculated coordinates of T are then plotted on the map.

Another step is the calculation of the coefficient z_i, i.e., the selection of a town for the location of the central warehouse according to the minimum distances of existing towns from the calculated centre of gravity T. The general formula for calculating the distances of towns from the centre of gravity is as follows (see *Equation 3*) [28]:

$$minz_i = \sqrt{(x_i - X)^2 + (y_i - Y)^2} \tag{3}$$

Where: x_i, y_i – the coordinates of the i-th object located, X, Y – the coordinates of the centre of gravity T, z_i – distance of the i-th warehouse from the centre of gravity, A suitable alternative is determined by selecting the shortest distance.

4. RESULTS – A CASE STUDY

The application of the centre of gravity method was carried out according to individual steps and formulas specified in the methodology. The collection of textile waste is executed using the Iveco Eurocargo ML75E18. The total number of containers is 119; the average volume of textile waste in one container is 81 kg. The warehouse is currently situated in Tábor. The coordinates of the South Bohemian towns where containers are located are shown in *Figure 1* below.

Textile waste collection is currently carried out in 10 towns in the South Bohemian region. Monday's route currently includes the following towns: Tábor, Soběslav, Veselí nad Lužnicí, Jindřichův Hradec, and Týn nad Vltavou. In total, there are 44 containers on this route. Tuesday´s route includes Písek, Strakonice, and Sušice. In these towns, there are 39 containers. Wednesday's route includes České Budějovice and Prachatice, with a total of 36 containers. The following table shows the volume of textile waste collected in these towns expressed in kilograms per month for each of the towns. The calculated values necessary for determining the most suitable town for the location of the warehouse are also presented in Table 1.

Tab. 1

Calculation according to centre of gravity method

Collection point	x_i	y_i	Σq_i (kg)	$x_i \Sigma q_i$	$y_i \Sigma q_i$
Tábor	97	88	9072	879,984	798,336
Písek	63	75	8100	510,300	607,500

Strakonice	48	69	2916	139,968	201,204
Soběslav	100	68	972	97,200	66,096
Veselí nad Lužnicí	99	61	648	64,152	39,528
Týn nad Vltavou	81	66	648	52,488	42,768
Prachatice	54	42	1620	87,480	68,040
Jindřichův Hradec	120	57	2916	349,920	166,212
Sušice	22	67	1620	35,640	108,540
České Budějovice	85	38	10,044	853,740	381,672
In total	X	X	38,556	3,070,872	2,479,896

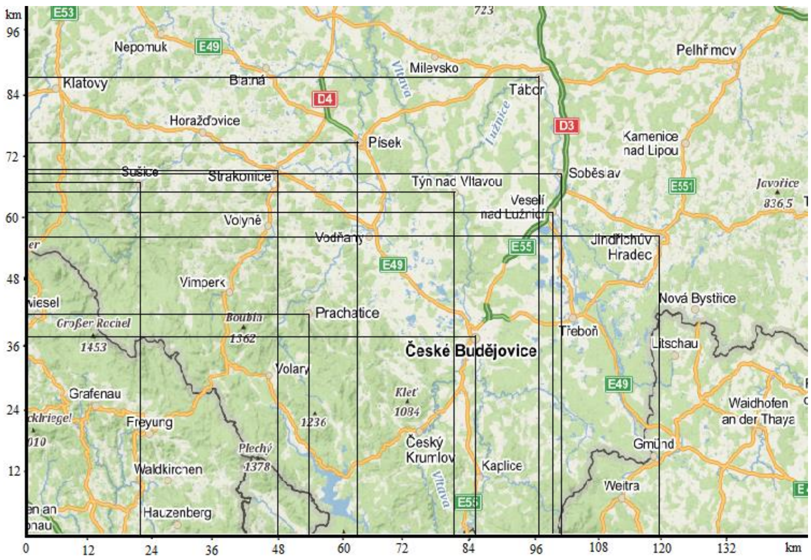

Fig. 1. Centre of gravity method – coordinates of towns under investigation
Source: https://google.com/maps – modified by the authors

The centre of gravity coordinates for the optimal location of the warehouse centre are calculated using the *Equations (1)* and *(2)* above.

$$X = \frac{3,070,872}{38,556} = 79.6471$$

$$Y = \frac{2,479,896}{38,556} = 64.3193$$

The coordinates of the centre of gravity are on the axes X = 79.6471 and Y = 64.3193. The position of the centre of gravity is plotted in Figure 2.

These are only the coordinates of the centre of gravity. The next step is to determine the coefficient “z”, which indicates the distance between the centre of gravity and individual towns. This calculation using the *Equation (3)* above enables determining the optimal location of the central warehouse. Table 2 below shows the calculations using the given formula for each town and the results of these calculations. The optimal place for the location of the warehouse is the town with the lowest resulting value.

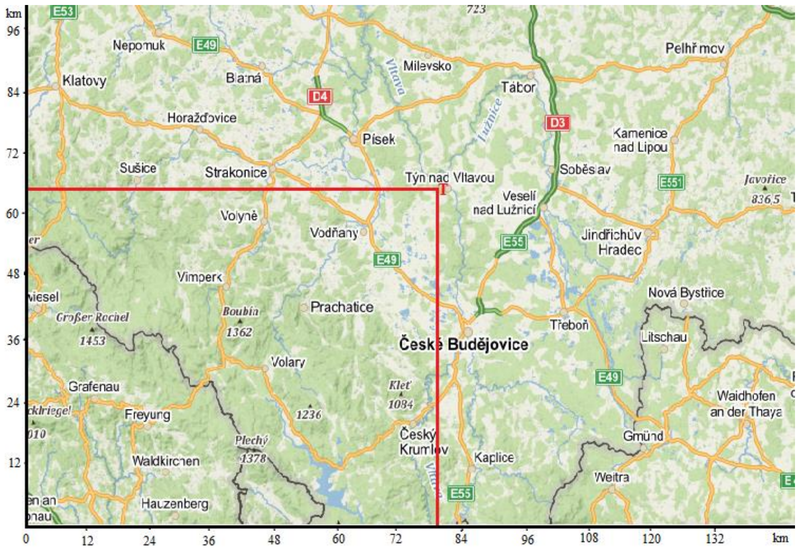

Fig. 2. Centre of gravity coordinates
Source: https://google.com/maps – modified by authors

Tab. 2

Calculation of distances of individual towns from the centre of gravity

Town	Calculation	Resulting distance in km
Tábor	$\sqrt{(97-79.6471)^2+(88-64.3193)^2}$	29.36
Písek	$\sqrt{(63-79.6471)^2+(75-64.3193)^2}$	19.78
Strakonice	$\sqrt{(48-79.6471)^2+(69-64.3193)^2}$	31.99
Soběslav	$\sqrt{(100-79.6471)^2+(68-64.3193)^2}$	20.68
Veselí nad Lužnicí	$\sqrt{(99-79.6471)^2+(61-64.3193)^2}$	19.64
Týn nad Vltavou	$\sqrt{(81-79.6471)^2+(66-64.3193)^2}$	2.16
Prachatice	$\sqrt{(54-79.6471)^2+(42-64.3193)^2}$	33.99
Jindřichův Hradec	$\sqrt{(120-79.6471)^2+(57-64.3193)^2}$	41.01
Sušice	$\sqrt{(22-79.6471)^2+(67-64.3193)^2}$	57.71
České Budějovice	$\sqrt{(85-79.6471)^2+(38-64.3193)^2}$	26.68

The town with the lowest value of the coefficient is represented by Týn nad Vltavou, which means that it is the most suitable town for the textile waste warehouse. One of the drivers employed by the company works in the town; therefore, it is advisable to assign the driver to textile waste collection, as it would enable him to save funds for fuel and time necessary to commute to Tábor. This could contribute to reducing employee turnover and increasing employee satisfaction.

4.1. Design of the optimal location for warehouse

The volume of one swap body is 96 m^3. In order to ensure storage in the case the swap body is not installed for the whole week (it usually happens that instead of Thursday, the swap body is exchanged in a week), the warehouse space must be at least 96 m^3 plus additional space to allow movement and manipulation with goods. The total size of the warehouse should thus be at least 150 m^3 to accommodate the whole weekly volume of the collected textile waste (including some spare space). Storage space conforming to the above requirements was found in the offer of a real estate agency. The storage space is situated in a closed and monitored area in Malá Strana, Týn nad Vltavou. The size of the storage space in this area varies from 35 m^2 to 160 m^2. The height of the warehouse is 3 m, which means that when renting the currently offered storage space of 58 m^2, the volume would be 174 m^3; in terms of the volume of textile waste, it is a space for nearly two swap bodies, which is sufficient for the needs of company K. The warehouse could be heated, which is a positive fact mainly in terms of preventing textile wetting and deterioration. Storage of bags with textile waste does not require any special conditions. The only requirements are dryness and a certain level of cleanliness.

Another important aspect of selecting a suitable warehouse is the possibility of using outdoor spaces outside the object. This is a key condition due to the necessity to place the swap body. The best solution would be an agreement with the owner of the object concerning the rent of the space for the swap body. The price for renting 58 m^2 is € 200 per month. The rental of the area for placing the swap body is € 120. The cost of renting the warehouse and the area for placing the swap body is thus € 320 per month. The following *Table 3* shows the comparison of the size of the original warehouse in Tábor with the proposed warehouse in Týn nad Vltavou.

Tab. 3

Comparison of warehouses

	Size	Price in € per month
Original warehouse (Tábor)	40 m^3	80
Proposed warehouse (Týn nad Vltavou)	174 m^3	200

Due to the change in the location of the warehouse, it is necessary to plan new collection routes starting and ending in Týn nad Vltavou. Planning of these routes is described in the following part.

4.2. Route optimization based on the centre of gravity method application

The previous section dealt with determining a suitable location for the warehouse. The change will have a significant impact on the distance travelled on individual routes, which is addressed in this chapter. A recommendation for planning the most appropriate routes considering the new location of the warehouse and the traffic situation will be formulated as well [6].

Original Route 1: *Tábor – Soběslav – Jindřichův Hradec – Veselí nad Lužnicí – Týn nad Vltavou – Tábor* (*Figure 3* shows the existing route of the waste collection).

As for the Route 1, the length of the original route is 137 km. The lengths of the original and the proposed routes are the same because the warehouse is now situated in Tábor. On this day (Monday), waste containers are collected in all these towns, even after the change in the location of the warehouse. In Týn nad Vltavou, textile waste collection will not take place on Monday because, according to the new plan of routes, it will be carried out on Wednesday in order to achieve a more even distribution of the number of containers on individual routes. With the change of the coordinates of the warehouse, the starting and ending points of connection changed from Tábor to Týn and Vltavou; however, the towns that were serviced on Monday will remain the same even according to the new planned route. So far, textile waste has been collected using the same method, which has been evaluated as optimal by a computer odometer. This means that the number of kilometres has not changed. Although the length of the new Route 1 (see *Figure 4*, wherein it is indicated by green arrows) is the same as the original route (red arrows), the effect of the change in the location of the warehouse in terms of the total number of kilometers traveled will be significant. In the figure, letter *A* represents Týn nad Vltavou, *B* Tábor, *C* Soběslav, *D* Jindřichův Hradec, and *E* Veselí nad Lužnicí.

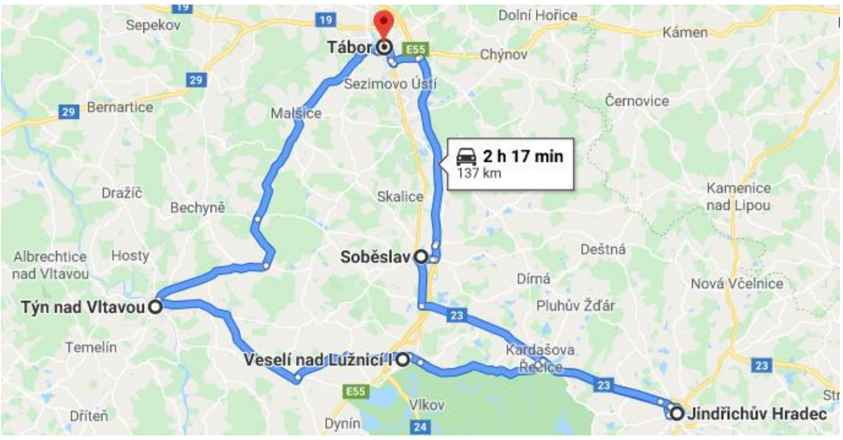

Fig. 3. Original route 1
Source: https://google.com/maps

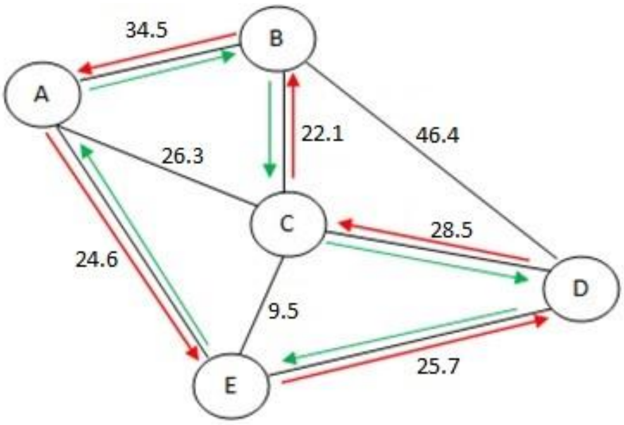

Fig. 4 Route 1, original as well as proposed route

When the coordinates of the warehouse changed, the starting and ending collection points changed as well (now it is Týn nad Vltavou) but there is no change in the towns serviced on this route on this day. The driver has used the same route, which is now considered the most suitable by the computer odometer, and the number of kilometers traveled has thus remained the same. On the existing route, Tábor is the starting and ending point. The driver first goes to Týn nad Vltavou, next to Veselí nad Lužnicí, then Jindřichův Hradec, Soběslav, and finally Tábor.

Proposed Route 1: Týn nad Vltavou – Tábor – Soběslav – Jindřichův Hradec – Veselí nad Lužnicí – Týn nad Vltavou.

Based on the direct observation of the route and upon the consultation with the owner of the company, it was found that the most suitable method now is to start loading in Tábor after leaving Týn and Vltavou and continue in the opposite direction to the original route, with the last served town being Veselí nad Lužnicí. This method is more advantageous because it enables the driver to avoid traffic congestion, which is now a daily occurrence even in off-peak hours. The driver should start at 4 a.m., which enables him to drive through risky places during low traffic times, thus avoiding congestion. Textile waste collection in Týn nad Vltavou will be moved to Wednesday's route in order to achieve an even distribution of handling the containers between the collection days.

Original Route 2: *Tábor* - *Písek* - *Strakonice* - *Sušice* - *Tábor* (the existing route is presented in Figure 5).

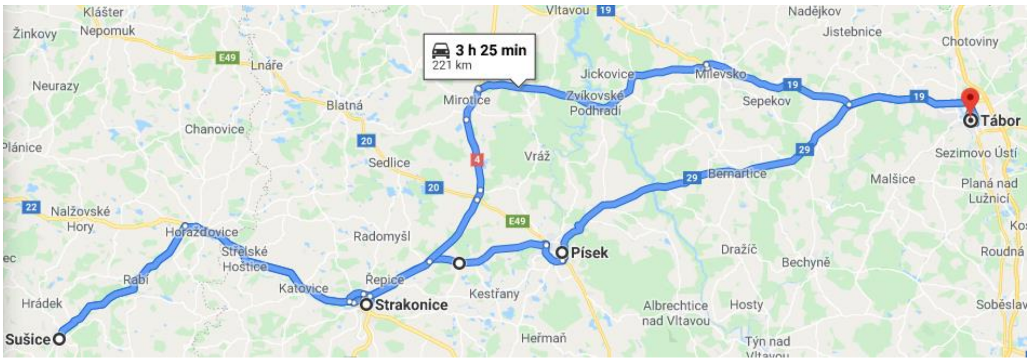

Fig. 5. Original Route 2
Source: https://google.com/maps

According to the existing scenario of textile waste collection on the Route 2, the driver now starts in Tábor, goes to Strakonice via Písek, then to Sušice, and back to Tábor. The length of the route is 221 km. In *Figure 6*, it is represented by red arrows. In the figure, letter *A* represents Týn nad Vltavou, *B* Písek, *C* Strakonice, *D* Sušice, and *E* Tábor.

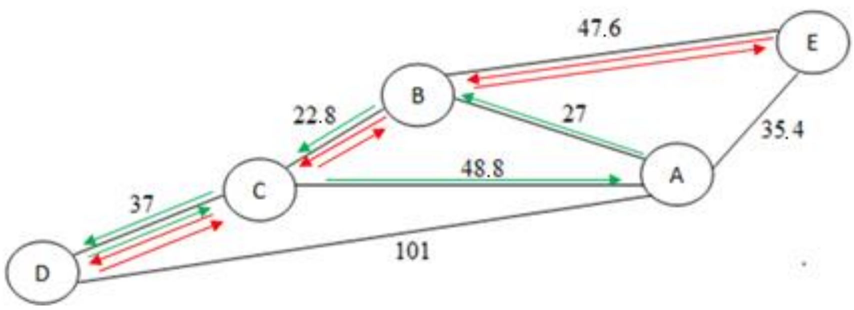

Fig. 6. Route 2, original as well as proposed route

Green arrows mark the new route, which starts in Týn nad Vltavou, continues to Písek and Strakonice to Sušice and back to Týn nad Vltavou. The length of the route is 174 km, which means that the new route was shortened by 47 km and the time necessary to serve this route was reduced by 33 min.

Proposed Route 2: *Týn nad Vltavou* – *Písek* – *Strakonice* – *Sušice* – *Týn nad Vltavou* (*Figure 7* below shows the optimal Tuesday´s route).

Fig. 7. Proposed Route 2
Source: https://google.com/maps

Compared to the original route, the new proposed route is 47 km shorter. The first collection is carried out in Písek, the driver then goes to Strakonice, Sušice and back. The use of this route will save 2444 m per year (52 weeks). When converted to financial savings, at a cost of € 1.04 per 1 km, the company will save € 48.88 weekly.

Original Route 3: *Tábor – Prachatice – České Budějovice – Tábor* (see Figure 8).

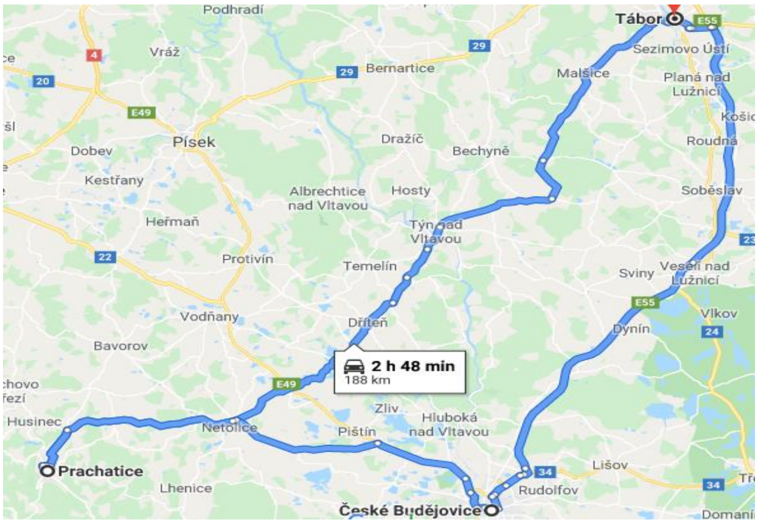

Fig. 8. Original Route 3
Source: https://google.com/maps

The length of the current Route 3 is 188 km in total. Thanks to the new location of the warehouse in Týn nad Vltavou, the length of this route will be reduced to 124 km, i.e., 64 km shorter. The number of kilometers traveled will thus be, 3328 lower per year (with 52 weeks in the year). When converted to financial savings, at a cost of € 1.04 per 1 km, € 66.56 will be saved per week. *Figure 9* below shows the comparison of routes, where the original route is represented by red arrows (with a total length of 188 km) and the proposed route by green arrows (124 km). In the figure, the letter *A* represents Týn nad Vltavou, *B* České Budějovice, *C* Prachatice, and *D* Tábor. On this day, containers in Týn and Vltavou, whose collection was originally a part of Route 1, will also be served.

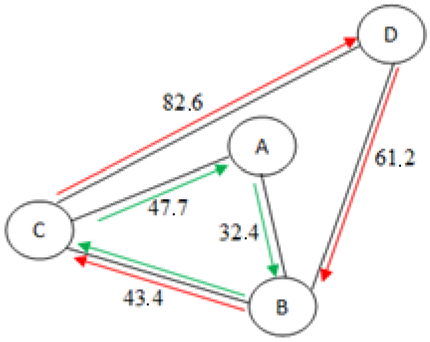

Fig. 9. Route 3, original as well as proposed route

Proposed Route 3: *Týn nad Vltavou – České Budějovice – Prachatice – Týn nad Vltavou*. On the proposed Route 3, which is shown in *Figure 10* below, the first town served will be represented by České Budějovice. As for the time, the earlier the driver leaves Týn and Vltavou, the better. Assuming that the driver leaves Týn and Vltavou at 4 a.m., it will be possible to handle most of the containers before the morning peak hour. This applies mainly to containers in the centre; the containers in the suburban areas will be served during peak hours, but in these areas, traffic congestion is not such a big issue.

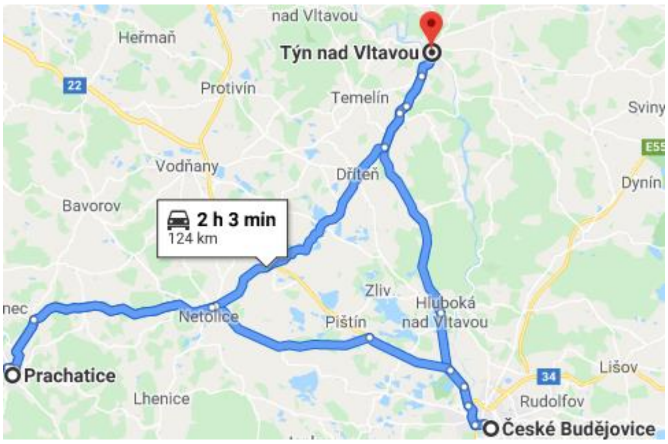

Fig. 10. Proposed Route 3
Source: https://google.com/maps

The newly proposed optimized routes were compared with the existing ones and based on the results of the comparison, *Table 4* was compiled, which summarizes relevant attributes of the newly designed status after the process of optimizing the routes.

Tab. 4
Effects of the proposed location of warehouse in Týn and Vltavou on the relevant attributes

	Collection points (towns)	Number of containers in town	Time needed to handle containers	Time spent driving through the town
Monday (Route 1)	Tábor	28	2 h 20 min	1 h 18 min
	Soběslav	3	15 min	17 min

	Veselí nad Lužnicí	2	10 min	6 min
	Jindřichův Hradec	9	45 min	29 min
In total	-	42	3 h 30 min	2 h 10 min
Tuesday (Route 2)	Písek	25	2 h 5 min	1 h 2 min
	Strakonice	9	45 min	28 min
	Sušice	5	25 min	16 min
In total	-	39	3 h 15 min	1 h 46 min
Wednesday (Route 3)	České Budějovice	31	2 h 35 min	1 h 55 min
	Prachatice	5	25 min	18 min
	Týn nad Vltavou	2	10 min	8 min
In total	-	38	3 h 10 min	2 h 21 min

The number of containers handled on the first and third routes has changed. Textile waste collection in Týn nad Vltavou has been moved to Wednesday, which increases the number of containers on Route 3 to 38 and reduces the number of containers on Route 1 to 42. Moreover, the method of collection on Routes 1 and 3 has been changed.

Table 5 presents the number of kilometers traveled and the duration of individual routes after the change in the location of the warehouse to Týn nad Vltavou, the modification of the method of collection according to the computer odometer, and the logical arrangement of the order of collections in towns considering the traffic density.

Tab. 5

Effects of the proposed location of the warehouse on time attributes regarding waste collection

	Km	Duration of the route without waste collection	Duration of the route with waste collection	Volume of textile waste	Swap body loading time	Duration of the route, including all activities
Route 1	137	2 h 17 min	7 h 57 min	3402 kg	2 h 33 min	10 h 30 min
Route 2	174	2 h 52 min	7 h 53 min	3159 kg	2 h 22 min	10 h 15 min
Route 3	124	2 h 3 min	7 h 24 min	3078 kg	2 h 19 min	9 h 43 min

5. DISCUSSION

The proposals include the following changes:

- Concept of a new warehouse and its parameters – The financial requirements related to the new warehouse are higher than the costs related to the current warehouse. However, this was expected because the existing warehouse is 134 m^3 smaller than the new warehouse. The monthly costs of the room used for the storage of textile waste now amount to € 80. The new warehouse in Malá Strana, Týn nad Vltavou, with an area of 174 m^3 would cost the company € 120 more. The cost of placing a swap body outside the new warehouse would amount to € 120 (which is the same amount as in Tábor now). Overall, the new warehouse would cost the company € 320, while the current costs (warehouse in Tábor) amount to € 200.

- Proposal of a new location of warehouse – Moving the warehouse to Týn nad Vltavou would bring savings to the company thanks to the reduction of the number of kilometers traveled, specifically 111 km per week (5772 km per year). At a cost of € 1.04 per 1 km (VAT not included), the overall savings per year amount to € 6002.88 (52-week year).
- Optimization of routes in regard to the proposed location of the new warehouse – The routes were planned so that the driver could avoid congestion and serve the route in the most economical way and as fast as possible [27].

Table 6 below shows the comparison of distance traveled and time savings, and other potential savings are presented underneath the table itself.

Tab. 6

Comparison of original and new routes in terms of km and time savings per year

	Original route	Designed route	Km saved	Expected time saved
Route 1	137 km	137 km	0	20 min
Route 2	221 km	174 km	47 km	33 min
Route 3	188 km	124 km	64 km	21 min

Route 1: The new route does not include textile waste collection in Týn nad Vltavou, which saves time spent driving through the town and handling containers. Another saving of time results from the change in the order of serving towns on Route 1 (20 min). With Tábor being the first town on the route to be served in the early morning hours (4 a.m.), the driver can avoid congestion occurring currently in Tábor due to the closure of Budějovická Street. The estimated time savings achieved due to avoiding congestion are about 40 minutes. On Route 1, there are no savings in terms of kilometers traveled reduction; however, there will still be time savings resulting from serving Tábor first, which enables the driver to avoid congestion that arises mainly because of the reconstruction of Budějovická Street and the morning peak hours.

Route 2: The length of Tuesday's route will be reduced by 47 km (33 km). The same towns will be served on the route; the savings are only due to the location of the new warehouse.

Route 3: Wednesday's route (Route 3) is 64 km shorter, which entails significant fuel savings. This route will include Týn nad Vltavou, which has been served on Monday's route (Route 1) so far. This change will bring an overall time saving of 21 minutes, as the time for serving Týn nad Vltavou and driving through this town must be added. This amounts to 18 minutes, by which the route would be faster if Týn nad Vltavou was served on Route 1. However, this change was evaluated as positive due to a more even distribution of the number of containers on individual routes. The financial savings resulting from the reduction of the distance traveled thanks to the new location of the warehouse are summarized in Table 7 below.

Tab. 7

Comparison of transport costs (per fuel consumed) of original and newly designed routes

	Costs		
	Original route (€)	New route (€)	Savings in €
Route 1	142.48	142.48	0
Route 2	229.84	180.96	48.88
Route 3	195.52	128.96	66.56
In total (per week)	567.84	452.4	115.44
In total (per year)	29,527.68	23,524.8	6002.88

Financial savings per year account for € 6002.88, which represents 20.33 % of the original costs of waste collection. The alternative of moving the warehouse to Týn nad Vltavou would reduce the costs by nearly 25 %. The reduction in the distance traveled would account for 5772 km per year. This applies to any subsequent 52-week year.

6. CONCLUSION

The goal of the paper was to analyse the current situation of a company operating in the field of logistics and apply a suitable optimization method in order to increase performance in the given line of business. To address this issue, the centre of gravity method was used, which was followed by the proposal of a specific size of warehouse necessary for textile waste storage. Based on the new location of the warehouse, optimal routes for serving towns were proposed.

The proposed location of the warehouse brings savings in distance traveled and significantly helps increase traffic and logistics flow. The application of this method allows for finding ways to improve overall corporate performance and efficiency.

Due to the changed location of the warehouse based on the output of the centre of gravity method, it was necessary to optimize the routes, including the change in the starting and ending points. The optimization of the routes was based on measuring individual routes to the collection points and direct observation of the routes during the collection. The shortest possible routes were chosen while considering the traffic and complications that may occur in the given towns. A computer odometer was used to determine the shortest possible route for each day, determined according to the network chart.

The optimization of waste collection routes, as well as the optimization of other related logistics processes, have resulted in overall cost savings and more efficient swap body loading before its collection by the customer.

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