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ORGANISATION OF THE WORK ON COLLECTING ROUTES IN POSTAL ACTIVITY THROUGH AN AUTOMATED SYSTEM FOR COLLECTION OF INFORMATION

Summary. In the present study the transport work on collecting routes in "Bulgarian Posts" EAD has been analysed. Routes have been defined, in which a reduction of the transport costs is possible if pre-collected information about the availability of letters in the mailboxes is available. For this purpose, an automated system was created, which can recognise the availability of letters and send notifications. The method and the recognition criterion are described and the critical value of the colour temperature criterion was experimentally obtained. The system was tested with typical envelopes and the results showed that recognition had a 100% success rate.

1. INTRODUCTION

The problems related with the optimisation of collecting and delivering routes are of great importance for the efficient distribution and operation of transport companies. In a number of studies are presented algorithms for improved routing of the vehicles involved in the supply and distribution, most of which are based on the criterion of the lowest cost [5, 8, 7]. Other methods also exist, which try to offer fast real-time decision-making, at the cost of some inaccuracy [11] or optimising the postal transportation network with respect to planned road infrastructure [10].

In Bulgaria, the postal activity is regulated by the Postal Services Act (PSA). Under this law, postal services are divided into universal postal services (UPS) and non-universal postal services (NPS) [16]. The universal postal service includes acceptance, transport and delivery of domestic and international postal items, as follows:

- correspondence shipments – up to 2 kg;
- small packages – up to 2 kg;
- printed matter – up to 5 kg;
- secogrammes – up to 7 kg.

The main operator performing universal postal services in the country is "Bulgarian Posts" EAD. Since 2010, with changes in the PSA, the state obliged Bulgarian Posts EAD to perform UPS, in the territory of the whole country. As of December 2016, 2981 post offices operate in the territory of the country. According to the annual postal report [15] the number of mailboxes for collection of items of correspondence in them is 4814. The servicing of these stations and 63 postal agencies is done through 473 own vehicles, which run on 303 routes. Also, the company carried out a courier service called "EMS" (Express Mail Service), through its specialised enterprise "EMS Bulpost".

According to the acting PSA, Bulgarian Posts EAD is obliged to ensure postal services to all settlements in the country during all working days, at least 5 days a week. Further, it provides collection of postal items at least once every working day from the access points and at least one delivery to the recipients. Deviation from this procedure is allowed only in certain settlements, located in hard-to-reach areas. For them the working days to perform the universal postal service are determined by the postal operator, in agreement with the mayors of the respective municipalities.

From conducted researches of the organisation of transport activities at UPS in Bulgarian Posts EAD in the territory of the town Ruse in 2011 and 2016, it was determined that the mailboxes, 32 in number, are divided into two separated collection routes [4]. The results of the study also showed that 75% of the mailboxes were empty when visited by a postal employee to perform a collecting service, which provides great opportunities for optimisation of the process, using the capabilities of modern intelligent systems and software products for analysis of the daily vehicle movement routes. Further, optimisation of the collecting routes can lead to a significant reduction in fuel consumption and, as a result, affect the final price of the postal service [9].

2. ANALYSIS AND LITERATURE REVIEW

Numerous studies have investigated the available options for optimisation of vehicle movement routes and a number of mathematical models for reduction of the empty mileage of vehicles and to shorten travel time exist. In [2,3] the authors have presented a whole theory on the issue, backed up with practical solved examples, and in [12] graph theory was used for choosing an optimal route. The last article aims to create dynamic routes to reduce the distance travelled by postal cars, exclude empty boxes, and adhere to the PSA through the creation and use of an automated system for reporting the presence of letters in mailboxes.

Different studies have already tried to solve similar problems. Subramaniam et al. presented a system that monitors whether a letter is available in a mailbox with the use of two infrared (IR) sensors. If this is is discovered, the system sends an e-mail or SMS via a GSM modem [13]. A similar approach was suggested in the study by Suhami, in which the system discovers the availability of new e-mail with the use of 4 IR sensors [14]. Once letters are discovered the system sends an SMS to the user’s mobile phone. Both systems can also count the number of letters entering the mailbox. Such functionality is of no importance in our case, and might lead to higher energy consumption, which is a problem in some cases because some remote mailboxes are not connected to the electrical distribution grid.

Transport service of the universal postal services in Ruse

Servicing of mailboxes is carried out by a postal employee who travels by car. Cars that are mainly used for performing of postal services are Citroen Berlingo or Dacia Logan, whose engines run on diesel or gasoline. The travel time and waiting time for the postal employee using a car to arrive at the individual boxes were determined, as was the distances between them. The obtained results on the collecting routes in Ruse are presented in Tab. 1.

From the analysis of data the average time for the car to stay at the mailbox on schedule 1 is 60.8 s, and for schedule 2 is 55.5 s. For this time, the postal employee gets out of the car, goes to the box, opens the box, takes the letters, closes it and returns to the car. The trip time for the entire route is on average 3 160 s for Route 1, with 23 km length, and 3 362 s for Route 2, with 28 km length. The total time of operation on route 1 ranges from 56 min to 1 h and 13 min. On route 2, the total running time is in the range of 1 h and 3 min to 1 h and 26 min. The distribution of mailbox time in percentage for the mailing officer is as follows: 72% - driving time and 28% walking time from/to the mailboxes, opening/closing of the mailbox and collecting the mail when applicable. Because of the requirements of the PSA, "Bulgarian Posts" EAD are obliged to visit all the mailboxes on the working days of the week, regardless of whether there are letters or not. This means that, every working day, postal cars travel along the two-route total of 51 km for an average time of 1h and 48min.

The location of all the mailboxes in the territory of the city of Ruse, which are serviced daily by Bulgarian Posts EAD, is presented in Fig. 1.

Table 1

Servicing mailboxes in Ruse

Mailboxes			Time of movement, *t*, *s*				Time to stay, *s*		Distance *L*, *km*	
			From	To	From	To				
№	Route 1	Route 2	Route 1		Route 2		Route 1	Route 2	Route 1	Route 2
1	Mailboxes, Tsar.Osvobod-itel. 42	Serving node, Mailboxes 7001	360	240	180	300	60	49	1	3
2	Mailboxes, Tsar.Osvobod-itel. 48	Mailboxes, Shipca 48	60	180	180	300	58	50	1	2
3	Mailboxes, Tsar.Osvobod-itel. 118	Mailboxes, Ruse 7006,	60	120	60	180	56	53	1	1
4	Mailboxes, Nikolaevska 19	Mailboxes, Petrohan 96	180	300	120	180	60	60	1	1
5	Mailboxes, St. Stanbolov 64	Mailboxes, Ruse 7005	180	240	60	120	62	60	2	1
6	Mailboxes, Ruse 7016	Mailboxes, Ruse 7013	180	300	120	300	73	58	1	2
7	Mailboxes, Hristo Botev 38	Mailboxes, Tulcha 3	300	420	300	301	62	56	1	2
8	Mailboxes, Ruse 7015	Mailboxes, Ruse 7003	180	300	120	180	60	60	1	2
9	Mailboxes, Ruse 7019	Mailboxes, Dorostol 125A	240	360	60	180	65	48	1	2
10	Mailboxes, Ruse 7018	Mailboxes, Dorostol 79	180	240	60	62	55	53	2	0,5
11	Mailboxes, Ruse 7008	Mailboxes, Dorostol 29	540	660	60	60	60	50	1	0,5
12	Mailboxes, Ruse 7010	Mailboxes, Ruse 7004	180	300	60	120	58	60	7	1
13		Mailboxes, Ruse 7017			120	180		62	3	1
14		Mailboxes, Ruse 7020			180	240		49		1
15		Mailboxes, Nezavisimost 2			180	240		66		1
16		Mailboxes, Aleksandrov-sca 93			180	180		52		1
17		Mailboxes, Ruse 7002			120	360		58		1
18		Mailboxes, Ruse 7012			360	360		62		3
19		Mailboxes, Borisova 97			120	120		57		1
20		Mailboxes, Borisova 51			60	60		46		1
Total			**2640**	**3660**	**2700**	**4023**	**729**	**1109**	**23**	**28**
Average time, *s*			**220**	**305**	**135**	**201.2**	**60,8**	**55,5**		

Fig. 1. Location of the mailboxes in the city of Ruse on both routes

Fig. 1 shows that the mailboxes are located throughout the whole territory of Ruse so that the service of the citizens is complete, according to the requirements for access to the postal service of all the inhabitants.

3. OBJECTIVES AND METHODS

The main objective is to reduce the cost of transport through pre-collected information about the letters available in mailboxes through an automated system to recognise letters in mailboxes and collect information from them.

Method to create an organisation of movement of cars on collection routes

From research carried out in April and May 2016 and 2017 it was found that in three of the boxes there were never letters inside. These are the boxes marked in red in Fig. 1. In the others marked with yellow and green, letters have been found. In one of the days of the experiment, letters have been found only in the 8 mailboxes, marked with green. In this case a suitable method for organisation of the movement of collecting vehicles, based on an automated system for monitoring of letters availability in the mailboxes, is employed.

Automated system for mail recognition

The object of the investigation is a typical Bulgarian mailbox with dimensions 320x340x260 mm, presented in Fig. 2. The developed automated system consists of client and server parts. The client part is implemented with an Arduino Mega 2560 microcontroller, a SIM800H GSM Shield and an Adafruit TCS34725 colour sensor, installed in the mailbox (fig. 3a). The colour sensor “reads” the average colour of the mailbox, which is then analysed by the microcontroller. If the system recognises a mail was dropped in the box, it notifies the server over a GSM network.

The server part of the system is implemented using an Arduino Mega 2560 microcontroller, a SIM800H GSM and a personal computer (PC), (fig. 3b). The microcontroller continuously checks for new SMS messages. When such a message is received its content is displayed on the PC to the operator.

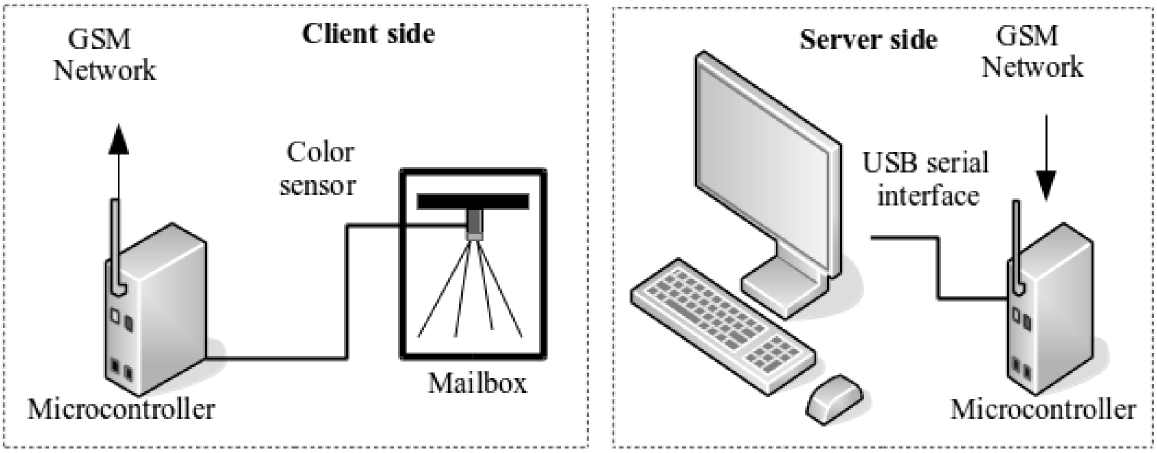
Fig. 2. A typical Bulgarian mailbox

Method for mail recognition

It is important to note that in the present study we use the colour sensor in an unusual way. It is supposed to be used to read the object colour from a few millimetres' distance, whereas we use it to read the average colour of all surfaces it "sees". In order for the method to work we assume the following:

1. the inside surfaces of the mailbox are painted black;
2. no black letters will be dropped in the box.

This means that when there is no letter in the mailbox the average colour that the sensor sees will be black – RGB (0,0,0). Next, when a letter is dropped in the mailbox, the sensor will return a different average colour. An example for this behaviour is presented in Tab. 2.



a) b)

Fig. 3. Structure of the client side (a) and server side (b) of the system

Possible criteria for recognition

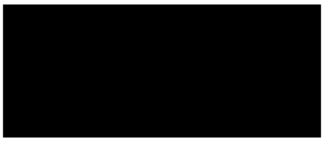
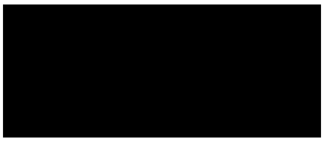
The sensor reads the colour as R (red), G (green) and B (blue) values, taking values form 0 to 255.

It is impossible to compare two three-dimensional values (colours). For this reason a criterion is required, which will present the RGB colour as a single value. We have tested two possible criteria. The first one is the Perceived brightness (PB) criterion, which has been successfully used for colour comparison in [1]. PB is calculated with the following formula:

$$PB = 0{,}299.R + 0{,}587.G + 0{,}114.B \qquad (1)$$

Table 2

An example for mail recognition

Situation	**What the sensor “sees”?**	**Average color**	**Average RGB color**
The letterbox is empty			RGB(0,0,0)
There is a mail in the letterbox			RGB (77,77,77)

Another option is to use the correlated colour temperature (CCT) in Kelvins. First the CIE 1931 values are obtained, using the RGB colour [6]

$$\begin{aligned} X &= 0{,}14282.R + 1{,}54924.G \quad 0{,}95641.B \\ Y &= 0{,}32466.R + 1{,}57837.G \quad 0{,}73191.B \\ Z &= 0{,}68202.R + 0{,}77073.G + 0{,}56332.B \end{aligned} \tag{2}$$

Next the CIE 1931 chromaticity diagram coordinates are estimated

$$x = \frac{X}{X+Y+Z} \tag{3}$$

$$y = \frac{Y}{X+Y+Z}$$

Finally the correlated colour temperature is estimated as follows:

$$CCT = 449.n^3 + 3525.n^2 + 6823{,}3.n + 5520.33\ , \tag{4}$$

where

$$n = \frac{x - 0{,}3320}{0{,}1858 - y}$$

The results are further processed and the following numerical characteristics are defined:

1. The average of the measured parameter – $\overline{X}$

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}\ , \tag{5}$$

where x_i is the value of the parameter at each measurement, n is the number of the sample.

2. The dispersion – $S^2\ (X)$

$$S^2 = \frac{\sum_{i=1}^{n} (x_i - \overline{X})}{(n-1)} \tag{6}$$

3. The span determined on the basis of the difference between the largest X_{max} and the smallest X_{min} of the variable magnitude – R

$$R = X_{max} - X_{min}\ . \tag{7}$$

4. RESULTS

4.1. Choosing the letter-recognition criterion

In order to investigate the applicability of the two criteria for recognition of letters in the mailbox, the following method is used:

1. typical letters are chosen with different sizes and colours, to be used in the tests;
2. for each test object the following are carried out:
2.1. the sensor reads the colour of the empty mailbox;
2.2. the letter is dropped into the mailbox and the sensor reads the colour again.
2.3. steps 2.1. and 2.2. are repeated 20 times.
3. for each RGB colour its PB and CCT values are obtained;
4. for each situation (empty mailbox, mailbox with a certain test object) the following are obtained:
4.1. the average value of the two criteria;
4.2. the swing (minimal and maximal) values of the two criteria.
5. the obtained values from 4.1. and 4.2 are investigated:
5.1. if the swing of the empty mailbox overlaps with the swing of one of the other situations (non-empty mailbox), the criterion is dismissed;
5.2. if the swing of the empty mailbox situation doesn't overlap with any of the swings of the other situations, the criterion is accepted.

The chosen test objects are typical mails, presented in Tab. 3.

Table 3

Test objects (letters)

No	Dimensions	Colour
1	12/16 cm	White
2	11/22 cm	White
3	16/23 cm	White
4	23/32 cm	White
5	13/18 cm	Green
6	13/18 cm	Yellow

The results from the experiment are presented in Fig. 4 and Fig. 5. From Fig. 4, it can be seen that the PB criterion fails the test because its swing for empty mailbox overlaps with the swings of test letters 5 and 6. This means that the PB criterion is dismissed.

The results for the CCT criterion (Fig. 5) show that there is no overlap between the swing of the empty mailbox and the swings of the non-empty mailbox situations. Therefore, the CCT criterion is chosen for implementation of the system.

Letter-recognition procedure

In order to recognise the presence of letters in the mailbox, a critical value for the CCT criterion should be chosen, which would allow the system to distinguish between an empty and a non-empty mailbox. Considering the criterion returned higher values for the empty mailbox, than for all other situations, the critical value is determined as follows:

$$\boldsymbol{CCT_{CR} = MIN(CCT_{MIN}^{EMPTY} - CCT_{MAX}^{LETTER})}, \qquad (8)$$

where $\boldsymbol{CCT_{MIN}^{EMPTY}}$ and $\boldsymbol{CCT_{MAX}^{LETTER}}$ are the minimal and maximal value of the criterion when the mailbox is empty and non-empty, respectively.

The letter recognition procedure includes the following procedure:

1. the colour sensor reads the average colour of the mailbox when there is no letter inside it and obtains its CCT value CCT_0;

2. after a certain amount of time, the sensor reads the average colour again and obtains the new value CCT_1;

2.1. if $|CCT_0\text{-}CCT_1| \geq CCT_{CR}$, there is a letter in the mailbox;

2.2. if $|CCT_0\text{-}CCT_1| < CCT_{CR}$, the mailbox is empty.

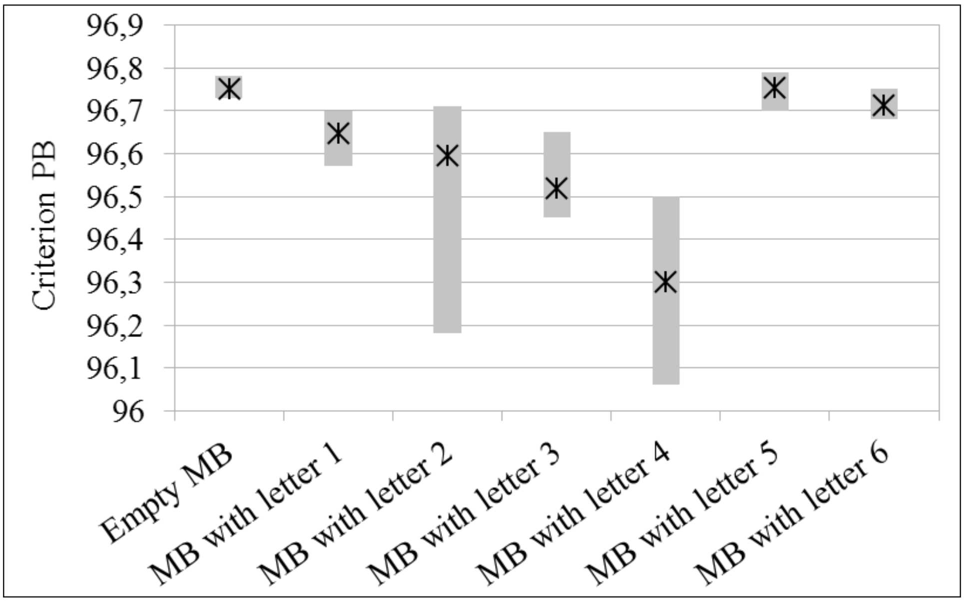


Fig. 4. Average value and swing of the PB criterion for the 7 situations

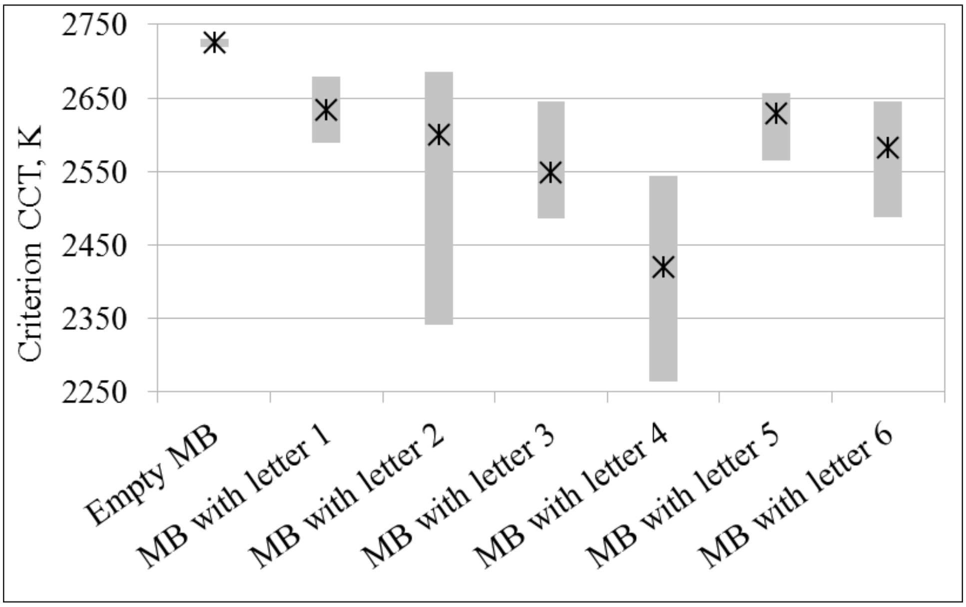


Fig. 5. Average value and swing of the CCT criterion for the 7 situations

Testing the system

The implemented system has been tested to see whether it correctly recognises letters inside the mailbox using the following procedure:

1. the system is initialised with an empty mailbox and the initial CCT value is obtained;
2. one of the test objects is inserted into the mailbox and the new CCT value is obtained;
3. the criterion difference $|CCT_0\text{-}CCT_1|$ is evaluated and recorded.

The described procedure has been implemented 20 independent times for each test object and the results are presented in Fig. 6.

It can be seen that the system correctly recognises the letters in the mailbox, and has a 100% success rate, as the criterion difference is always higher than its critical value. This also means that the criterion and its critical value have been correctly identified.

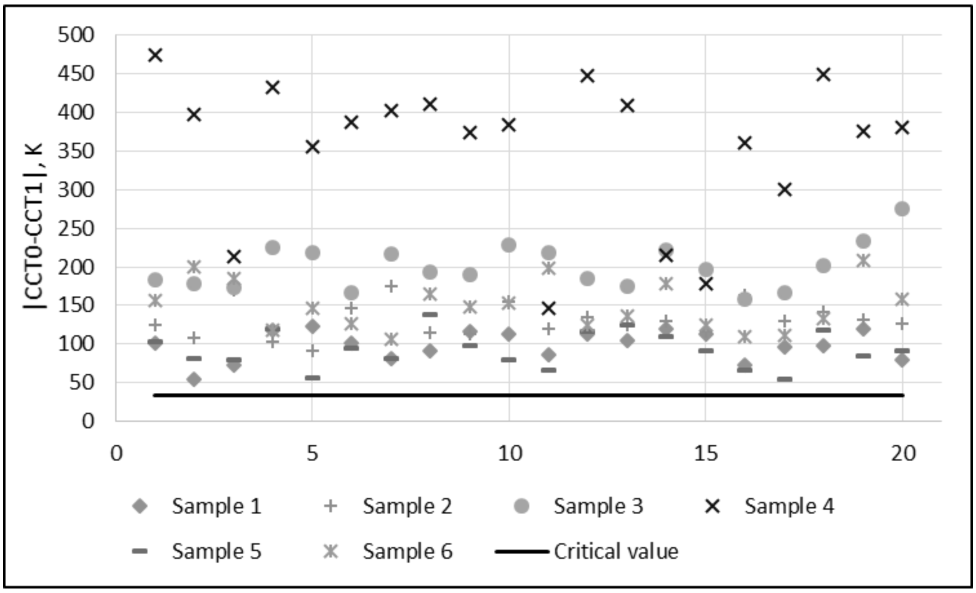


Fig. 6. The obtained criterion results from the testing of the system

4.2. New organisation of service of mailboxes at Bulgarian Posts EAD

After it was established that the proposed automated system for collecting data from mailboxes in real-time was operating successfully and 100% availability of letters in them was reported, a new organisation for the service of mailboxes was proposed. According to it only those boxes are visited in which letters are available. One of the exemplary routes created by reporting pre-received information about the presence of mail in a mailbox is shown in Google MAPS, [17] in Fig. 7. The results show that the postal employee must walk the route with only 8 points with a total distance of 15,1 km. Total time for carrying out the transport work is 49.2 min.

To create optimal routes for the movement of cars IGO 8, owned by the Department of Transport in University of Ruse "Angel Kanchev", are used for navigation, which allows the automatic arrangement of the stations on the shortest route.

The created new route for the day reduces the distance travelled by the postal employee to 35,9 km. At the same time, time to commit transport work is decreased to 58.8 min. This situation clearly shows the benefit of using an automated system, which provides a real-time notification about the presence of letters in the mailboxes. The overall benefit of using such a system can be evaluated after analysing the work at the end of the calendar year. Each year the company makes an annual report of its activities. Intermediate research results are presented at this stage.

5. CONCLUSIONS

In the conditions of the city of Ruse, most often there are no letters available in many of the mailboxes served by "Bulgarian Posts" EAD during the working days. Out of 32 boxes, the empty ones vary between 3 and 29 for the different working days. This is a prerequisite to propose the creation of dynamically changed daily collecting routes, based on actual information about the availability of letters in the mailboxes.

Fig. 7. New route of service of the post boxes

The results of the research show that it is possible to optimise transport operations and collecting routes in urban environments with the use of an automated system that collects information in real time.

An automated letter-recognition system is created in the mailboxes, which uses a colour sensor for recognition, and the colour temperature as the criterion. Experimentally, the critical colour-temperature criterion was obtained to be 34 K for the object of the investigation. The system was tested with typical envelopes and the obtained results showed that the recognition has a 100% success rate.

The proposed system could be applied in the current mailbox collecting procedures as it does not contradict the law on postal activity in the country, and as it guarantees that the services are executed with high quality, accuracy and efficiency.

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