Advanced Logistic Systems – Theory and Practice, Vol. 17, No. 3 (2023), pp. 5-23.
https://doi.org/10.32971/als.2023.019

IMPROVING THE LOGISTICS OF INSTITUTIONAL POSTAL SERVICES

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Abstract: *Postal services are often considered by the different institutions as a back-up service. Taking into account that in case of large geographical coverage these services can generate significant costs, it is important to optimize the postal service functions within these institutions and to develop the already existing conventional postal services. Within the frame of this article the authors review the logistics processes of the postal services at the University of Miskolc to propose improvements to these processes focusing on delivery. The main regulatory elements and the logistics processes of the institutional postal services are discussed and some critical remarks are described focusing on three main areas: the facility location optimization of the institutional postal services, the lack of use of modern technologies and the lack of modern administrative facilities. On the basis of these criticisms, the authors define recommendations for improving institutional postal services. Regarding the facility location optimization problem, a mathematical model and an optimization algorithm is described to evaluate the efficiency of the logistics processes of delivery services. The proposed methodology supports a cost-based analysis of different solution variants and a priority-based differentiation between institutions and offices. The suggested approach is tested with a real scenario, where the numerical results validate the efficiency of the evaluation of optimization algorithm. The second improvement direction is the application of a pneumatic tube system. The authors show the most important parts of the proposed pneumatic tube system, which can lead to decreased labor cost and increased service level.*

Keywords: *postal services, optimization, facility location, service network, pneumatic tube system*

1. INTRODUCTION

Today, there is a decline in the turnover of traditional postal products. For example, the number of letters sent has fallen, greetings cards are not as popular as they used to be, and the number of payment services is also declining. In contrast, the number of parcel deliveries is increasing year on year. The conclusion is that consumer habits have started to change dramatically over the last decade. Furthermore, diversification can be observed, which implies that post offices widen their service areas. A survey has shown that post offices that diversify their services have higher revenues and are more successful than their counterparts that only offer conventional postal services.

The key elements of logistics in postal services are adequate service quality, speed, competitiveness, availability and efficiency with other service providers. In response to this pressure, the post offices are constantly striving to provide the highest possible quality of services, while of course maximizing profits. Optimization of technologies and costs are also becoming increasingly important in everyday life of postal services.

Within the frame of our research work, we have used the systematic literature review methodology to identify the most important research topics regarding in-house postal service solutions and to find potential research gaps. Within the frame of our systematic

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literature review, we have defined research questions, selected sources from the Scopus, and analysed them. We have used the following keywords to search in the mentioned database: (TITLE-ABS-KEY (postal AND service) AND TITLE-ABS-KEY (logistics) AND TITLE-ABS-KEY (mail AND delivery)) AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "DECI"))). Within the frame of our research we are focusing on engineering problems, therefore we have defined filters for the subject area, because we did not want to include articles from not specific research fields, so we have limited our search to the following subject areas: engineering, computer science, business and management, decision making (Figure 1). Initially, 16 articles were identified. Our search was conducted in January 2022; therefore, new articles may have been published since then.

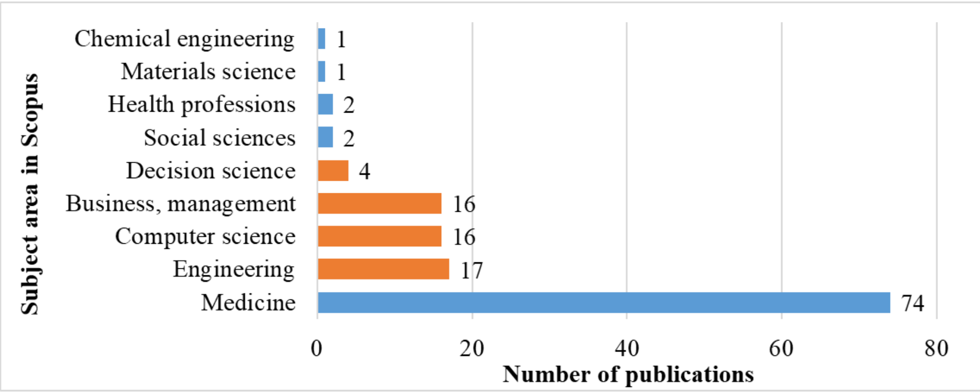

Figure 1. Classification of articles considering subject areas based on a search in Scopus database using search: TITLE-ABS-KEY (postal AND service) AND TITLE-ABS-KEY (logistics) AND TITLE-ABS-KEY (mail AND delivery)

The organization structure of postal services has high labour intensity and short response times, therefore load analysis and optimization of technological and logistics resources and infrastructures such as post offices, distribution and exchange centres, and delivery stations is required for optimal process efficiency [1]. The digitalization of production and service processes becomes more and more important, because the transformation of conventional production and service systems into cyber-physical systems using Internet of Things technologies can lead to increased availability, flexibility, efficiency, sustainability and transparency [2, 3]. Other focus area of service performance improvement is the analysis of past and future data from demand forecasting point of view, which can be used to support the logistic management, staff scheduling and topology planning of postal services [4].

A qualitative and quantitative survey methodology was employed to evaluate specific public postal service providers to improve the last mile segment of postal services [5]. This research direction validates, that data analysis and forecasting plays an important role in the first mile and last mile segment of postal services. The material handling design is a core part of the postal service design including facility layout, routing, scheduling and assignment problems. The facility location problems can focus both on the optimization of distribution centres and on the post offices [6, 7]. The facility location problems are generally solved with various graph theory approaches [8]. In the scheduling and optimization cargo cycles plays a more and more important role, because these solutions have great impact on the efficiency on the performance of first mile and last mile operations, especially in dense urban areas [9]. This cargo cycle is also applicable in the institutional level of postal services.

The design on strategic, tactical and operational level is generally focusing on both the reduction of service time and costs, where the optimal multi-level distribution network has a great influence on this objective [10, 11]. In the case of complex system not only analytical and heuristic methods but also discrete event simulation can be used to support the design and operation of postal services [12].

In the Industry 4.0 era electronic commerce become an important tool to transfer physical processes into the cyber-space, which means, that in the case of postal services the physical distribution is widely supported by e-commerce solutions focusing on the improvement of the logistics and transport process and infrastructure, while new distribution channels and delivery concepts appears [13]. Other important impact of the fourth industrial revolution on the postal services is that the smart sensor technology, the digital twin solutions and the big data solutions make it possible to transform physical systems into cyber-physical systems, and using discrete event simulation tools we can perform real-time design processes to make the optimization of postal services more efficient [14], while the integrated design and operation stay in the focus [15]. Table I summarizes the most important approaches in the field of design of postal services.

Table I.

Main research topics focusing on logistics-related optimization of postal services based on the results of Scopus search.

Topic of the research	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**	**[8]**	**[9]**	**[10]**	**[11]**	**[12]**	**[13]**	**[14]**	**[15]**
demand forecast	X														
algorithms, optimisation	X	X	X			X	X	X	X	X	X				
digitalization, Industry 4.0		X		X	X								X	X	X
process automation		X		X											X
statistical analysis	X				X										
facility location						X	X	X	X						
routing						X	X		X						
simulation							X					X			
other postal services															X

Based on the analysis of the above mentioned literature sources, we can conclude, that:

- Postal services have high labour intensity,
- Postal services can be characterized as processes having short response times,
- The digitalization of postal services can lead to the improvement of key performance indicators (KPI),
- Demand forecasting can support the processes of operation management, scheduling and dynamic topology design,
- The integrated approach in the design and operation of postal services has a great impact on the expected solutions of routing, facility layout, scheduling and assignment problems,
- Cargo cycles represent suitable solutions for external and in-house first mile and last mile operations of postal services,
- The organizational aspects of postal services influence the design problems on strategic, tactical and operational level.

As the literature review section shows, the majority of the articles in the field of postal services focuses on the optimization of large, external solutions and only a few of them describes the design aspects of in-house postal services. The application of suitable design and control methods and Industry 4.0 technologies can increase the efficiency, availability and sustainability of these in-house postal services. Based on this fact, the paper is organized as follows. Section 2 presents a systematic literature review, which summarizes the research background of in-plant manufacturing supply. Section 3 describes the identification of bottlenecks in an institutional in-house postal service system. Section 4 presents an optimization approach for the solution of facility location problems in in-house postal services. In Section 5 we make a proposal to improve the efficiency of in-house postal services using a pneumatic tube mail system, while in Sections 6 and 7 we show the potentials of drone-based technologies and biometric signature pads to improve the efficiency of postal services. Conclusions and future research directions are discussed in Section 8.

2. IDENTIFICATION OF BOTTLENECKS IN THE INSTITUTIONAL POSTAL SERVICE SYSTEM

In the case of the analysed institution, postal services are also seen as a back-up service. However, this thinking is wrong, as maintaining an inadequately designed system is not cost efficient and requires more manpower. We have made a questionnaire to identify the bottlenecks of the institutional postal system and then to assess the structure of the system, the current location of the postal service and the technologies used. Our ultimate goal is to improve the delivery process of postal items. As a first step, the following main questions were included into a questionnaire to assess the functioning of the postal system of the analysed institution:

1. What rules and instructions govern the operation of the postal system of the institution?
2. What are the rules for handling electronic and paper documents?
3. Where and when do the staff of the institutional mail centre receive letters and parcels?
4. How many items do they have to receive per day?

5. What is the procedure once the mail has been received?
6. Is the receipt and dispatch of mail recorded in an electronic system?
7. Do electronic mailings have to be recorded after receipt and, if so, in which system?
8. How long does the sorting process take?
9. Are there any external institutions to which you deliver mail, and if so, which ones, and how often do you deliver to them?
10. What are the institutes, centres, offices and departments to which the mail hand-delivered by the postal staff?
11. Which are the institutions, centres, offices or departments to which the mail handler's staff do not deliver the mail but where the postal assistants or administrators have to personally arrange for the collection or delivery of the mail?
12. When can outgoing mail be delivered by clerks and administrators?
13. When can clerks and administrators deliver incoming mail?
14. When exactly can outgoing mail and parcels be posted by postal employees?
15. What is the authentication process?
16. On average, approximately how much internal mail is generated per day?
17. What was the total cost of outgoing mail last year?
18. Which types of mail are preferred by institutions, centres, offices, departments, chairs and divisions?
19. Are there any tasks other than mailing which you have to perform?
20. Are you also responsible for the control and management of the Client Gate?

On the basis of the responses received and the regulations and instructions, the operational process of the institutional postal system was identified. Within the frame of the evaluation of the institutional postal services, we found that it does not use the possibilities offered by modern technologies, either in its delivery processes or in its administrative processes. Based on these critical facts, we make four recommendations for improvements to modernize the mail delivery processes. Second, we will analyse in depth the pneumatic tube mail systems. Thirdly, we will analyse in detail two cases of the use of drones, one for mail or small package delivery and the other for inventory. Our last development proposal focuses on the improvement and digitalization of administration processes. In order to create a more modern system and to speed up the administrative process, it is essential to make use of the achievements of modern Industry 4.0 technology. In order to increase the efficiency of the administration, we propose the use of digital signature pads.

3. FACILITY LOCATION OPTIMISATION TO IMPROVE SERVICE PERFORMANCE

The objective of this chapter is to present a functional and mathematical model to determine the optimal location of the institutional post office. In order to determine the optimal location, the following main phases have been implemented:

1. Determination of the locations of the offices in the institution.
2. Computation of the priority parameters of each office, department or group as a function of the average expected mail volume obtained from the statistical analysis of past mail delivery activities.
3. Definition of a specific facility location model that takes into account the specificities of the institutional buildings.
4. Determination of the optimal location of the post office.

For the first time, we have included the names of the centres and their exact location in the optimization software, where x represents the horizontal distance from the selected origin and y is the floor on which the centre is located. Second, we placed a cell next to each centre that calculates how the distance between them would vary for different locations of the institutional post office. Next, we scored each centre on a five-point priority scale and distributed the daily mail volume between them according to the priority scores.

The annual postal cost for the institutions is about 40000 USD. Furthermore, the cost of mailing 1 mail was about 1 USD, and in 2020 the institutions has 256 working days, which also can be taken into consideration while computing mail delivery parameters. Dividing the annual postage cost by the price of 1 mail gives the result of approximately how many letters are mailed per year.

$$PM = APC/PPL = (40000\,USD)/(1\,USD) = 40000\,pcs, \tag{1}$$

where PM is the number of mails posted per year, APC is the annual postal cost and PPM is the postal cost per mails.

The resulting mail volume is then divided by the number of working days, which in 2020 was 254, to obtain the average daily volume of outgoing mail.

$$ADV = \frac{\text{PM}}{NWD} = \frac{40000\text{ pcs}}{256\,days} = 156\,pcs, \tag{2}$$

where ADV is the average daily volume of outgoing mails, NWD is the number of working days in the analysed time frame.

In addition, the daily number of incoming mails is about 150 pcs, and the daily volume of internal mails is between 300 and 2000 pcs. Given the following data, the average daily number of mails can be calculated as follows:

$$ADM = \text{ICM} + \text{ISM} + \text{OM} = 1506\,pcs. \tag{3}$$

So these 1506 pieces of mails have been distributed according to the priorities. We used the following formula to determine the quantities of mails for each location:

$$DMVC = \frac{PC}{TP} \cdot \text{ADM}, \tag{4}$$

where DMVC is the daily mail volume of the office (centre), PC is the priority of the given centre or office, TP is the sum of the priorities.

In the last column of the table, we calculated the value of the objective function, which is calculated as follows for a given location:

$$VOF = DT \cdot ADM, \tag{5}$$

where VOF is the value of the objective function and DT is the travelled distance in the mail delivery process.

The optimal location of the institutional post office was determined using the Excel Solver, namely the evolutionary heuristic algorithm. The optimal solution is not far from the current location of the post office, which is now located in the offices of building A5, office 100-102. However, this is because our objectives were to locate the post office in the A4 and A5 buildings, in a relatively central position. Figure 2 summarizes the input data of offices in the in-house postal service system, while Figure 3 shows the layout of the institution.

ID	Office	x [m]	y [floor]	Route [m]	Priority	Value [pcs]	Objective function
1	Institute for Geophysics and Geoinformatics	18	0	38.5	1	18	699
2	Institute of Logistics	-35	1	35	1	18	635
3	Mentorius	36.1	1	36.1	2	36	1310
4	Department of Descriptive Geometry						
...							
85	Rector's office	75	1	75	5	91	6804
86	Institute of Mathematics	50.5	3	91.5	1	18	1660
87	Institute of Mechanics	60	4	121.5	1	18	2205

Figure 2. Input and output data of the facility location problem (sample)

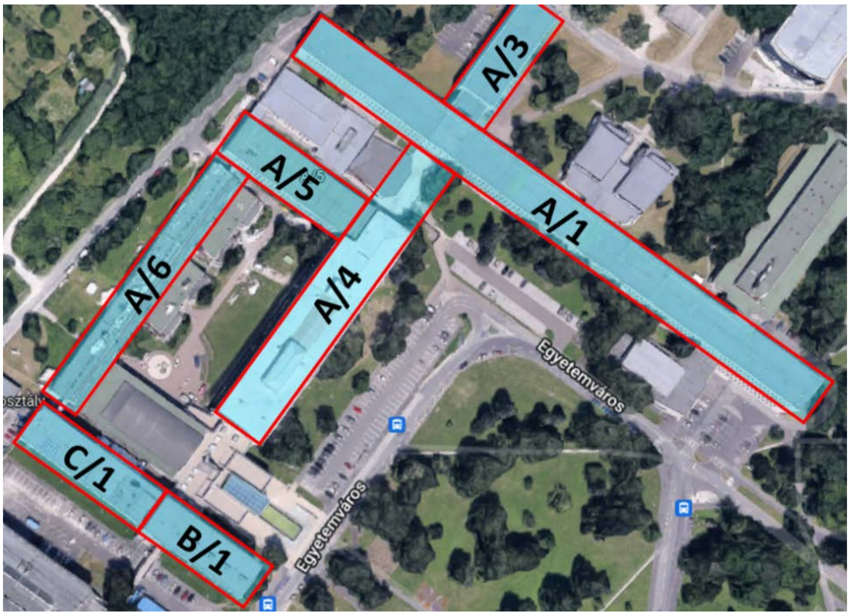

Figure 3. Layout of the buildings of the analysed institutional postal service system

In the next part of this chapter we describe the notations used and then present the mathematical model applied to the different groups of locations in the institutional postal system. The formulas we have defined are presented with a corresponding example. We have used the following notations in the mathematical model: $z_i \in Z$ is the ID of location i in the set of the locations of the postal service system, p is the post office and $e_i = e_i(z_i)$is for the identification of the floor.

The displacement in the y direction is the product of the number of floors and the distance between the floors. The distance between two adjacent floor level is equivalent to 20.5 metres. The calculation of the y-displacements for both office i and the post office is as follows:

$$y_i = e_i * 20{,}5m \text{ and } y_p = e(p) * 20{,}5m, \tag{6}$$

Let us assume that the post office can only be located in building A4 or A5:

$$p \in Z\_A4 \vee p \in Z\_A5, \tag{7}$$

For the first group of offices, we can define two possible cases, depending on whether the office is located on the same level of building A4 or A5. If the offices are on the same level of the building, then the required optimized route between these two offices can be calculated as follows:

$$z_i \in Z_{A4} \vee z_i \in Z_{A5} \wedge e_i(z_i) = e(p) \text{ and } l_i = |x_i - x_p|, \tag{8}$$

Assume that the post office is located on the second floor of building A4 and that it is 80 m from the origin in the positive direction. Calculate the distance between the Department of Descriptive Geometry and the post office (see Figure 4)!

$$l_i = |x_i - x_p| = |16{,}5m - 80m| = 63{,}5\ m, \tag{9}$$

Figure 4. Computation of the distance between two locations on the same floor

If the offices are on different levels of the building, then the required optimized route between these two offices can be calculated as follows:

$$z_i \in Z_{A4} \vee z_i \in Z_{A5} \wedge e_i(z_i) \neq e(p) \text{ and } l_i = |x_i| + |x_p| + |y_i - y_p| \tag{10}$$

Assume that the post office is located on the second floor of building A4 and that it is 20 m from the origin in the positive direction. Calculate the distance between the Institute of Mechanics and the post office (see Figure 5)!

$$l_i = |x_i| + |x_p| + |y_i - y_p| = |20m| + |60m| + |20{,}5m * 2 - 20{,}5m * 4| \\ = 121m \tag{11}$$

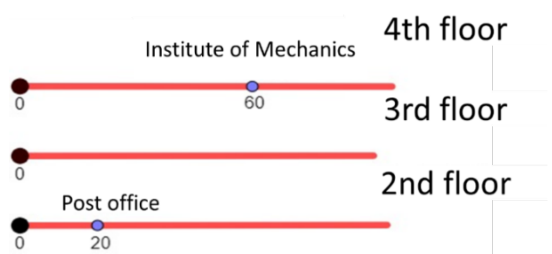

Figure 5. Computation of the distance between two locations on different floors

If the office is located on the ground floor of building A1, A3, B1 or C1 and the post office is also located on the ground floor, then the required optimized route between these two offices can be calculated as follows:

$$z_i \in Z_{A1} \vee z_i \in Z_{A3} \vee z_i \in Z_{B1} \vee z_i \in Z_{C1} \wedge e_i(z_i) = e(p) = 0 \quad (12)$$

$$l_i = |x_i - x_p| \quad (13)$$

Assume that the post office is located on the ground floor of building A4, and it is 52 m from the origin in the positive direction. Calculate the distance between the Institute of Machine and Product Design and the post office (see Figure 6)!

$$l_i = |x_i| + |x_p| + |y_p| = |-76{,}5m| + |24m| + |20{,}5m * 3| = 162m \quad (14)$$

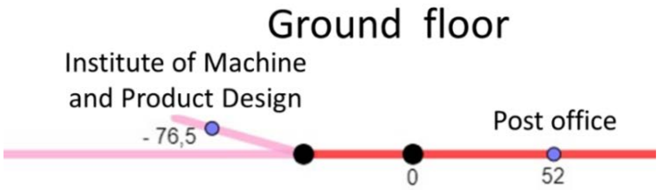

Figure 6. Computation of the distance between two locations on the ground floor in different buildings

If the office is on the first floor of building A1, A3, A6, B1 or C1 and the post office is also located on the same floor, then the required optimized route between these two offices can be calculated as follows:

$$z_i \in Z_{A1} \vee z_i \in Z_{A3} \vee z_i \in Z_{A6} \vee z_i \in Z_{B1} \vee z_i \in Z_{C1} \wedge e_i(z_i) = e(p) = 1 \quad (15)$$

$$l_i = |x_i - x_p| \quad (16)$$

Assume that the post office is located on the first floor of building A4, and that it is 30 m from the origin in the positive direction. Calculate the distance between the Dean's Office of the Faculty of Mechanical Engineering and Informatics and the post office (see Figure 7).

$$l_i = |x_i - x_p| = |164{,}35m - 30m| = 134{,}35m \quad (17)$$

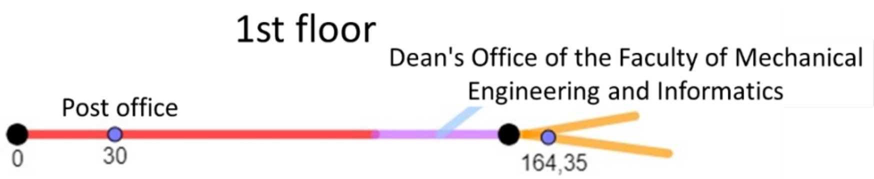

Figure 7. Computation of the distance between two locations on the first floor in different buildings

If the office is located on the first floor of building of A1, A3, A6, B1 or C1, but the post office is on a different floor, then the required optimized route between these two offices can be calculated as follows:

$$z_i \in Z_{A1} \vee z_i \in Z_{A3} \vee z_i \in A_6 \vee z_i \in B_1 \vee z_i \in C_1 \wedge e_i(z_i) = 1 \wedge e(p) \neq 1 \quad (18)$$

$$l_i = |x_i| + |x_p| + |y_p - 1| \quad (19)$$

Assume that the post office is located on the third floor of building A4, and that it is 40 m from the origin in the positive direction. Calculate the distance between the Dean's Office of the Faculty of Mechanical Engineering and Informatics and the post office (see Figure 8).

$$l_i = |x_i| + |x_p| + |y_p - 1| = |164{,}35m| + |40m| + |60{,}5m - 20{,}5m| = 245{,}35m \quad (20)$$

Figure 8. Computation of the distance between two locations on the first floor in different buildings

If the office is located on the second, third or fourth floor of building A1, A3, A6, B1 or C1, then the required optimized route between these two offices can be calculated as follows:

$$z_i \in Z_{A1} \vee z_i \in Z_{A3} \vee z_i \in Z_{A6} \vee z_i \in Z_{B1} \vee z_i \in Z_{C1} \wedge e_i(z_i) = 2 \vee e_i(z_i) = 3 \vee e_i(z_i) = 4 \quad (21)$$

$$l_i = |x_i| + |x_p| + |y_p - 1| + |y_i - 1| \quad (22)$$

Assume that the post office is located on the fourth floor of building A4 and that it is 45 m from the origin in the positive direction. Calculate the distance between the Institute of Physics and Electronic Engineering and the post office (see Figure 9).

$$l_i = |x_i| + |x_p| + |y_p - 1| + |y_i - 1| = 195{,}5m \quad (23)$$

Using the metrics described above, the heuristic option of the Excel Solver was used to optimize the facility location problem (Figure 10), taking into account not only the objective function for material handling performance, but also the constraints on the location of the post office. The presented metrics can be generalized to other building structures and can even be applied to buildings with pavilion systems.

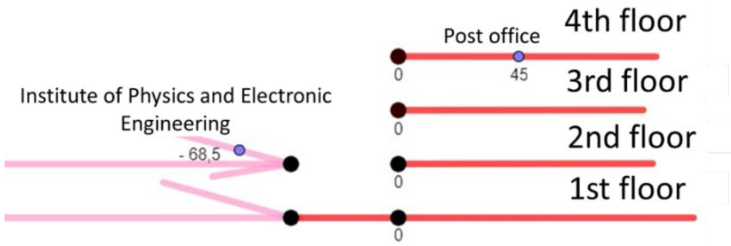

Figure 9. Computation of the distance between two locations on different floors in different buildings

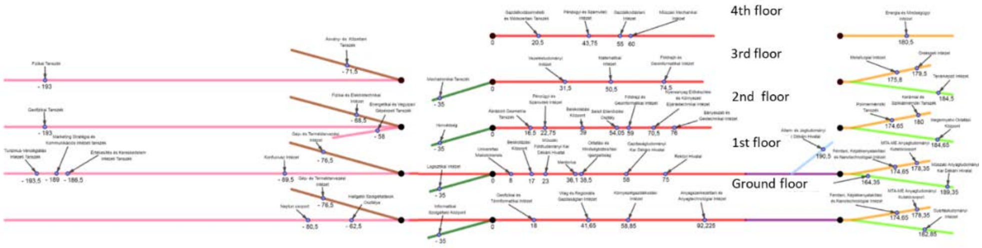

Figure 10. The structure of the whole in-house postal service system

4. APPLICATION OF PNEUMATIC TUBE SYSTEM

In this chapter, we will analyse in detail the pneumatic tube mail system and explore its potential applications. First of all, the literature that we have used to gain a comprehensive knowledge of the pneumatic tube mail system and to develop the analysis is presented.

We found a wide range of research results in the Scopus database, which are focusing on the application of pneumatic tube systems. Some of them are quite old, such as the work "Modular Pneumatic Tube System for High Frequency of Dispatches" by E. Richet, written in the 1970s, which analyses and describes the pneumatic tube systems for mail services [16]. In 1976, a work giving an insight into the history of pneumatic tube mail systems was written by Hochuli and Marcel [17], entitled "50 Years of Swiss PTT Pneumatic Tube System". We would like to highlight three works whose research is mainly focused on the materials of pneumatic tube systems. From the system design of pneumatic tube mail systems point of view there are two important literature sources to be taken into consideration. We came across a paper detailing the development of a simulation framework for pneumatic tube systems for mail delivery [18]. The paper describes a decision support system that allows the creation of discrete event simulations, provides the possibility to analyse the current system or a still theoretical system, and provides information on the system traffic and its performance. This work is the "Simulation analysis of pneumatic tube system". One of the most recent literature to be found is "The Modern Pneumatic Tube System Transport with Reduced Speed Does Not Affect Special Coagulation Tests" by L. Slavík et al. published in 2020, which investigates whether blood samples are not damaged when they are transported by the pneumatic tube system for evaluation [19].

Each system includes a sending station from which shipments are dispatched and a receiving station to which shipments arrive. These stations may be equipped with locks that can only be opened with a mechanical key or a pin code for security reasons. The stations are controlled by microcomputers, each with both an LCD display and a keypad. At the stations we can define the destination and the amount of deliveries. Thanks to the LCD display, it is easy to read the status of the system and its operation. It is also possible to indicate the arrival of capsules by means of light or sound effects [20-22].

A pipe system must be installed among the stations. The diameter of the pipe network can vary from 110 mm up to 315 mm. In terms of material, it can be made of PVC, Plexiglas, aluminium, steel, PEHD, halogen-free material [21]. Shipments (mails, envelopes, small packages) must be placed in so-called capsules. The capsules guarantee that the documents, parts, samples and other items arrive intact at their destination. There are three types of capsules: sliding roof, leak-proof and swing top capsules (see Figure 11).

Figure 11. Types of capsules for pneumatic tube systems: leak-proof, sliding roof and swing top capsules (Source: https://www.vitalassist.hu/upload/csoposta.pdf)

To ensure that the capsule can only be opened by the recipient, they can be equipped with a combination lock, eliminating the possibility of important items (confidential documents) falling into the hands of unauthorised persons. The transport of the capsules is driven by an air pump creating a vacuum or compressed air in the piping systems and a motor driving the air pump along the transport route. The path of the capsules is defined by computers. There may be a period when the system is overloaded. In order to reduce the load, a multi-zone pneumatic tube mail system should be designed. With a multi-zone system, there can be several capsules in the network at the same time, each separate zone being operated by a separate compressor. Of course, the zones can be interconnected by a transfer unit, so that the pneumatic tube mail systems can form a large, complex network [20].

In the case of the analyses institution, a multi-zone system should definitely be developed, but the zones would not be separate units, as the Transfer Unit would provide the interchange between them. This system would be based on a single set of three start stations. For security reasons, each station would be equipped with a lock. Traditional key locks could be used, or more modern combination locks are already available. We recommend the use of combination locks, since this way, when the administrator takes out the capsule, he or she only has to enter a simple numerical code and the door will automatically lock again when closed. In the traditional key case, the administrator may forget to lock the station door. As a next step, we have placed the stations needed for the deployment of the pneumatic tube mail system on a map of the corridor network of the institution, which can be seen in Figure 12.

The optimal location of the institutional postal centre is already marked on this map. In any case, more stations would be built at the postal centre in order to be able to serve the other stations without delay. For the different centres, the stations have been located according to the priority of the centres along the corridor. Two stations were placed on the first floor of building A4 because it handles a significantly higher volume of traffic than the other corridor sections. This is due to the fact that the Rector's Office, the Dean's Office of the Faculty of Economics, the Dean's Office of the Faculty of Earth Sciences and other centres are located here. In the case of buildings C1 and B1, I have placed the stations at the junction of these two buildings, as there is less traffic when projected onto the centres located along the corridor.

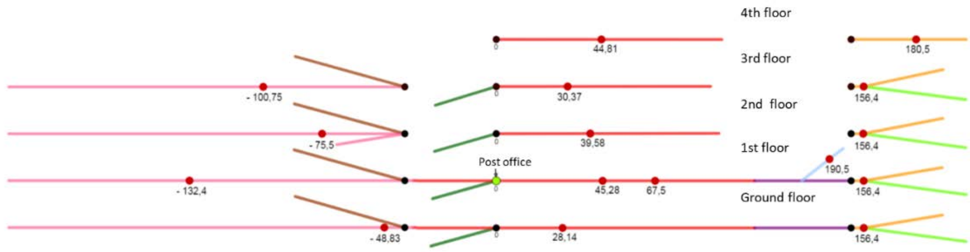

Figure 12. Positions of loading and unloading stations of pneumatic tube mail system

The next step was to find the suitable capsules for the system. There are three types to choose from: sliding top, leak-proof and swing top. In this case, the option of using leak-proof capsules was immediately discarded, as in our case only paper mail is to be transported. Of the two remaining types of capsules, we preferred the sliding top design, which is a relatively more cost-effective type than the other, specially designed swing top capsule. The size of the capsules would be NW 160. Furthermore, only capsules with a combination lock would be purchased. This would ensure that only the person to whom the mail delivery actually belongs would have access to it. The code would be sent to the administrators by e-mail as soon as the capsule is dispatched. They would also be notified before the capsules are dispatched that a consignment has been sent to them. In the case that they are not able to confirm within a few minutes that they are ready to receive the capsules, they would attempt to deliver the consignments at a later date. In addition, RFID technology could be used to track capsules in the system and provide feedback if a capsule has not been received by the administrator. The capsules are available in different colours (Figure 13).

Figure 13. Capsules and carriers for pneumatic tube systems (Source: https://conceptionsmg.com/en/produits/carriers/)

On the one hand, the colours would make it possible to distinguish between letters on the basis of priority. Another way of thinking is that centres located in the same corridor would have a separate colour code. This would avoid the capsules being mixed up by administrators and the wrong capsule being taken over. Of course, even if the wrong capsule were taken by mistake, they would not be able to open it, as they would not have the number code.

Overall, if a pneumatic tube mail system were to be developed at the institution, a much more efficient delivery process could be achieved. Although initially relatively expensive, cost savings can be achieved in long-term. Furthermore, one of its most important advantages is that it allows for fast delivery and frees up labour.

5. APPLICATION OF SMART TECHNOLOGIES IN INSTITUTIONAL POSTAL SERVICES

In the current system, the potential of modern administration is not being exploited. Although progress has been made, a unified electronic document management system is used. Administration could be further modernized by introducing digital signature pads. Signature pads allow signatures to be captured electronically thanks to an LCD display and a pen-style input device. They are equipped with LCD displays of different sizes depending on the model or type. Some signature pads can also display the documents or contracts to be signed. Once digital signatures have been captured, they can be adapted to software and security programs [23]. Types of signatures: electronic signature, biometric signature, qualified electronic signature and advanced electronic signature [24].

The biometric signature pad would be available in the postal centre and in all centres to record the receipt or delivery. Based on our analysis, 55 signature pads would be needed, including the postal centre and the 54 centres examined. We then started to research which signature pad would be optimal for this purpose. We chose an entry-level model, the Evolis Sig100 Lite 4" signing pad, with a purchase cost of about 200 USD per unit. The total purchase cost for the 55 centres is 11000 USD. In addition, there is the purchase of software and the installation of an appropriate IT support system.

We have come to the conclusion that it would be appropriate to extend the use of signature pads. A biometric signature pad could be installed in every office, as it would not only facilitate the administrative process related to postal administration but also make it more efficient. It could also be used for the authentication of documents and contracts in general, as it allows a much more secure authentication compared to traditional signatures. In order to increase the level of security, the Public Key Infrastructure (PKI) technology, based on the principle of public key encryption and infrastructure, could be used for authenticating users and devices in the digital environment (see Figure 14).

In the long term, many results can be achieved through their use. We would highlight in particular the cost savings and the environmental aspects. Thanks to the introduction of signature pads, we can create a more environmentally friendly system. Documents do not need to be printed in order to record a signature, because we can do this easily with these devices, and they will also be authentic. Its introduction will therefore reduce the use of printing paper. In addition, it is a cost-effective solution, as there will be less consumption of printing paper. Another important argument is that it reduces the amount of ink and toner cartridges that have to be purchased. In summary, the application of signature pads would allow a more efficient and smoother workflow, reducing the amount of time spent on administration. In addition, the long-term implications of the above-mentioned cost reduction and the environmental considerations should not be neglected.

6. Application of drone-based technologies to improve flexibility of institutional postal services

Within the frame of this chapter, we will first discuss the feasibility of the delivery process. In this case, the delivery would not be carried out by an employee of the institutional post office or by an office assistant or administrator, but by a drone. It should be pointed out that delivery drones are generally suitable for delivering items weighting less than 2.5 kilograms. The vast majority of mail and small packages do not exceed this weight, so the UAV-based delivery is a potential way to automatize the delivery process.

Of course, there are some small packages and parcels that weigh more than 2.5 kilograms, but this is not the norm, and delivery of these items would still be the responsibility of employees and administrators. As the delivery would take place within the walls of the buildings of the institutions, no special permits would be needed to fly the drones, as they would not require the use of external airspace. Furthermore, security issues may arise under this solution, whereby drones would deliver within the building. Is it dangerous to use drones in close proximity to people? The answer is no, if they are equipped with appropriate software and sensors. The software would allow the drones to fly in swarms, and they would also be able to 'communicate' with each other, avoiding the possibility of crashing into each other. On the other hand, thanks to the advanced sensors, the drones would also avoid the possibility of colliding with people, and the high ceiling height would allow them to fly relatively far away from people. In addition to this, drones would be checked before take-off, if any malfunctions were detected they would not take off, or if a malfunction was detected during delivery they would immediately attempt to land in a safe area.

As we mentioned, the delivery process would take place within the walls of the buildings, therefore, GPS positioning would be quite complicated. With this information in mind, our research was focused on finding an ideal solution that would allow drones to navigate inside buildings. Solving this problem led us to the possible application of so-called BLE iBeacon devices or gateways. So, the system can be based on either BLE iBeacon beacons, which are radio signal transceivers that can also transmit Bluetooth signals or beacon gateways. Overall, by using this technology, it is possible to enable drones to be positioned indoors and to perform delivery tasks. An additional advantage of using BLE Beacons is that they use a small amount of energy to operate, so they can last up to five years using a single battery [25].

In order to set up our system, we need to create security zones where the loading and unloading operations of drones can be performed, and we should also provide the possibility for administrators and office staff in each area to place mail on UAVs, so that they can post outgoing mail as well as internal mail. In addition, a system should be set up that would immediately notify the administrator or the office assistant of the area when a drone is going to deliver a shipment to them, and the drone would only start delivering if it receives a confirmation that it is expected.

The Central Management Group is required to periodically review the documents and records in the archives and to sort them according to their expiry date. These processes could be automatized by drones. One potential way is to automatize this review process is the application of a special tool developed by the company EyeSee. EyeSee drones are easy to control using a tablet, and they are equipped with advanced software that can also be used to fly in a swarm [26]. Figure 14 shows the structure of the integrated BLE Beacon gateway-supported drone based mail delivery system, where we can use for the communication between server and gateways MQTT, which is an OASIS standard messaging protocol for Internet of Things solutions.

To design the system, each document need a special unique identifier, that the drone can read. The documents should be stored in an orderly way because the drone does not fly into the rack structures. On the other hand, the design of the system would require a map of the repository to be drawn up and used by the UAV as a guide. Once the drone has scanned the documents, it would compare them with the database, so that it could identify exactly which aisles and shelves contain documents whose retention period has expired and could be sorted out.

All in all, the use of drones would have many advantages, including energy efficiency from both operation and maintenance point of view [27]. In particular, it would free up human resources, which could be redeployed to other tasks. Another important argument in favor is that in the long term, cost savings can be made by using them and, most importantly, that the use of this technology will allow us to work much more efficiently.

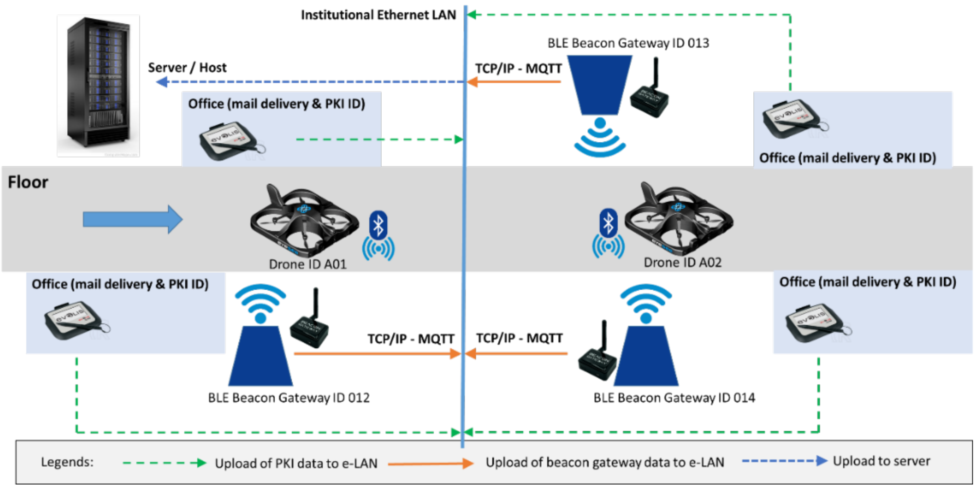

Figure 14. Integration of Industry 4.0 technologies to improve conventional mail delivery service: EyeSee inventory and mail delivery drone solution with Beacon gateway navigation and biometric signature pad using public key encryption and infrastructure

7. CONCLUSIONS

Today, the improvement of efficiency become more and more important both in the fields of services and production. The logistics aspects of service activities become more and more important as they have a major impact on cost efficiency, but also have a significant impact on logistics performance and environmental aspects. Postal services represent a specific area of services that are subject to strict regulatory constraints. We have chosen to focus our research work on the efficiency improvement of postal services in the area of institutional postal services. With this in mind, we are focusing on the logistics analysis and development of postal services in a higher education institute. To this end, we carried out an in-depth study of the institutional postal service system and identified the gaps and improvement opportunities in the system. We have proposed four major areas for improvement. Firstly, we defined the optimal location of the institutional post office using a new facility location algorithm. We analysed the floor system of the institution, which helped us in the modelling of the whole service process from logistics point of view. We created a mathematical model and an optimization algorithm, which makes it possible to define various groups of locations and compute the optimized routes for the offices of these sets of locations. This model was created in such a way that it can be used for priority-based discrimination and for cost-based analysis of different solution cases. Our next development proposal is focused on the application of state-of-the-art technologies. Firstly, we proposed the application of a pneumatic tube mail systems, and on the corridor network system we defined the optimal locations for tube stations depending on the priority of each office.

We then investigated the possibility of using drones for the delivery of mails. Other improvement potentials can be found in the application of biometric signature pads. The introduction of these signature pads would allow for a more secure, faster and more efficient administration. The use of this technology would further enhance the security of the system. Overall, it is not insignificant that the introduction of signature pads would lead to a certain reduction in the use of paper.

Although these ideas would initially be more expensive to implement, in the long-term operation they could lead to cost reduction. Some development proposals have the additional advantage of freeing up resources and saving time.

The added value of the paper is the description of the planning methods of an institutional postal service system focusing on facility location planning and application of new Industry 4.0 technologies. The results can be generalized because the model can be applied for different in-bound collection and distribution systems. The described method makes it possible to support also managerial decisions. Potential research direction is the improvement of the facility location with clustering methods [28]. Other research direction is the analysis of potential required maintenance processes and related costs [29].

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