



Impact of Takt-Time Planning on Plastering Work Productivity: A Case Study

Mária Kozlovská¹, Daria Kempecova^{1*}

¹Technical university of Kosice, Slovakia

Faculty of Civil Engineering, Department of Technology, Economics and Management in Civil Engineering

*e-mail: daria.kempecova@tuke.sk

Abstract

This article aims to analyze productivity issues during the implementation of plastering works on the case study of a residential complex. The results of the study revealed that establishing a proper work schedule and adhering to the Takt schedule resulted in a 19% increase in plastering productivity compared to non-Takt schedules. Furthermore, the study identified the existence of waste, which had a negative impact on the progress of the plastering work and could have been prevented through better project planning during the initial project phases.

Keywords: takt-time planning, productivity, project management, construction, plastering works.

1 Introduction

Productivity in construction is an important factor that can greatly impact the success of a project. It refers to the amount of output or work completed in a given time period and can be influenced by various factors such as the quality of materials and equipment used, the efficiency of workers, the effectiveness of management and planning, and the overall project design [1]. Improving productivity in construction can lead to cost savings, increased profitability, and timely project completion. However, it can be a complex challenge, requiring careful analysis and implementation of various strategies and tools to optimize processes and resources [2]. Construction productivity specifically pertains to the measure of output or work completed per unit of labor, materials, and resources employed in construction projects. It evaluates the efficiency and effectiveness of the construction process and is essential for project managers and stakeholders to ensure timely project delivery and cost-effectiveness. Labor productivity refers to the measure of output or work accomplished per unit of labor input. It assesses the efficiency and effectiveness of workers in each timeframe. Labor productivity is a crucial metric for evaluating the performance of a workforce and identifying opportunities for improvement in various industries, including construction [3].

Construction projects are often complex, involving multiple tasks and resources that must be carefully coordinated to ensure successful completion. Lean construction can be very helpful in improving construction processes and reducing waste. Lean construction is a methodology that

aims to eliminate waste and improve efficiency in construction projects by focusing on continuous improvement, value creation, and collaboration among all stakeholders [4], [5], [6]. One lean tool that can help with improving productivity is Takt time planning, a method that originated in manufacturing but has been adapted for use in construction [7], [8], [9].

Takt time planning is a method of scheduling work that is based on the time available for production and the rate at which work must be completed. In manufacturing, takt time refers to the rate at which a product must be produced in order to meet customer demand. In construction, takt time planning involves breaking down the construction schedule into smaller tasks and then scheduling those tasks based on the available time and resources [10], [11]. A construction schedule is a detailed and time-bound plan that outlines the sequence of activities, tasks, and milestones required to complete a construction project. It includes start and finish dates for each activity and helps project managers and stakeholders monitor progress, allocate resources, and manage the overall timeline of the construction project. The construction schedule is a vital tool for ensuring that the project is completed on time and within the allocated budget [3].

To begin the Takt time planning process, the construction team must first establish the overall project timeline and identify the key milestones that must be met along the way, this can be usually done by the last planner. The team must also determine the total number of working hours available for the project, as well as any other constraints, such as limited access to the site or the availability of materials and equipment. Once these parameters have been established, the team can begin to divide the project into smaller tasks that can be completed within the available time. The next step would be to divide the workstations into work areas that have similar work volumes. The takt time planning process also involves identifying the resources that will be needed to complete each task, such as labor, materials, and equipment. The team must ensure that these resources are available when needed and that they are used efficiently to minimize waste and maximize productivity. One key benefit of takt time planning is that it can help to identify potential bottlenecks and other issues that could delay the project. For example, if a particular task is scheduled to take longer than the available time, the team may need to allocate additional resources or adjust the schedule to ensure that the project stays on track. Another benefit of takt time planning is that it can help to improve communication and collaboration among the construction team. By breaking the project down into smaller tasks and establishing clear timelines and resource requirements for each task, the team can work together more effectively to ensure that the project is completed on time and within budget [10], [12], [13].

Signs of effective work practices often include [14]:

- Fluidity of work: This refers to the smooth flow of work, where work crews are able to move from one work area to another without unnecessary breaks. It also includes the efficient utilization of production resources, such as materials, machines, workers, and finances, without delays or bottlenecks.
- Uniformity of work: Uniformity of work refers to the consistent and planned level of productivity maintained by workers within designated workspaces over a specific period of time. It encompasses not only the equal distribution of working hours but also the deliberate effort to ensure that each worker performs their tasks with a standardized level of productivity. By adhering to this principle, work crews aim to achieve a sense of regularity and stability in their output, thereby minimizing disruptions or variations in the work process.

- Rhythmicity of work: This refers to the repetition of work in certain or consistent rhythms. This can include having a set pace or rhythm for completing tasks, which can help maintain productivity and avoid unnecessary delays.

The main goal of this article is to analyze the productivity issues during the implementation of plastering works on the case study of residential complex Popradská. The purpose of this study can be categorized into two main objectives: i) to map the process of performing plastering works by manually monitoring workers at least once a week; ii) to design an improved work schedule by utilizing Takt time planning to enhance workers productivity.

The result of the mapping will be a time-space display of the duration of the work and the location of the workers. After the mapping, the takt time will be determined and an analysis of the real productivity that workers could achieve will be made.

2 Methods

This article aims to analyze productivity issues during the implementation of plastering works on the case study of residential complex Popradská. Building SO 104 - Apartment building "B" is designed as a separate rectangular building with overall dimensions of 81.58 x 20.71 m. It consists of three sections (Figure 1), which are connected on 2 underground floors within a shared garage, which is also connected on the 2nd floor by a tunnel to parking facility G (building site SO 106 G). The building is designed as a 3-section, detached 9-storey building (2 underground and 7 above-ground floors) [15].



Figure 1: Case study residential complex Popradská: apartment building "B", divided into three sections with marked work zones: (a) 2.th Floor plan, (b) section C-C [15]

In order to fulfill the goal of the study, three main research steps were established:

1. Initial analysis and evaluation of existing literature.

In order to prepare a relevant and up-to-date article on the impact of Takt-time planning on plastering performance, an initial analysis and evaluation of existing literature and practice was carried out. Two sources, namely the Web of Science and SCOPUS databases, were utilized to obtain up-to-date information. The search engine was utilized with keyword combinations such as "Construction productivity" and "Takt-time planning" as well as "Construction schedule" and "Takt-time planning." This made it possible to create a theoretical basis for the study.

2. On-site data collection through manual observation, photo documentation and interviews with workers.

The next step after the initial literature review is to create a methodology for gathering and examining data from a case study. The case study residential complex Popradská is located in Kosice, Slovakia. Plastering work was chosen as the main process for the data gathering as it is an important part of interior construction. Three teams that perform plastering work were selected for productivity measurement. Each team consisted of three workers with the same work skills. At this stage, the progress of the plastering work will be mapped by manually monitoring the performance of workers using Excel forms on mobile on a weekly basis. The data used in this article were collected over a period of five months. The mapping will result in a spatio-temporal display of work duration and workers' location.

3. Design an improved work schedule using Takt-time to improve productivity.

At this stage, an analysis of the actual performance will be carried out to determine the required takt time. A takt work schedule will be prepared based on actual performance with better use of spatio-temporal management principles. One working zone is equal to one floor in one section. Underground floors were not taken into account, since work was not executed there, therefore the total number of working areas is 21. In Figure 1, it can be seen that section number 2 is smaller in area than sections number 1 and 3, which are equal. The difference in the areas of the working zones should be taken into account when determining the duration of the takt.

3 Results and Discussion

Mobile forms of monitoring were used to document the execution of plastering work. The forms were prepared in Excel and placed on Google Drive in order to enable editing this file through phone and computer without having to download it. The used form consisted of date, work zone, section number, number of the apartment, completion indicator for each construction for the plastering (ceiling and walls), number of work team, and the number of workers in subsequent team. For the ease of documenting each work zone in the form was named according to its floor and section, for example 1.1 work zone represents (1.NP, section B1). The evaluation of the level of completion of the construction was made in percentage and based on the subjective opinion of the author during the visual screening. The example of the used spreadsheet is presented in Figure 2.

Plastering work monitoring form					Date:	
Work zone	Section	Apartment	Completion indicator for ceiling	Completion indicator for walls	Work team	Number of workers
2.1	B1	201	100%	100%	1	3
2.1	B1	202	100%	50%	1	3

Figure 2: Example of output from monitored data of plastering works

Since it was important to reflect the true production process, the work status had to be documented at least once a week, with a re-creation of the movement of workers through personal interviews with workers. The results of mapping the direction of the work of individual work teams are depicted in Figure 3.

From picture 3, it can be observed that the work process is disorganized, irregular, and unnecessary breaks occur. Teams work at different speeds without smoothness, uniformity, and rhythm, which are three fundamental characteristics of an effective construction process. Additionally, it is evident that the direction of process organization was not controlled since the teams initially worked in a horizontal-ascending direction, but subsequently, the direction of plastering started to show a chaotic nature. Such inconsistent organization can have a negative impact on the efficiency and flow of the work process.



Figure 3: The results of mapping the direction of the plastering work of individual work teams on a typical plan of the 3rd floor and in section (— - team № 1, — - team № 2, — - team № 3)

The data collected is a detailed record of the progress of work over a period of five months, with daily updates. However, to make it easier to visualize and analyze the data, it was decided to group the daily progress updates into working weeks instead and create a simplified form of a table that shows the progress made during each week. This type of data aggregation can be helpful for identifying patterns and trends in the progress of work overtime and can make it easier to spot areas where progress is lagging or where adjustments may need to be made. The results of the data collection are depicted in Figure 4.

The completion indicator column is used to track the progress of construction, where each floor is divided into sections that need to be completed. The green color indicates that the section has been fully completed (100%), the red color indicates that the section has not been started yet (0%), and the yellow color indicates that the section has been started but is not yet complete,

with an approximate percentage of completion being assigned. This system allows for a quick visual representation of the progress being made on the project.

As it was mentioned before, three teams that perform plastering work were selected for productivity measurement and each team consisted of three workers. However, the number of workers is not a constant value and could change, so this value should also be monitored. Teams are depicted in different colors in Figure 4 with the number of workers in each team is shown. This type of visual representation can be helpful for quickly identifying which teams are working on the project, how many workers are in each team, and potentially how the workload is being distributed among the teams.

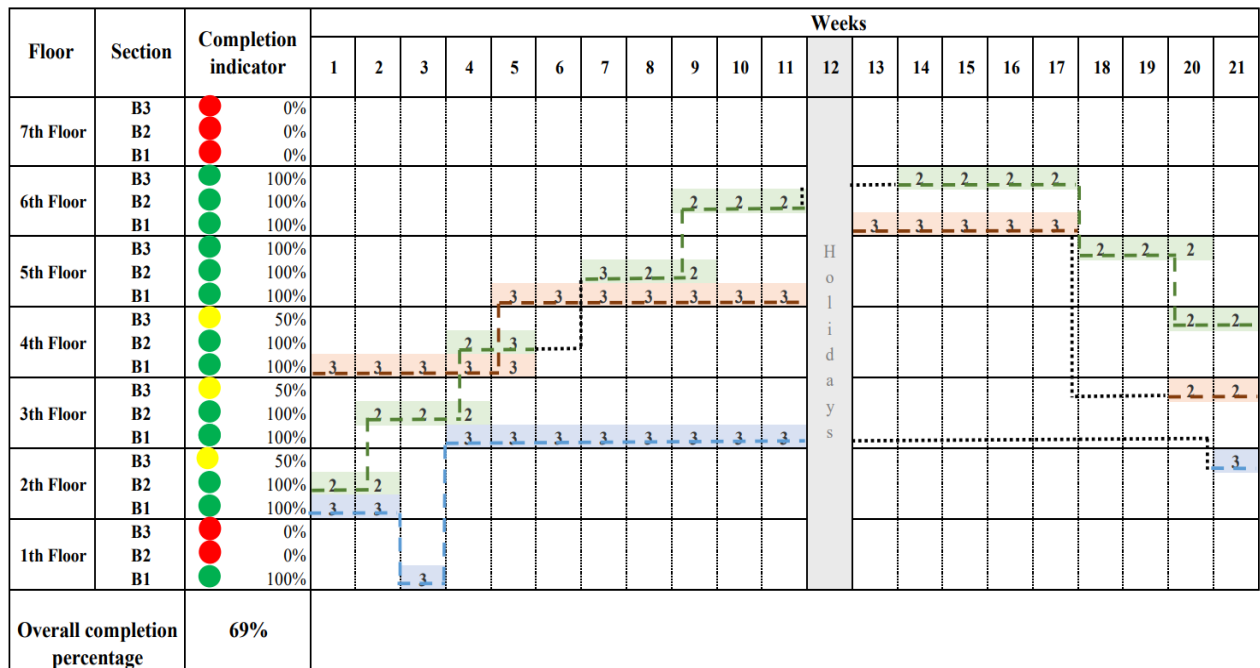


Figure 4: Spatio-temporal representation of the execution of plastering works by 3 work groups

(- color display of work teams, with the number of the workers in each team;
 - spatio-temporal movements of each team; - unproductive time;
 - work has not started; - work in progress; - work completed).

In addition, the overall plastering work completion percentage was calculated as the average of each section's completion rate (1).

According to Figure 4, the overall completion percentage is 69%.

$$y = \frac{\sum_{i=1}^n x_i}{n} \quad (1)$$

y - overall completion percentage; x - completion indicator; n – total number of work zones.

From Figure 4, it can be seen that workflow is chaotic, not smooth, there are unnecessary breaks, teams work at different speeds without consistency. During data collection, several cases of inefficient use of production resources such as materials, machines, workers were noted, which led to delays. For example, the lack of adequate water supply and electricity has been identified as critical issues that could be mitigated by improved project planning during the construction organization phase.

Takt time planning principles were used to optimize the plastering workflow. At first, the direction of the progress of work was designed. The implementation of an organized work process successfully addressed deficiencies in work organization (Figure 5), which were previously evident through the chaotic progression of individual teams within the workspace (Figure 3). By having each team follow a unified horizontal-ascending direction, they were able to transition seamlessly between floors. This streamlined approach optimizes workflow, ensuring tasks are carried out sequentially and efficiently, thereby increasing productivity and minimizing redundancy. The consistent direction assigned to each floor facilitates easy orientation for individual trades in the work environment, promoting standardized production procedures. This clear guidance fosters improved coordination, cooperation, and performance among the various trades, enhancing overall project efficiency.

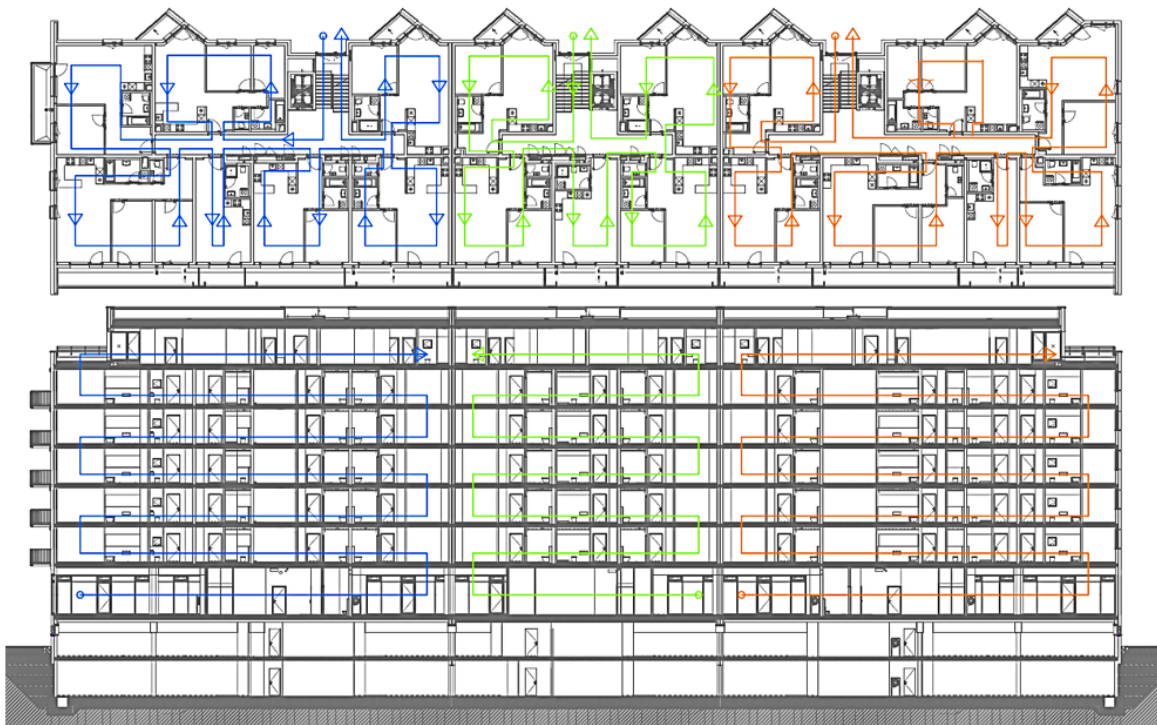


Figure 5: The designed direction of the progress of work on the example of a typical plan of the 3rd floor and in section (— - team № 1, — - team № 2, — - team № 3)

In the next step the length of the takt time was defined based on analysis of the spatio-temporal representation of the execution of plastering works, where the duration of the work at work zone weren't set. The real work rate was defined. It should be noted that the work rate was found not to measure how much square meters were done within 1 hour, but to determine how many days it takes to complete the work in one working zone. The green team (number 2) was chosen as a sample for the work rate calculation because it demonstrated the most effective execution of work with no significant waste occurrences. Selecting a sample group, such as the green team, that represents a high level of efficiency and effectiveness in executing work can be useful for determining work rates or productivity benchmarks. According to the results the average duration of work for the 2 workers in section B2 is three weeks, whereas in section B3 is four weeks. Therefore, the production takt time was set at four weeks for each section, but with different number of workers. Sections B1 and B3 were assigned three workers, while section

B2 required two workers due to its smaller square footage. It is assumed that the workers are not working at 100% capacity in order to provide time buffers necessary to eliminate possible wastes. The designed takt schedule of the execution of plastering works is presented in Figure 6.

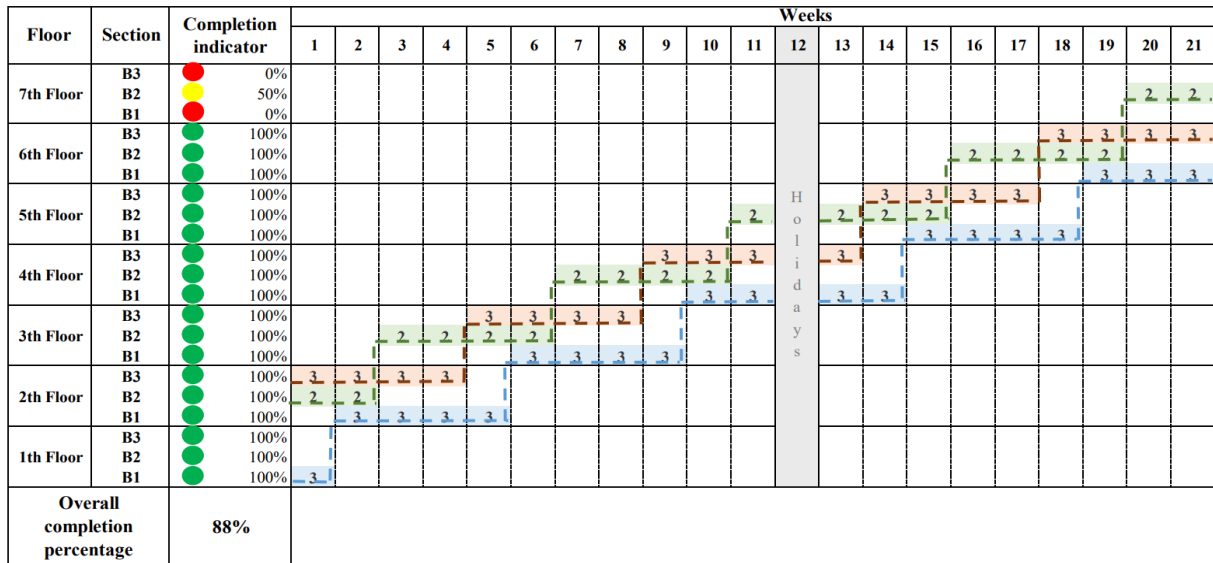


Figure 6: Designed takt schedule of the execution of plastering works by 3 work groups with 4 weeks takt (- color display of work teams, with the number of the workers in each team; - spatio-temporal movements of each team; - work has not started; - work in progress; - work completed).

As shown in Figure 6, the overall completion rate after implementing takt time principles is 88%, indicating a 19% increase in productivity. Designed schedule is fluid, it means that there are no unnecessary interruptions or delays in the work process, and resources are being used efficiently. It is uniform, it means that there is consistency in the work process, which helps prevent disruptions or inconsistencies. And work is rhythmic, it means that there is a set pace or rhythm for completing tasks, which helps maintain productivity and avoid unnecessary delays. All of these factors contribute to a more efficient and effective work environment. In addition, the workflow is smooth, paced, standardized, there is no unproductive time, therefore it can be considered efficient.

4 Conclusion

The article's findings are based on plastering work performed on the Popradská residential complex construction project, which was the subject of the case study.

According to the study findings, it was observed that a correctly established work schedule and adherence to the Takt schedule led to an increase in plastering workers productivity in 19% compared to non-Takt schedules. Additionally, the study identified the presence of waste, which adversely impacted the progress of the plastering work. Specifically, the lack of adequate water supply and electricity were identified as critical issues that could have been mitigated through improved project planning during the construction organization phase.

In conclusion, takt time planning is a valuable tool for construction project planning and scheduling. By breaking the project down into smaller tasks and establishing clear timelines and resource requirements for each task, the construction teams can work together more efficiently and effectively to ensure successful project completion. While takt time planning may require some additional effort upfront, the benefits in terms of improved productivity, reduced waste, and greater project success make it well worth the investment.

Acknowledgments

The activity presented in the article is part of the VEGA research grant No. 1/0336/22 “Research on the effects of Lean Production/Lean Construction methods on increasing the efficiency of on-site and off-site construction technologies”.

References

- [1] Hossain A., Bissenova A. & Kim J. R. (2019). Investigation of Wasteful Activities Using Lean Methodology: In Perspective of Kazakhstan’s Construction Industry. *Buildings* 9(5), 113. DOI: 10.3390/buildings9050113.
- [2] Rajkumar K. B. & Biswas A. P. (2016). Identification of Non-Value Adding Activities using Lean Technology in Construction. *Int. J. of Engineering Research & Technology (IJERT)* 5(3), pp. 640-643. Retrieved date of access 11.04.2023 from <https://www.ijert.org/>.
- [3] Chamulová B. (2013). Dynamický časový plán v procese riadenia výstavby. 1. vyd. Brno: Tribun EU, 97.
- [4] Issa Us. H. & Alqurashi M. (2020). A Model for Evaluating Causes of Wastes and Lean Implementation in Construction Projects, *Jour. of Civ. Eng. and Man.* 26 (4), 331.
- [5] Mughees, A., Zhili, G. & Gary, S. (2020). Framework for selection of lean construction tools based on lean objectives and functionalities. *International Journal of Construction Management*, DOI:10.1080/15623599.2020.1729933.
- [6] Zhanga, L. & Chenb, X. (2016). Role of lean tools in supporting knowledge creation and performance in lean construction. International Conference on Sustainable Design, Engineering and Construction. *Procedia Engineering*, 145, pp. 1267 – 1274. DOI: 10.1016/j.proeng.2016.04.163.
- [7] Brioso X., Murguia D. & Urbina A. (2017). Teaching Takt-Time, Flowline, and Point-to-Point Precedence Relations: A Peruvian Case Study. In Creative Construction Conference, 19-22 June 2017, Primosten, Croatia.
- [8] Yassine T., Bacha M. B. Sa, Fayek F. & Hamzeh F. (2014). Implementing Takt-Time Planning in Construction to Improve Workflow. In IGLC-22 Production Planning and Control 22, June (pp. 787–798). Oslo.
- [9] Fabian A., & Adel F. (2020). Spatiotemporal Planning of Construction Projects: A Literature Review and Assessment of the State of the Art. *Front. Built Environ.* 6. DOI: 10.3389/fbuil.2020.00128.
- [10] Keskiniva K., Saari A. & Junnonen J.-M. (2021). Takt Production Monitoring and Control in Apartment Renovation Projects. *Buildings*, 11, 92. DOI: 10.3390/buildings11030092.
- [11] Keskiniva K., Saari A. & Junnonen J.-M. (2020). Takt Planning in Apartment Building Renovation Projects. *Buildings*, 10, 226; DOI:10.3390/buildings10120226.

- [12] Frandson A., Berghede K. & Tommelein I. (2013). Takt Time Planning for Construction of Exterior Cladding. In 21st annual conference of the International Group for Lean Construction, 31-2 Aug (pp. 527–536). Fortaleza, Brazil.
- [13] Brioso X., Murguia D. & Urbina A. (2017). Comparing three scheduling methods using BIM models in the Last Planner System. *Organization, Technology and Management in Construction: An International Journal*, 9(1) 1604-1614. DOI: 10.1515/otmcj-2016-0024.
- [14] Gašparík, J., Motyčka, V., Šťastný, P., & Szalayová, S. (2021). Multi-Criteria Optimization of Mechanized Earth Processes and Its Impact on Economic and Environmental Sustainability. *Sustainability*, 14(1), 78. DOI: 10.3390/su14010078.
- [15] Gonos R. & Kušnírik M. (2021). Polyfunkčný súbor “Popradská“ I.etapa. Realizačný projekt, 1-22.