IMPACT OF HUMAN RESOURCE DEPLOYMENT ON ELECTRICITY CONSUMPTION AT TEMPORARY SITE FACILITIES

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Abstract

This research paper focuses on a systematic analysis of the impact of human resources and temporary facilities on electricity consumption at construction sites. The study was carried out through the installation of metering equipment at three construction sites, with each site operation being separately metered. The primary focus was on the energy consumption of the construction offices for site personnel. The results show the relationships between human resources, containers and the overall energy performance of site operations. The paper presents data that identifies areas where measures can be implemented to increase energy use efficiency while optimising working conditions for construction personnel. The results of this study will contribute to a better understanding of the factors influencing energy consumption on construction sites and provide a basis for designing sustainable measures.

Keywords

Human resources, site operations, site equipment, electricity consumption

1 INTRODUCTION

The construction and management of construction sites in the current era requires a deep understanding of the interactions between human resources and temporary facilities, and these aspects fundamentally affect the overall efficiency and sustainability of construction projects. In this context, we focus on the study of the impact of human resource deployment on the electrical power consumption of temporary equipment on a construction site, with emphasis on various factors such as productivity and resource utilisation.

The research incorporates the latest findings from the literature and highlights the key role of project managers and their ability to effectively manage human and material resources. The literature on this topic identifies that the proper deployment of project managers is critical to achieving optimal production and avoiding potential time overruns [1]. However, this cannot be adequately set up and energy efficiency optimisation processes cannot be developed without a closer understanding of the impact of the above factors on electricity consumption.

At the same time, the complex nature of the deployment of temporary facilities on construction sites emerges, which has been analysed in more detail in the work of Elbeltagi and Hegazy. Their research highlights that the correct deployment of these facilities is a crucial yet complex process that has a significant impact on the safety, efficiency and overall productivity of construction activities [2].

On top of this, effective site layout planning becomes a critical factor as the lack of any application of constraints can lead to inefficient travel routes and excessive costs arising from the installation and relocation of temporary equipment [3]. These shortcomings can have a negative impact on the optimisation of site layouts, which forces us to consider strategies and measures to improve them. The main energy source for temporary facilities is electricity, and the redundant measures that go into, for example, container relocation, negatively affect the efficiency of the site electrical grid.

Overall, it can be argued that the impact of human resource deployment on the electricity consumption of temporary site facilities is a multi-dimensional issue, involving productivity, safety, resource utilisation and overall project efficiency. In this context, the strategic deployment of human resources, i.e. site personnel, is a key factor for proper resource management and achieving higher levels of productivity with minimised risk of time overruns.

The size, layout and purpose of construction offices are designed for use on construction sites depending on the size, location and scope of the site, the number of contractors and their workers, as well as the progress of work on site [4]. Subsequently, the connection of the electrical power supply is also designed, for which information on the maximum rated power of the large electrical appliances used is required [5]. In this way, adequate working conditions are created for the site operations personnel.

DOI 10.13164/juniorstav.2024.24142

It is this analysis in particular that focuses on the electricity aspect, with a specific focus on identifying the impact of temporary facilities and site personnel on electricity consumption. It takes into account the various aspects that affect the energy profile of construction site operations in order to support effective planning and management that will not only result in energy savings but also in the overall optimisation of projects in the construction sector.

2 METHODOLOGY

This research proposed a systematic approach to analysing the impact of human resource deployment on the electricity consumption of temporary equipment on construction sites. The aim is to gain a detailed understanding of the electricity consumption and relationships between personnel and temporary facilities, which will help to understand, optimise and manage the energy aspects of construction projects more effectively.

The use of smart metering devices enables the real-time monitoring of electricity consumption on temporary site facilities. This provides a comprehensive view of energy consumption patterns and helps to identify areas of high consumption and the impacts of staff deployment. The data collected from these devices can be analysed using statistical methods to identify trends, patterns and correlations in electricity consumption.

Statistical methods used in the analysis include descriptive statistics such as the calculation of averages, standard deviations and ranges of electricity consumption. In addition, regression analysis was used to identify factors that influence electricity consumption, such as working hours or the number of workers on site [6].

The combination of analysis and statistical methods provides a comprehensive understanding of the impact of the aforementioned factors on site electricity consumption. This approach enables energy management decisions and the implementation of electricity saving measures to be based on evidence. The research methodology included the following steps:

1. selection of the monitoring system,
2. selection of building sites,
3. installation of measuring equipment,
4. real-time monitoring,
5. data processing and analysis,
6. impact assessment.

Choosing a monitoring system

The monitoring device meets the basic criteria set by the research objective of recording and evaluating electricity consumption at hourly intervals and storing the data on a remote storage device. The same type of metering equipment was used for each site, and all devices were factory calibrated to 99% accuracy. In order to achieve compatibility, the equipment was selected so that installation could be made on a DIN rail in the site switchboards. The selected monitoring system allows remote access and management. This allowed data to be monitored from afar and simplified the management of the entire system.

Selection of building sites

The basic criterion for site selection was for there to be temporary buildings on site, with a minimum of 10 units of container offices for site personnel. The three construction sites studied had a number of parameters in common such as: the main building structure had a reinforced concrete frame, the utility grid was used for power supply, and the main machinery was tower cranes.

The site wiring allowed the consumption of the temporary buildings to be monitored separately. The electrical network was functionally branched and for the temporary buildings, the main metering node was the site switchboard that supplied the offices under investigation. These criteria allowed the similarities between the investigated construction sites to be evaluated, and provided important information for decision making.

Tab. 1 provides a basic overview of the appliances on site, listing the quantity and electrical output of the various tools and equipment used at temporary facilities. They provide information on the electrical equipment on site, helping to provide a comprehensive understanding of the energy requirements to enable effective management.

DOI 10.13164/juniorstav.2024.24142

Tab. 1 Electrical appliances in temporary buildings on construction sites.

	Construction site					
	A 10 temporary buildings 22–24 employees		B 12 temporary buildings 30–32 employees		C 13 temporary buildings 23–25 employees	
Electric tools	**Quantity**	**Active power Entire 230 V**	**Quantity**	**Active power Entire 230 V**	**Quantity**	**Active power Entire 230 V**
Lights	*10*	*1.5 kW*	*12*	*1.5 kW*	*13*	*2.4 kW*
Heaters	*10*	*20.0 kW*	*12*	*24.0 kW*	*13*	*26.0 kW*
Water heating equip.	*1*	*1.0 kW*	*1*	*2.0 kW*	*2*	*3.0 kW*
IT equipment	*5*	*0.5 kW*	*7*	*0.8 kW*	*6*	*0.6 kW*
Air conditioning	*2*	*4.0 kW*	*3*	*7.2 kW*	*0*	*0,0 kW*
Electric kettles	*2*	*4.0 kW*	*4*	*8.0 kW*	*3*	*6.0 kW*
Refrigerators	*1*	*1.0 kW*	*2*	*2.2 kW*	*2*	*3.4 kW*
Microwaves	*3*	*2.5 kW*	*1*	*1.3 kW*	*3*	*3.6 kW*
Sockets	*10*	*10.0 kW*	*12*	*12.0 kW*	*13*	*13.0 kW*
Total		**44.5 kW**		**59.0 kW**		**58.0 kW**

Tab. 1 provides information on the quantity and electrical output of the various tools and equipment used in the temporary structures at the surveyed sites. Each row represents a specific type of appliance, while the columns describe the individual construction sites (A, B, C). The values are given in units of quantity and power kW. The total power for each construction site is given as a summation. The first 8 appliances are basic equipment common for each of the construction sites. However, other appliances were used at some sites that were not present at the others, and their use was sporadic, so the replacement power was determined as the power for one 1.0 kW electrical outlet for each construction container.

The average number of workers on site was influenced by the scale and complexity of the construction work. On the construction sites studied, the average was with a spread of two employees: site 'A' had an average of 22–24 employees, site 'B' had 30–32 employees and site 'C' had 23–25 employees. The standard working hours at the sites were set at 8 hours per day, 5 days per week. However, depending on the specific conditions and schedule of the project, working hours were extended to 10 or more hours per day, up to 6 days per week. The year of manufacture and age of the temporary site structures for "A" was 2008 (15 years), for "B" it was 2016 (7 years), and for "C" 2022 (1 year). The average number of workers on site was important as it leads to variability in energy needs. In addition, information on the production year and age of the temporary buildings provides context regarding their life cycle.

Installation of measuring equipment

Each metering device was installed in a switchboard designed to supply temporary offices and placed on a DIN rail next to the main supply so that the terminal transformers were at a sufficient distance from the individual phases L1, L2, L3. Once the devices were connected, an internet connection was installed to transmit the electricity consumption data obtained. Each site had its own internet network, and this was used to connect the metering equipment to allow the remote monitoring of consumption. The connection of the metering equipment was carried out by a qualified person who had a certificate of competence to carry out work on technical electrical equipment, including lightning protection [7].

Real-time monitoring

Real-time monitoring was a key element of the analysis of the impact of the deployment of human resources. With the selection of a monitoring system that allowed for the evaluation of electricity consumption at hourly intervals and the storage of data on a remote storage device, the capability to monitor the energy parameters of temporary objects in real time was achieved. For the present investigation, a time period was selected in which measurements were carried out at all the investigated sites, namely from 15.6.2023 to 11.10.2023. In this time period of 150 days, the consumption profile was recorded at the three different sites. Through the analysis of the data received, it is possible to determine exactly which months and periods were characterised by increased or decreased electricity consumption at the sites. This information is essential for effective planning and management of a construction site's energy resources throughout its lifetime. In addition, real-time monitoring provided a detailed view of the use of temporary facilities, allowing the identification of specific trends and factors affecting energy efficiency at the sites.

Data processing and analysis

This research proposed a systematic approach to analysing the impact of human resource deployment on the electricity consumption of temporary equipment on construction sites. The aim was to gain a detailed understanding of the electricity consumption and the relationships between personnel and temporary facilities, in order to understand, optimise and manage the energy aspects of construction projects more effectively.

The use of smart metering devices enabled the real-time monitoring of electricity consumption on temporary site facilities, providing a comprehensive view of energy consumption patterns and identifying areas of high consumption and the impact of staff deployment. Data from these facilities was then analysed using statistical methods to identify trends, patterns, and correlations in electricity consumption.

Statistical methods, including descriptive statistics (calculation of means, standard deviations and ranges of electricity consumption) and regression analysis, were effectively used to identify factors affecting electricity consumption, such as working hours and number of workers on site. In this way, it was possible to determine exactly how these factors affect the energy requirements on site.

The combination of analysis and statistical methods provided a comprehensive understanding of the impact of the use of temporary equipment on construction site electricity consumption. The approach enabled evidence-based decision making regarding energy management and the implementation of energy conservation measures. The overall research methodology included the selection of the monitoring system, site selection, the installation of metering equipment, real-time monitoring, analysis and statistical methods, and finally an assessment of the impact of temporary equipment usage on electricity consumption.

Each site was first surveyed separately to establish baseline levels of comparison. The observation period examined 150 days of consumption at temporary site facilities, which was divided into working days and non-working days. The non-working days included days such as Saturday, Sunday and holidays during the working week.

Tab. 2 Overview of consumption in temporary buildings.

			Site A	**Site B**	**Site C**
	Time period		**Average number of employees**		
	Identification	**number of days**	**22–24**	**30–32**	**23–25**
Total consumption kWh	*all days*	*150*	*6,765.38*	*8,627.19*	*8,022.19*
	working days	*102*	*5,284.70*	*6,403.40*	*5,769.47*
	rest days	*48*	*1,480.68*	*2,223.79*	*2,252.72*
Average consumption kWh	*all days*	*150*	*45.10*	*57.51*	*53.48*
	working days	*102*	*51.81*	*62.77*	*56.56*
	rest days	*48*	*30.85*	*46.33*	*46.93*
Highest consumption kWh	*all days*	*150*	*165.33*	*217.16*	*222.66*
	working days	*102*	*165.33*	*217.16*	*222.66*
	rest days	*48*	*126.75*	*198.57*	*193.17*
Lowest consumption kWh	*all days*	*150*	*10.51*	*16.66*	*9.43*
	working days	*102*	*14.98*	*29.42*	*12.54*
	rest days	*48*	*10.51*	*16.66*	*9.43*

Tab. 2 contains information on the energy consumption at three different construction sites (Site A, Site B, Site C) depending on different parameters and time periods. The total consumption kWh shows the energy consumption for each construction site at different time periods. The average consumption kWh gives the average energy consumption per day for each construction site in the given time periods, distinguishing between all days, working days and rest days. The highest consumption kWh and the lowest consumption kWh show the specific daily energy consumption for each construction site in different time periods, with details for all days, working days and rest days. Overall, the table provides an overview of the dynamics of energy consumption on construction sites depending on the different time periods and types of days.

DOI 10.13164/juniorstav.2024.24142

The comparison of the highest and lowest consumption values creates an important indicator that highlights increased energy consumption, especially for the heating of temporary site buildings during cold days. This trend is strongest in the winter months when weather conditions are more challenging and heat is needed in working areas. Conversely, in summer, temperatures are higher and there is a decrease in energy consumption. This effect is further accentuated by the long daylight hours, as the need for artificial lighting in temporary buildings is not required. Autumn represents a transitional period where the effect of lighting conditions on energy consumption is noticeable. With the short daylight hours in the autumn months, site staff are forced to use artificial light for longer periods of time, causing an increase in electricity consumption.

Another data processing method was to plot the averaged electricity consumption histories for each site over the time periods. This will give an insight into the average dynamics of energy consumption at each construction site during the different time periods. The resulting averaged electricity consumption histories allow the specific identification of patterns and trends in energy use for individual construction sites. In this way, working hours, periods of low consumption, and potential needs to optimise energy use at each construction site can be prioritised.

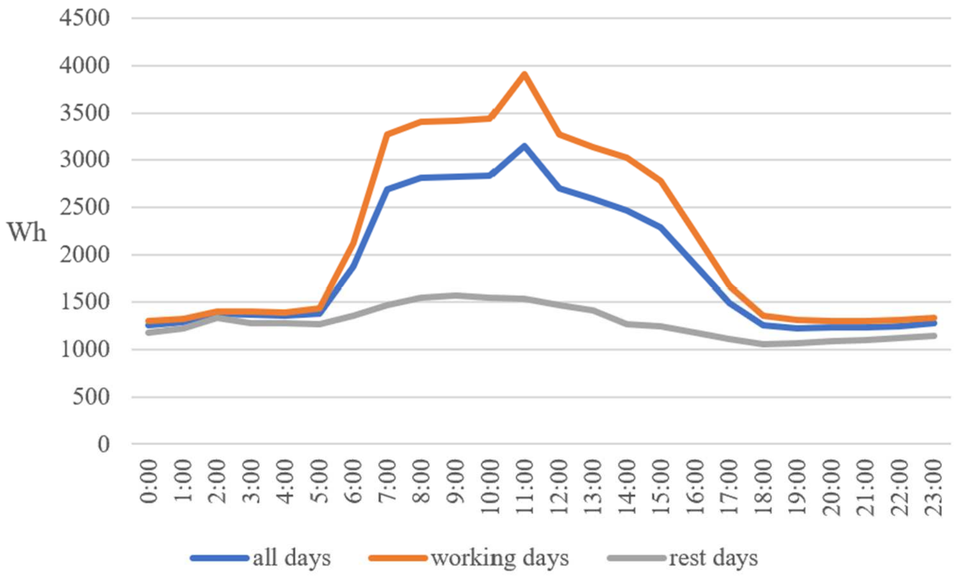

Fig. 1 Consumption history of temporary buildings on site A.

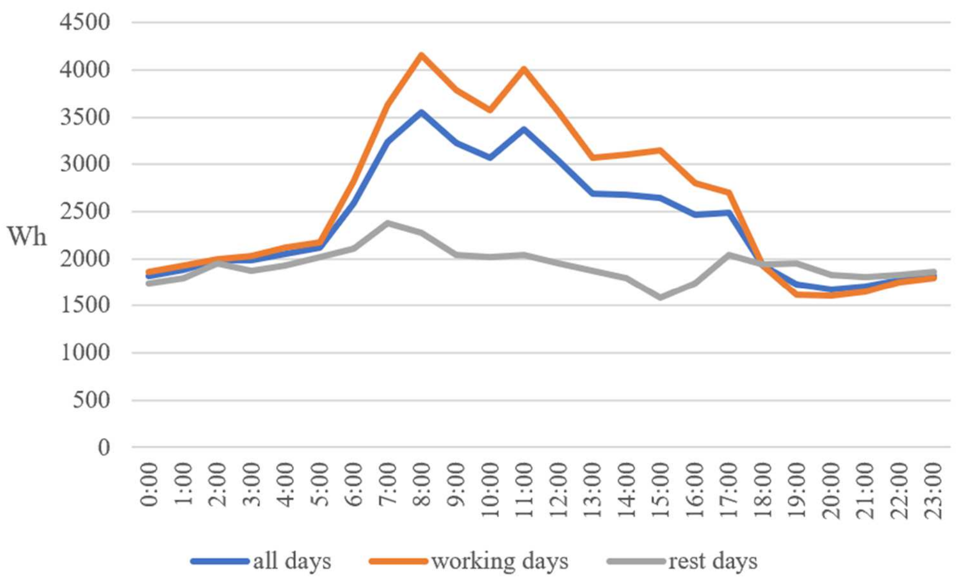

Fig. 2 Consumption history of temporary buildings on site B.

DOI 10.13164/juniorstav.2024.24142

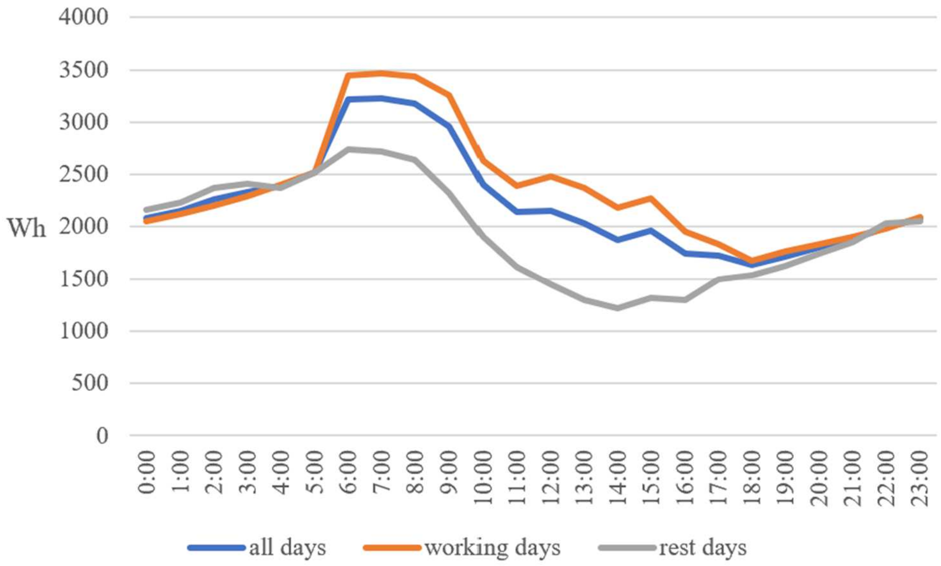

Fig. 3 Consumption history of temporary buildings on site C.

Figs. 1 to 3 describe the average electricity consumption patterns for temporary site buildings 'A', 'B' and 'C', clearly showing the difference in consumption on weekdays and non-working days. The time period with the highest consumption is between 6 am and 6 pm. Peak consumption is identified for site 'A' at 11:00 hours during the working time pool, for site 'B' at 8:00 hours during the working time pool and for site 'C' at 7:00 hours during the working time pool.

The rest of the days (i.e. non-working days) see limited operations and fewer workers. Overall, average consumption is lower compared to weekdays. These characteristics indicate that electricity consumption is closely linked to work activities and the daily cycle, with possible opportunities to optimise energy efficiency at specific time periods.

Regression analysis can be used to analyse the impact of human resource deployment on electricity consumption at temporary workplace facilities in order to understand the relationship between these variables. In the context of electricity consumption, regression analysis was used to predict future electricity consumption.

Tab. 3 Overview of consumption in temporary buildings.

Monthly	**June**	**July**	**August**	**September**	**October**	**November**
Number of days	*16*	*31*	*31*	*30*	*31*	*11*
Site A – consumption kWh	*465.52*	*880.58*	*876.99*	*801.15*	*2,454.53*	*1,286.61*
Site B – consumption kWh	*569.45*	*959.57*	*1,240.01*	*1,122.80*	*2,828.02*	*1,907.34*
Site C – consumption kWh	*446.19*	*768.54*	*771.34*	*886.61*	*3,221.46*	*1,928.05*

Tab. 3 provides consumption data for the individual months at the surveyed construction sites. It should be noted that the consumption values given for the months of June and November are for periods of time which are shorter than the whole month. In particular, it is noteworthy that for the 11 days in November the consumption is the second highest compared to the other months.

DOI 10.13164/juniorstav.2024.24142

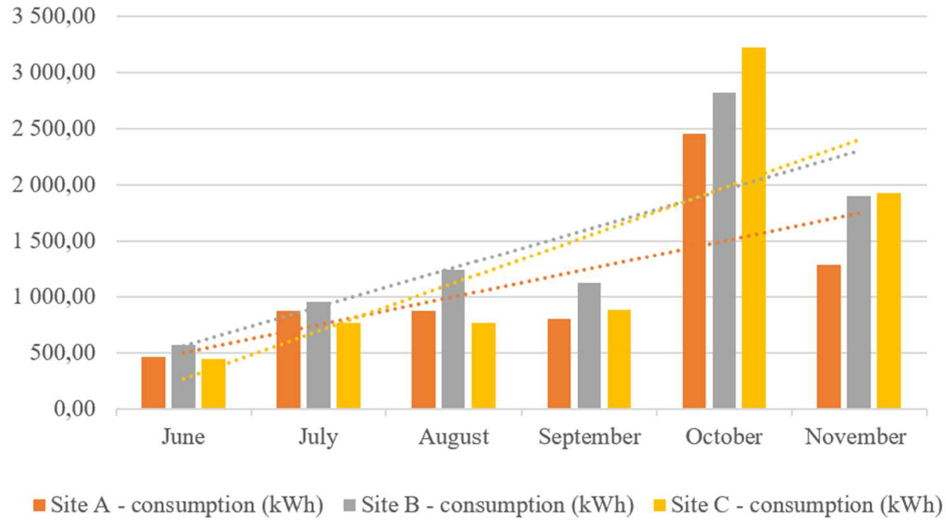

Fig. 4 Overview of consumption by month.

Based on the regression analysis, a function can be created to predict energy consumption for the months in question. The Fig. 4 displays the trend line functions for each site separately. The representation shows that the trend lines are not significantly different and, in all cases, have an increasing tendency. This trend is mainly attributed to the arrival of cold weather. On examination, it can be assumed that consumption will be higher in the winter months of December, January and February, reaching peaks before the weather then warms up, with a downward trend in monthly consumption.

Impact assessment

The first and clearly demonstrated impact of personnel on electricity consumption in temporary buildings is the curve of increased consumption during the working hours at all construction sites. The curve of consumption during working days increased significantly on all graphs, reaching its peaks during the morning between 6:00 am and 12:00 pm. This is mostly due to the preparation phase – the period when site staff get ready for their activities during the day. With the arrival of employees at the site, electrical appliances providing, e.g. light and heating are switched on. The workers also refresh themselves, using mainly kettles to heat water and microwaves to heat food.

Site 'C' also demonstrates the level of work activity on days off. This is due to the setup of the construction schedule, where there is no interruption of the main construction work during these days, so the performance of work at the site is therefore continuous.

Tab. 4 Analysis of the calculation of electricity consumption.

	Site A	**Site B**	**Site C**
Quantity of temporary buildings (pcs)	10	12	13
Average quantity of personnel on site (pcs)	23	31	24
Quantity of personnel per temporary building (pcs)	2.3	2.6	1.8
Calculation of consumption per temporary building per day (kWh)	4.48	4.78	4.03
Calculation of consumption per temporary building per 150 days (kWh)	676.54	718.93	617.09
Calculation of consumption per employee per 150 days (kWh)	294.15	278.30	334.26

Tab. 4 summarises the conversion of consumption into units per temporary facility and per employee. It provides a detailed view of the relationship between the number of temporary buildings, the average number of employees and the energy consumption at the three construction sites (A, B, C). Site 'B' is characterised by the highest average number of personnel (31), while site 'C' has the lowest ratio of personnel per temporary building (1.8). The higher number of temporary buildings on site 'B' may lead to increased total energy consumption. In terms of efficiency in the use of personnel and temporary buildings, Site C achieves the highest total consumption. Analytical parameters, such as the conversion of consumption per building and per employee, are important to increase trends and areas for optimising energy use on construction sites.

DOI 10.13164/juniorstav.2024.24142

3 RESULTS

In the area of methodology, a real-time monitoring system with smart metering devices was successfully implemented, enabling the monitoring of energy patterns on construction sites. The statistical methods used, including regression analysis, helped to identify factors that influence electricity consumption, such as working hours and the number of employees on site. A review of smart meter data analysis highlighted the importance of methodologies and applications in understanding energy patterns [8].

The research results demonstrate relationships between human resource deployment, temporary facilities and electricity consumption on construction sites. The total consumption is influenced not only by the number of workers, but also by their working hours, the types of appliances in temporary buildings, and their energy output. Site "A" with fewer workers shows the lowest total consumption, but does not reach the lowest energy consumption per temporary building. This may be due to the age of the buildings, as the buildings on site 'A' were the oldest. Site 'C', with its newer temporary buildings, shows a lower average consumption per temporary building. This can be explained by the modern and energy efficient nature of the equipment installed in the temporary buildings, which contributes to the overall energy savings. In contrast, site 'B' has a larger amount of workers, and has a higher total consumption, but a lower average consumption per worker.

The relationship between human resources and electricity consumption is clearly shown in our results, where a complex relationship between the number of workers on site and electricity consumption is evident, with a significant increase in consumption as the number of workers increased. The impact of temporary buildings such as containers was also highlighted by the analysis, which showed that their age and efficiency have a significant impact on overall electricity consumption. Older temporary buildings often showed higher consumption, which could motivate investment in retrofitting and more energy efficient solutions.

Trend lines are plotted based on a linear regression against consumption values for individual sites. This results in an increasing trend of consumption at all the construction sites studied. This is due to the maintenance of the thermal comfort of the working environment in the temporary buildings for the site personnel.

4 DISCUSSION

This study clearly demonstrates the importance of analysing electricity consumption on construction sites for managing costs and improving efficiency in the construction industry. An important aspect is temporary facilities, i.e. construction containers, where differences in consumption patterns have been identified. Reducing energy consumption on construction sites has not only economic but also environmental benefits, contributing to global goals of reducing greenhouse gas emissions [9].

The discussion further focuses on aspects such as the age and condition of temporary buildings, where older containers may have higher energy consumption, indicating the need for maintenance. The findings have practical implications for site managers who design and can already take energy considerations into account when planning and managing site operations. Overall, our findings contribute to the understanding of the factors influencing energy consumption on construction sites and provide a basis for sustainable measures in the construction industry.

The development of energy consumption in building containers predicts us the possibility of implementing renewable energy sources. Electricity consumption starts to increase during dawn, which can be a suitable predisposition for the maximum use of electricity generated from, e.g. the sun [10]. The proposals are in line with the global imperative to reduce carbon emissions and promote sustainable development in the building industry during the construction phase.

It would also be useful to investigate the options for implementing different renewable energy sources on construction sites and their potential impact on the overall sustainability of construction projects. This could include the integration of solar panels, wind turbines and other renewable technologies into temporary buildings and construction infrastructure.

Regression analysis is often used to predict future electricity consumption [11]. The almost identical tendencies displayed by the three investigated construction sites points to the fact that such an analysis can be homogeneously applied to other construction sites with similar parameters. This claim should be verified by continuing the research in this area and retrospectively comparing with the claims.

5 CONCLUSION

In this scientific paper, a systematic analysis of the impact of the deployment of human resources and temporary facilities on electricity consumption at construction sites was carried out. The study focused on the energy consumption of construction offices and involved the installation of metering devices on three different construction sites.

The results suggest that there are relationships between the number of workers, temporary buildings and total electricity consumption on construction sites. The main findings include:

1. the number of workers and their working hours have a significant impact on total electricity consumption,
2. the quality and age of temporary buildings are critical to the energy efficiency of the site,
3. the external ambient temperature creates conditions where environmental modification is required in the premises of temporary buildings,
4. electricity consumption is cyclical and has defined periods of higher and lower consumption during the working pool.

The work provides data that can serve as a basis for designing sustainable measures to improve the efficiency of construction processes. Statistical methods such as the analysis of means, standard deviations and regression analysis have been effective in identifying factors affecting electricity consumption on construction sites. The research methodology, which includes monitoring system selection, site selection, installation of metering equipment, and real-time monitoring, provided comprehensive insights into the energy profile of construction sites.

Overall, it was concluded that effective management of human resources and temporary facilities is the key to achieving sustainable energy goals on construction sites. The study contributes to a better understanding of the factors influencing energy consumption in the construction industry and provides valuable information for practitioners, project managers and all stakeholders that can lead to the implementation of measures to improve the efficiency and sustainability of construction projects. Such measures entail concomitant phenomena and play a key role in solving problems, improving safety and working conditions and minimising occupational hazards [12].

The need to investigate other sites in different geographical locations and climatic conditions is crucial to strengthen the external validity [13] of our findings. Further research should include different types of construction projects with varying specific requirements regarding temporary facilities and human resources. In addition, consideration should be given to the different types of construction containers and their energy efficiency depending on climatic conditions, as all three of the studied construction sites were located in the same region.

Acknowledgement

The article was written with the support of a programme aimed at motivating and supporting the improvement of the quality and efficiency of the scientific research activities of young scientists in 2022 under registration number 1656.

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