Zeszyty Naukowe Politechniki Częstochowskiej. Zarządzanie
Research Reviews of Czestochowa University of Technology. Management

No 55 (2024), pp. 135-147, ISSN: 2083-1560
DOI: 10.17512/znpcz.2024.3.10, https://znz.pcz.pl/

Received: 14.07.2024; Revised: 15.08.2024;
Accepted: 19.08.2024; Published: 30.09.2024.

AUTOMATION IN CONSTRUCTION: MEASURING THE LEVEL OF AI ADOPTION IN THE URBANIZATION PROCESS

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Abstract: Within the framework of Industry 4.0, recognized by the application of Artificial Intelligence – AI – and with the aim of relating performance evaluation strategies to human resources in this new environment, applied research is established in a construction company, targeting the main operational process within the organization: urbanization of residential development. To achieve this, a baseline study has been proposed to discover the level of adoption of AI through the automation of tasks performed within the process. Therefore, the objective of this article is to present a case study with a qualitative approach and diagnostic information management in order to evaluate the level of automation This is achieved by identifying operations that consider different types of technology and examining how human resources effectively perform their functions based on this technology. The results indicate a medium level of automation, due to the lack of awareness among personnel about the disruptive technologies and equipment that define the automation of processes. The objective of this study is to promote the continuity of research with the aim of contributing to the development of a human resources performance evaluation system based on technological elements and skills.

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Keywords: AI, automation, technological competencies, urbanization process

JEL Classification: O320, M140, L720

Introduction

In the era of the incursion of Industry 4.0, organizations use technological tools to facilitate processes and demonstrate the effectiveness of indicators, that is, to demonstrate the results obtained; automation becomes valid through the application of Artificial Intelligence (AI), which with its various tools is very useful for the analysis, management of services and external and internal processes.

In terms of business, intelligence is defined as the continuous search for ways to reduce time and resolve adverse situations. It allows personnel to work simultaneously with significant volumes of information and minimize errors, which provides additional benefits to organizations (Gómez, 2024; Rouhiainen, 2018).

By following the minimum steps to adopt AI tools, organizations can gain significant advantages before even considering digitization, modification, and adaptation of internal processes, as well as adaptation to regulations. The primary benefit will be not only the reduction of costs due to automation but also the quality of information from systems that provide early reliability for decision-making in the management of the organization (Claudin, 2024).

The construction industry in Mexico, as in many other countries, is undergoing a process of transformation due to the increasing adoption of advanced technologies and automation systems. This change, driven by the need to improve operational efficiency, quality, and sustainability is particularly relevant in the context of residential development.

In San Luis Potosí, a state with sustained urban growth, construction companies are faced with the challenge of integrating new technologies into their key processes in order to remain competitive and respond to the demands of today's market. This article deals with the measurement of the level of automation in DEPSA, a construction company located in the western area of the capital city of San Luis Potosí, Mexico, focusing specifically on its key operational process: the urbanization of residential development.

DEPSA provides the opportunity to conduct a comprehensive research study based on the implementation of AI tools. It currently has seven developments that are in different stages of urbanization, ranging from the initial phases to those that are solely operational, having already been integrated into housing.

The number of employees, between direct and subcontracted personnel, is 200, while the number of housing clients, considered as beneficiaries, is more than 1,185 families. It is made up of professionals who seek growth in areas of design and architectural functionality in the current urban context, with the aim of being at the forefront.

In its operational process, the urbanization area of the unit of analysis covers from the preparation of the land suitable for residential development to its sale; the equipment required to achieve the objectives of the area includes technological tools, minor equipment and major equipment.

This research study, in this first phase, uses the scientific methodology of a case study to analyze how automation is implemented in the different stages of this process. By identifying the degree of automation that exists, we seek to understand not only the current impact of the technologies used but also the technological capabilities and skills that will be necessary to optimize these processes in the near future.

The main objective of this research is to lay the foundation for the design of a performance evaluation system that will allow the company to analyze its efficiency in the development of residential spaces, taking into account the growing role of automation. This evaluation system will not only measure current performance but will also include a framework for the technological capabilities required in the face of the integration of disruptive automation technologies in the context of Artificial Intelligence (AI).

The importance of this approach lies in the need to prepare the workforce and operational processes for an increasingly automated environment, ensuring that the organization can adapt and thrive in a constantly evolving marketplace.

In summary, this article represents a first step in exploring how automation is being implemented in a key construction sector in San Luis Potosi and how it can be used to improve efficiency and competitiveness in the development of residential spaces. The results of this first phase provide the basis for the development of performance evaluation tools and training strategies that are essential to meet current and future technological challenges.

Literature review

Artificial Intelligence – AI

AI is one of the branches of computer science based on a series of logical algorithms that simulate the human mind in solving problems and making decisions. The acquisition of data by a machine is not progressive and does not depend on certain experiences that are visualized, which makes data acquisition more agile, in the same way that human memory has minimal capacity compared to digital memory (big data) (Russell & Norvig, 2022).

AI is changing the way we interact and innovate, and organizations are communicating through natural language interfaces that streamline search. In addition, it offers better interfaces through its tools, allowing more predictive analysis functions and combination with management tools to automate repair processes, optimizations that are more intuitive, easier to use, and allow a natural and satisfying interaction for users, adopting technologies that improve efficiency and transparency (Claudin, 2024).

Human decision-making involves time and the possibility of failure, while these thoughts can be copied into a set of algorithms that machines can interpret and streamline the process. Ultimately, AI aims to mimic human intelligence. With possible combinations of combined data, guidelines are given for solving problems and successfully navigating complex situations. Two branches can be distinguished within this field: machine learning (ML), based on regression algorithms, and deep learning (DL), based on a neural network mechanism (Russell & Norvig, 2022).

In terms of AI, there are established criteria for measuring success and defining intelligent processes, including task automation, problem-solving, and self-learning. By leveraging AI, organizations can identify new business opportunities, optimize processes, and enhance their value proposition to the company. Additionally, they can make strategic decisions in real-time, as discussed by Benítez et al. (2014) and García (2020).

Task automation

In accordance with AI theory, the foundation of task automation is defined as the set of methods and procedures to replace physical and mental tasks that were previously programmed, thereby creating automation as the application of process control. The primary advantages of AI implementation are increased employee productivity and production capacity (García, 2020).

As defined, it is a system that allows for the reduction and optimization of processes, acting directly on equipment through the use of monitoring and control technologies without human intervention. It has been present throughout all of the revolutions that the world of progress and technological development has experienced, also driving the learning of new skills in staff to adapt to the acceleration of processes. It continues to grow and generate benefits in all sectors and is key in the new era known as the Fourth Revolution or Industry 4.0 (Zapata et al., 2021).

The tasks that are considered to have greater cohesion with AI include information exchange and analysis of unstructured data. The training of machines to perform routine processes allows employees to focus their time and attention on developing priority activities more efficiently. This results in an improvement in strategy development, which is the main expected benefit. From the strategy deployed by the organization, guidelines can be established for the ethical replacement, disposal, and relocation of personnel performing tasks that will be automated. These guidelines must be followed according to the law (Garcia, 2020).

Considering the risks that may arise from the automation of tasks and the work that personnel currently perform, there are programs that can be reoriented and scaled for employees who obtain medium qualification and above; re-learning programs and counseling focused on the possibilities of reintegration in the medium and long term work are needed; at this time, medium qualified personnel need expert counseling services to redirect their career path based on a mapping of the different options to break down the plan and objectives in the activities and avoid job loss (García, 2020).

Technologies in automation

The landscape of automation has been transformed by the integration of cutting-edge technologies such as Machine Learning (ML), Deep Learning (DL), and the Internet of Things (IoT). These technologies are the pillars of modern automation systems, enabling machines and devices to perform complex tasks with minimal human intervention. ML, a subset of artificial intelligence (AI), allows systems to learn from data, improve their performance over time, and make decisions based on patterns and insights derived from large datasets (Goodfellow et al., 2016).

Deep Learning, an advanced form of ML, has further enhanced the capabilities of automation by enabling systems to analyze unstructured data such as images, audio, and text. DL models, particularly Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have been pivotal in developing applications like computer vision, natural language processing, and autonomous systems (LeCun et al., 2015).

In the automotive industry, DL-powered autonomous vehicles can interpret real-time sensory data to navigate complex environments safely. The ability of DL to handle high-dimensional data and extract meaningful features from it has opened new frontiers in automation, allowing machines to perform tasks previously thought to be beyond the reach of automation (LeCun et al., 2015).

The Internet of Things (IoT) plays a complementary role in automation by enabling connected devices to collect, share, and act on data in real-time. IoT devices equipped with sensors can monitor environmental conditions, track equipment performance, and even predict failures before they occur (Atzori et al., 2010).

When combined with ML and DL, IoT systems can create highly responsive and adaptive automation environments, The synergy between these technologies is driving the evolution of the Industrial Internet of Things (IIoT), where automation is not only about individual machines but entire ecosystems working together seamlessly (Atzori et al., 2010).

Moreover, other emerging technologies like Robotic Process Automation (RPA), cloud computing, and edge computing are also contributing to the automation revolution. RPA allows businesses to automate routine, rule-based tasks, freeing up human workers for more strategic activities. Cloud computing provides the scalability needed to handle large volumes of data and computationally intensive tasks, while edge computing brings processing power closer to the source of data generation, reducing latency and enabling real-time decision-making (Tata Consultancy Services, 2021).

These technologies, when integrated with ML, DL, and IoT, create powerful automation solutions capable of transforming entire industries, from healthcare to logistics. The ongoing advancements in these areas promise a future where automation systems are more intelligent, efficient, and ubiquitous than ever before (Tata Consultancy Services, 2021).

Urbanization process of residential developments, within the construction industry

The urbanization process in the construction sector is a set of coordinated and planned activities that transform virgin land into habitable areas, with adequate infrastructure to host residential, commercial, or industrial developments (González & Martínez, 2018). This process spans from initial planning to the delivery of the final project and includes a number of key phases that are essential to the success of the project.

A) Urban planning and design: involves the design of the land layout, the allocation of land uses, and the integration of basic infrastructure such as streets, drainage, electricity, and potable water (Rodríguez & López, 2020).

B) Infrastructure development: once planning is completed, the infrastructure development phase proceeds, which is fundamental to transform the land into an urbanizable space, including the construction of streets, sewage systems, water and electricity networks, and other essential services (Gómez et al., 2017).
C) Implementation of services and complementary works: these may include parks, recreational areas, and commercial areas (Martínez & Torres, 2020).
D) Project evaluation and delivery: a complete review is performed to ensure that all infrastructure and services comply with established regulations and standards. Project delivery marks the end of the process, where the already urbanized land is ready for occupation or further development (Sánchez & Ríos, 2022).

The operational process of development in the construction industry is a complex cycle that requires meticulous planning, rigorous execution, and constant supervision. Each phase of the process, from initial planning to final delivery, plays a crucial role in the success of the project. As technologies advance and development demands evolve, industry professionals must maintain a comprehensive and adaptable approach, incorporating innovations and best practices to meet contemporary development needs.

Urbanization can be defined as the transformation of society, based on the concentration of people, integration of basic services, generation of employment, and consequently, greater economic development; this phenomenon is usually presented as the adaptation of towns to cities. However, a complementary connotation is when it refers to the growth of the city, requiring then, the territorial division into colonies, plots, and blocks in order to build housing. The urbanization process, as part of the construction sector, requires the integration of services such as electricity, drinking water, waste collection, and transportation, among others, which are fundamental for future residents (COESPO, 2017; Pirez, 2013).

The success of this urbanization process depends largely on the use of tools and equipment, which could be classified as light and heavy; these facilitate the administrative and field activities of workers due to their technological development, being the mechanical field, the basis of its operation, however, as in any sector, automation has modified and improved the use and therefore the effectiveness in the tasks performed.

Research methodology

A *case study* is considered in which the company DEPSA, hereinafter referred to as the unit of analysis, is examined through a diagnostic methodology to formalize the validation of disruptive technology in its key process: *urbanization of residential development* and to be able to grant a level of automation derived from it. Based on this, the performance of personnel facing new processes or using automated equipment is related.

These disruptive technologies and automation itself are related to AI, through the bases it promotes (automation, solution, and self-learning), which indicates that it is a relevant study.

Case study

Description of the problem

Given the technological phenomenon faced by organizations with the introduction of AI in their processes, opportunities have been created to opt for new ways of working, in which those responsible for personnel must rethink the monitoring and evaluation of these, to ensure compliance with the established objectives. In this way, a theoretical-practical gap has been identified in the treatment of human resource effectiveness indicators in the face of the impact of AI, which is rapidly advancing within the structure of organizations.

It is considered that in order to effectively implement an improvement in performance evaluations, it is necessary to identify, implement and recognize in the first instance, the level of automation of some or all the processes of an organization; for this reason, the present study is designed, which makes it possible to analyze and establish the basis to develop an integral study of performance measurement in the urbanization process of the unit of analysis. The method used is a diagnosis, in which technologies are validated to know if they belong to the group of AI tools. In this way, it also facilitates the ability to grant a degree or level of automation that they provide in the development of activities.

General objective of the case study

The general objective of the case study of the unit of analysis is to determine the level of automation of the operational process urbanization of residential developments, using a diagnosis with descriptive information management to formulate strategies based on the evaluation of human resources in this new technological environment that has generated the application of AI, as a continuity of research.

Specific objectives

1. Identify the use and impact of digital content involved in the stages of the urbanization process.
2. Validate each stage of the urbanization process based on the impact on the existence and awareness of the staff.

Diagnosis

Based on the literary foundation of AI, disruptive technologies are cataloged in the following dimensions: pedagogical, technological, and communication. The validation of requirements is considered, that is, that they are defined, and verified and that they correspond to the system that the customer wants or that errors are detected at an early stage in the development.

This will help to avoid excessive repetition of work and provide assurance that the requirements are correct, consistent, and complete. It is comprehensive, evaluative, and adapts to the organizational context.

Observations in the field and in relation to personnel from the unit of analysis allowed us to catalog equipment or tools of the process and relate it to the dimensions depending on its scope and own descriptions with the learning opportunity and performance (Calvo, 2021). This cabinet work is summarized in Table 1.

Table 1. Observed dimensional relationship

Dimensions	Pedagogical Dimension (Training)	Technological Dimension	Communication Dimension
Learning	- Training: 3 ProCore users. - Field talks: slope stabilization, installation of services, paving. - Certifications in personnel management and human development.	- Use of minor equipment (personal: length laser, pc). - Use of common use equipment: internet, connectivity, devices, cabling, accessories, laboratories, drones, drilling equipment. - Major equipment use: vehicles, construction machinery.	- Connectivity: internet, e-mail. - Personal equipment: cell phones, common communication applications. - Communication radios. - Field signage. - Formal presentations--weekly. - Marketing: brochures, tv and radio spots.
Performance	- Presentation of results by area representatives. - Agreements on project continuity. - Review of progress by project / development.	- Fieldwork progress. - Sales indicators, sales collections. - *Not formally evaluated.*	- *Communication performance* is not evaluated.

Source: Own study based on informartions in field (Calvo, 2021)

The level of automation identified was carried out by stages of the process because it is channeled as a partial result. Each stage is subject to advanced, medium, and initial levels according to the degree of automation observed in the field, following the considerations that were agreed upon together with the personnel of the analysis unit (Table 2). This information is the result of all field research work, it is subject to a simple scale under the principles of Likert-type scaling (Machuca et al., 2023).

Table 2. Level in the stages of urbanization with respect to the technology "in situ"

Level	Field description to locate the appropriate level of task automation
INITIAL	- Basic equipment: - Staff are not necessarily aware of the technology they are using
AVERAGE	- Specialized equipment: - Software - Minor equipment - Major team (satellite)
ADVANCED	- Tools recognized as part of AI: - Comprehensive automation -equipment, machinery and management- - Collaborative Software

Source: Own study based on information in field (Machuca et al., 2023)

Following the diagnosis, during a visit to one of the most advanced developments in urbanization, the stages of the process were observed, which, once integrated, are related to technologies that involve a certain degree or level of automation, as derived from the analysis carried out jointly with the personnel (Table 3). The stages

that are presented, were provided by the unit of analysis, correspond to its process diagram of the urbanization operation, these are:

1. Issuance of permits
2. Drawing up plans
3. Contracts
4. Urban development project
5. Urbanization of services
6. Zoning
7. Sale

Table 3. Degree of automation by stages of urbanization process of the unit of analysis

Stages of the urbanization process	Operation requirements	Technology used	Degree of automation granted
Issuance of permits	- Request for guidelines - Legal certificates: lien freedom, legal status	- Basic: devices, internet, email	**INITIAL**
Drawing up plans	- Plots location plans - Urban map of the area: public roads, infrastructure networks (services) - Lotification: services	- Specialized software: autocad, civil 3D, SolidWorks - Survey equipment - Drones	**AVERAGE**
Contracts	- Municipal, state, federal: water, electricity, gas, drainage	- Basic: devices, internet, email	**INITIAL**
Urban development project	- Application for approval - Design feasibility - Design plans of the property - Environmental impact: landscape, land use - Road impact	- Specialized software: autocad, civil 3D, SolidWorks, ContPaqi - Survey equipment; drones - Laboratory Equipment - Transit vehicles	**AVERAGE**
Urbanization of services	- Drawing in field of roads - Marking of services - Preparation for installation of utilities	- Major equipment -Machinery: excavators, backhoes, compressors, articulated trucks, hammers, bulldozers, loaders, tractors, drills - Accessories for major machinery - Satellite location equipment	**AVERAGE**
Lotification	Lot delimitation - Plan preparation - Installation of service modules by lots (water, drainage, gas, electricity)	- Minor equipment: transport trucks, backhoes - Specialized software: autocad, civil 3D, SolidWorks Masonry equipment	**AVERAGE**
Sale	- Lotification Plans - Dissemination leaflets, Renderings (Marketing)	- Specialized software: autocad, Revit	**AVERAGE**

Source: Own study based on on information in field

Results

Based on a diagnosis of the presence and use of technology in the field and in the administration, the unit under analysis, with industrial activity in the construction sector, has automated 60% of its operational processes between 2010 and the present. Growth over the last 15 years, reflected in the number of direct employees, has increased by 7%, reaching 100 employees by March 2024.

Due to the nature of the civil works operations, it faces the need to subcontract a series of tasks that integrate conceptualized housing developments in the west zone of the city of San Luis Potosi, contemplating roads, lighting, drinking water services, drainage, gas, telephone, Internet, connectivity, thereby allowing to deliver lots to customers for private constructions; these indirect jobs show figures around 100 people.

The inclusion of advanced technology lies in the implementation of this in two ways:

1. Implementation of software -*ProCore*- which is classified within the so-called *integrated collaborative solutions*, due to the application in all areas of the organizations.
2. Acquisition of automated work equipment to execute urbanization operations or the use of automated equipment by subcontracting.

Looking at some of the figures available in the Human Resources, Training and Environment Department, it is noted that there are indicators related to training activities, turnover at lower levels and, at a lower level, absenteeism, but they are not statistically analyzed to provide a strategy for improvement.

The implications of the technological incursion *have yet to be fully identified*, creating an opportunity to design a system that identifies and provides levels for performance indicators and provides information that contributes to personnel-focused strategies once automation has reached operational and administrative processes.

Some indicators that are observed are recorded in the Human Resources module of ProCore, but they are not analyzed and therefore not *interpreted* in terms of decision-making following the findings.

The level of automation is generally present, as AVERAGE, since this urbanization process contemplates stages in which there is evidence of the use of tools typified as task automation within the IA, but *they are not fully explained in this way*, resulting in a lack of follow-up on the effectiveness of these and how the staff executes them.

Discussion

Each state of the Mexican Republic has the Secretariat of Agrarian, Territorial and Urban Development -SEDATU-, which contributes to the improvement of the immediate surroundings of housing, considering deficiency events in infrastructure, urban equipment and public spaces, and also attends to connectivity problems through planning instruments (SEDATU, 2022).

This Secretariat, through the *Municipal Construction Regulation*, oversees the urbanization process, which contains fundamental activities (Solminihac & Thenoux, 2005):

a) Land studies: topography, geology, hydrography, environmental, legal.
b) Lotification design, landscape architecture.

c) Regulatory conditions: background, land use.
d) Design of regulatory plans: streets, facilities.
e) Service conditions: water, electricity, sewage.

These long activities are distributed in stages, which depend on the policies and organizational structure of each company. As a whole, the stages that make up the urbanization process are considered previous and are integrated into the final projects, i.e. the construction of housing.

Based on these regulations, the automation of the urbanization process becomes valuable by laying the foundations for the efficient integration of these requirements, which must also be available to all personnel involved, including potential customers who may purchase the lots defined in each subdivision as a result of the good urbanization.

The elaboration of the studies and plans involved, as well as the digitization, will be more accurate and efficient as a result of the AI tools and the automation of the equipment and the process itself used for this purpose. The effectiveness will depend on the skills that the personnel present to design, create, digitize, improve, and use automated tools and equipment that employ disruptive technology. Connectivity is also a factor in distribution. Therefore, it is considered convenient to continue the study in terms of performance evaluation based on technological skills and the foundation of AI and automation.

Conclusions

Among the business initiatives that Industry 4.0 has brought about as part of its development, the application of artificial intelligence (AI) is a key area of focus. Given the three main areas where AI is used: (1) task automation, (2) problem solving, and (3) self-learning, the level of task automation has been identified as akey factor in evaluating the performance of human resources.

The criteria for measuring success and determining the intelligence of a process are based on temporal and strategic strata. The base used for this diagnosis is task automation, which was implemented by DEPSA to visualize activities and processes and make real-time decisions. To ascertain the effectiveness, it is essential to gauge the impact exerted, which renders this study highly pertinent (Benítez et al., 2014; García, 2020).

The diagnosis allowed observing and classifying the level presented by the urbanization process, contemplating the fulfillment of the objectives stated in the proposed design, that is, the stages of the selected process were identified, obtaining from them a total of seven, related each one, with the equipment with which they are executed and, based on this, the level was referred according to characteristics previously defined in conjunction with the personnel involved.

The unit of analysis presented elements that made it possible to identify the use and impact of digital content once the stages involved in the urbanization process were described and specified. This allowed for the validation of the content in a particular way based on the impact generated in the ability of execution by the staff. The findings revealed that the technological skills required by the integration of disruptive automation technologies in the context of artificial intelligence (AI) require specific attention for the correct application and use of them.

In the key operational process of urbanization of residential development, observations are made before the identification of technological skills requirements for staff, in which the medium grade obtained indicates the basic existence of disruptive technologies. However, to enhance this level, it is essential to invest in training and education for employees, ensuring that they are well-informed about the benefits and functionalities of modern equipment.

By fostering a culture of awareness and adaptability, the construction industry can better leverage AI and other innovative technologies to improve efficiency and productivity in urbanization processes.

In light of the theory behind task automation, which allows for the consideration of human resources based on their contribution to processes through their skills, it can be concluded that organizations must integrate updated performance evaluations into their automated operational activities.

In this personnel evaluation, the indicators must be related to the new work formats, which can measure and guide the skills and abilities of individuals based on their experience, efficiency, knowledge, commitment, and the service they provide and are paid for. This is a measurement that promotes, relocates, or releases them in accordance with the law and with recognition that allows them to join another organization with personal and professional growth goals.

The continuity of the study is viable and necessary. The comprehensive research approach suggests a system of indicators to evaluate personnel in a way that is consistent with the new automated work format. This study forms the basis for subsequent stages, such as the integration of a master's thesis.

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Authors' Contribution: *Dr. Rosa Elia Martínez Torres* has worked on this research from the idea and its approach, her participation goes from the approach with the Director of the company to the implementation and future follow-up as Thesis Director in this project; *Anel Sierra Segura,* student of Master in Administration, works in Thesis in DEPSA is in charge of the diagnosis; *Dr. Patricia Rivera Acosta* collaborates in this research as a reader and promoting it with the academic authorities of the IT academic organization of SLP; *Guillermo Villalpando Romo* contributes and monitors the application of the validation of technologies.

Conflict of Interest: There is no conflict of interest, the company DEPSA grants permission to carry out the diagnostic and for it to be published.

Acknowledgements: To DEPSA and the Technological Institute of San Luis Potosi, TecNM, due to their support, it was possible to carry out this first part of the project, in search of better opportunities for both sectors: construction industry and education.

SZTUCZNA INTELIGENCJA I AUTOMATYZACJA: INNOWACYJNE PODEJŚCIE JAKO STRATEGIA W URBANIZACJI

Streszczenie: W ramach Przemysłu 4.0, który uznano za sprawą zastosowania sztucznej inteligencji (AI), oraz w celu powiązania strategii oceny wydajności z zasobami ludzkimi w tym nowym środowisku w firmie budowlanej prowadzone są badania stosowane, mające na celu kluczowy proces operacyjny w organizacji: urbanizację osiedli mieszkaniowych. Aby to osiągnąć, zaproponowano badanie bazowe, które pozwala poznać poziom adopcji AI, poprzez automatyzację zadań, które są realizowane w ramach procesu. Celem niniejszego artykułu jest przedstawienie studium przypadku z podejściem jakościowym i zarządzaniem informacją diagnostyczną, które pozwala ocenić poziom automatyzacji poprzez identyfikację operacji uwzględniających różne rodzaje technologii i to, w jaki sposób zasoby ludzkie efektywnie wykonują swoje funkcje w oparciu o nie. Wyniki wskazują na średni poziom automatyzacji, ze względu na brak świadomości wśród pracowników na temat przełomowych technologii i urządzeń, które definiują automatyzację procesów. Zakres niniejszego opracowania wpisuje się w potrzebę ciągłości badań, aby dostarczyć elementy składające się na System Oceny Wydajności Zasobów Ludzkich oparty na współczesnych elementach technologicznych i umiejętnościach.

Słowa kluczowe: sztuczna inteligencja, automatyzacja, kompetencje technologiczne, proces urbanizacji