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Automation in Civil Engineering Design in Assessing Underground Space Energy Efficiency

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Abstract—*The main aim of this paper is to discuss the use of automated processes in civil design development to evaluate the energy efficiency of underground spaces. There is no longer a stigma attached to the use of automation in the designing of construction projects within the construction sector. It significantly improves efficiency and simplifies many of the intricate design elements. Since the beginning of the past forty years, automation has grown as a result of improvements in computer hardware and software, which have made it possible to automate a variety of design processes [1]. The technology now in use has significantly enhanced the design process, making it faster and more precise overall. The issues with computerized design, however, began with the potential for unintended or unforeseen outcomes as the design complexity increased. It is closely related to the hazard to human life posed by global warming. As a result, this article examines design automating and its use in civil design process, with a focus on evaluating buildings' energy efficiency. It does so by outlining its history, its applications, benefits, and drawbacks, as well as by offering recommendations for how artificial intelligence (AI) might be used to further enhance design automation in the field [1]. It was found that because of its many benefits, Adoption of BIM in civil design process has begun to become widely used in the construction sector over the last several years.*

Keywords: Automation, Civil Engineering Design, Underground Space, Energy Efficiency, BIM, artificial intelligence (AI).

I. INTRODUCTION

The needs (and potential) for subterranean space are extremely infrequently considered by futurists from both outside and within the geological engineering sectors [1], despite the fact that their utilization has some important consequences for a sustainable future above ground in metropolitan settings. Despite this flaw, it has long been acknowledged that using subterranean space would likely become more and more significant over time. Greater computer technology and accompanying software advancements over the last four decades have made it possible to computerize a vast array of designs [1,2]. The automation of design applications is growing as the construction sector advances its digital transformation, making the development process more structured and efficient [2]. The breakthrough in information and communications technology has, from the very beginning, been accompanied by the structural design stage. However, there are a number of crucial areas where the operations are completely reliant on the engineers and were until recently thought to be too difficult or even impossible to be programmed. This is particularly true given that they not only have a numerical character but also learn heuristics. These problems may now be resolved with the aid of several updated ICT programs [3]. Even in today's highly automated world, the early stages of an architecture or engineering project's design process still rely heavily on human judgment and creativity [4].] The ICT revolution and global climate change has also led to an increased focus on comprehensive digital representations among building owners, architects, and engineers, who are looking to include more features such as building lifecycles, sustainability, and energy performance into new construction projects. Automation of the whole building process will need the use of this technology in order to improve accuracy and efficiency [5, 6]. Here, further design process automation is currently developing in accordance with current expectations. Automation is a methodology, method, or system for running or directing a process by highly automated methods, such as electronic devices, usage of control systems, and information technologies, with little or no human participation. Automation, which reduces the need for human labor in the production of products and services, is the use of information technology and control systems [6]. Additionally, it has been noted that automation is a crucial development to ensure the success of CAD's progress. The computing capability of IT ought to enable the computer to carry out computations and provide results for people to evaluate and approve [7]. The use of automation in civil engineering design has several positive effects. In general, automation will make the design process quicker, more precise, and play a significant part in the reduction of mistake. The manual calculation was a frequent cause of design fault in the old-fashioned sense. A reliable piece of software will be able to practically solve this issue. Fast computing has made it possible to carry out several iterations of complicated designs, enabling optimization of solutions that were previously just not possible. Improved product performance will result from the swift investigation of fantastic design choices. Additionally, the computer modeling of complicated issues has produced more inventive and creative structures [8]. A machine never gets weary, works more quickly than a person, and consistently completes tasks in the same way.

Modern design automation can examine the life-cycle effect of initial design choices and take the long-term sustainability goal of a building into account as early as the design phase[8]. This opens up new options. Although automation may help in the features of sustainable construction, which is the current requirement for infrastructure design [8]. Automation allows engineers to focus on more creative tasks by letting computers do the time-consuming routine tasks [9]. Because of its capacity to create a variety of design possibilities and allow for design improvements, it may allow for the reuse of successful solutions rather than re-creating the wheel for every project.

Through the use of automation for infrastructure supply and with a specific emphasis on sustainable use of subterranean space, this study will provide geological engineers a better knowledge of both present and future needs and potential for under-ground space.

II. RESEARCH PROBLEM

The main problem that will be solved by this paper is to discuss the Automation in Civil Engineering Design in Assessing Underground Space Energy Efficiency. The analysis and division of the subsoil into groups with comparable qualities serves as the foundation for the appropriate design of all geotechnical engineering constructions. Systems for classifying rock masses are an essential component of geotechnical design nowadays. However, a request for more objective categorization is made since many of these classification methods are based on subjective or semiquantitative assessments [10]. The requisite laboratory tests and soil studies are often and inescapably expensive and time-consuming. In our most recent publication, we analyze subsurface conditions using several supervised machine learning models. The ability to do sophisticated studies, like ML on massive data, has been made possible by the expansion of machine computing capabilities over the last several decades. ML may be used to create reliable prediction models for soil and foundation engineering characteristics and behaviors in geotechnical engineering applications, where uncertainty is inherent [10]. Then, geotechnical design parameters are often approximated using empirical or numerical correlations that are created by regression fitting to a dataset rather than being always explicitly measured from laboratory and in-situ experiments. These empirical correlations typically use linear regression approaches, however multi-dimensional nonlinear modeling techniques like Artificial Neural Networks may significantly enhance them (ANNs).

III. LITERATURE REVIEW

A. Underground space development

The creation and exploitation of subterranean space has a lengthy history. Slave societies' usage of tunnels and tunnel systems has expanded throughout time; from ancient emperors' catacombs to modern-day subway systems, from World War II air raid shelters to modern-day subterranean communities. As the population density of cities increases, the need for subterranean development grows. It has been shown in recent decades that subterranean rooms may add 25–40% more usable space [10]. While urban land shortage continues to grow, subterranean spaces have the potential to alleviate this issue [11].

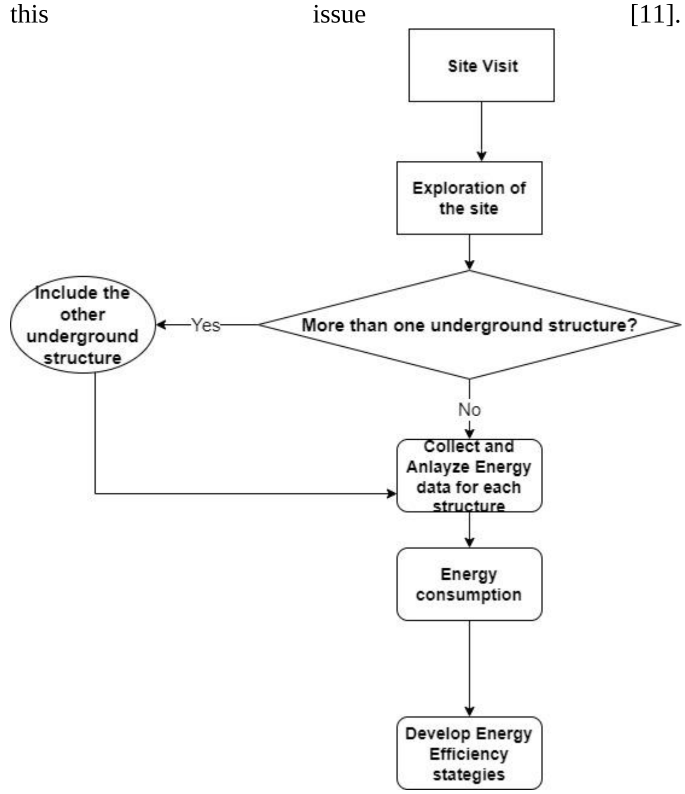

Fig i: Analysis process of underground space energy efficiency

B. Underground Spaces: Unresolved Issues

i. Pollutants

TVOC, CO, PM10, radioactive Rn, and other pollutants are common in subterranean places. Indoor malls have greater levels of formaldehyde and TVOC than outdoor malls. Nine subterranean malls in Xi'an, China, were studied for formaldehyde and TVOC concentrations [11]. TVOC and formaldehyde mass concentrations vary from 0.34 mg/m3 to 3.56 mg/m3, respectively, with the former averaging about 0.05 mg/m3. [12] studied the effects of traffic volume on pollution concentrations in naturally ventilated parking garages. However, they discovered that PM10 levels were substantially greater in parking garages with a lower ceiling than those in the open air. A massive subterranean parking garage in Hong Kong was studied by [13]. The number of automobiles on the road does not always translate into an increase in CO concentration. A parking garage's ventilation type may alter the amounts of PM and TVOC inhalation exposure and the health risks connected with them. Most of China's housing underground parking areas are naturally ventilated when building and operation expenses are taken into consideration. Ventilation systems need to be more effective based on the amount of traffic and the quality of the interior air (IAQ). People also urged that IAQ (the maximum permitted CO2 concentration specified in the standard) be further examined even if the concentration of CO2 may fulfill the standard's requirement. In addition to degrading air quality, excessive levels of relative humidity (RH) and carbon dioxide (CO2) also have a significant impact on human health. Similar agreements exist in Europe, requiring that the air conditioning filters in public transportation vehicles be changed on a monthly basis at a minimum frequency. As long as pathogens are kept under acceptable limits, the present agreement does not need to be modified. Filters, on the other hand, may keep air quality high for at least three months. They also argued that the WHO should devote more time and effort to improve the air quality below ground [13]. Hydraulic projects' subterranean excavation technology specifies that the air flow at which big subsurface areas may be ventilated must be 0.15 m/s [13]. Even while air velocity could keep dust levels under control, oxygen concentrations adequate, and temperatures below tolerable limits, the CO concentration remained too high [13].

Soil and construction materials are the primary sources of ambient radon, according to the World Health Organization. Short-lived radon progeny is the primary source of radon exposure in the real world. Due to poor ventilation and higher radon exhalation from surface materials, short-lived radon progeny in underground mines contributes to increased exposure. Throughout the day, radon levels in the structures below ground change in two distinct cycles. The reverse of what happens above ground surface, radon levels in subsurface structures are lower in winter than they are in summer. It's important to note that seasonal temperature changes outside are a major contributor to this occurrence. Even though construction materials are a major element, other variables such as geological structure, air tightness of the home, internal ventilation rate and people's living habits also play a role.Subterranean areas may become a breeding ground for a variety of dangerous substances, including CO, CO2, NO2, SO2, dust, and exhaust fumes from construction equipment. Worker health and productivity are directly impacted by ventilation during tunnel building, which is employed to regulate the subterranean space construction settings.

ii. Control of Smoke and Exhaust

When a fire breaks out in a structure that is subterranean, a few distinct features become apparent. To begin, it is impossible to expel hot smoke fumes in a timely way, the temperature in the room increases quickly, it is difficult to dissipate heat, and flashover ensues. Second, there is a significant accumulation of smoke over a protracted period of time. Because there was not enough oxygen present throughout the combustion process, it was only partially successful. The amounts of toxic gases, such as carbon monoxide and carbon dioxide, skyrocket. The layer of smoke is dense and readily moves to other locations because of its proximity. Last but not least, evacuating and combating fires in subterranean structures is tough due to the limited number of entrances and exits and the significant distances that must be traveled. When a fire breaks out in a facility that is located underground or in space, the aftermath is often catastrophic. For instance, a fire at a subway station in Daegu, Korea, resulted in the deaths of 198 people and injuries to 147 more. Another fire at a metro station in Baku, Azerbaijan, claimed the lives of 289 people and wounded 265. In the event of a fire, there will be considerable property damage and fatalities.

When a fire breaks out in a subterranean location, the smoke that is produced by the fire is the leading cause of both deaths and damage to property. The features of fire-induced smoke have been researched for a long time in both homogeneous and stratified situations. The temperature of smoke that is released by sources of fire is noticeably greater than the temperature of the air that is around it. Smoke may be propelled upward because of the buoyancy generated by the difference in temperature. During the process of ascending, the smoke plume draws colder air from its surrounds and incorporates it into itself. The quantity of air that is drawn into a plume by a fire is the primary factor that decides how much smoke will be created by the fire. The heat release rate (HHR), the longitudinal ventilation rate, and the vaulted ceiling are all related to the optimum heat flux that may be reached under the roof of the tunnel [15]. Experiments have shown that there are three distinct zones located just above the ignition point. Investigations on the early transport and detection of fire smoke were also carried out in big volume facilities that had stratified ecosystems within. An atmosphere that is thermally stratified has the effect of hastening the declines in axial temperature and velocity that a smoke plume from a fire experiences until it reaches its highest point. Smoke backflows and a rise in smoke heat beneath the roof may occur when a ceiling jet is restricted by vertical sides in long, narrow constructions [15].

C. Energy & emissions and underground space

Energy is in great demand, and its market value is rising. Because of the vast mapping of complicated geology that has been done globally, a lot of more fossil fuel resources have been discovered. Technology advancements have increased extraction efficiency, enabling the production of coal, oil, and gas from resources that were previously believed to be exhausted. Although a greater population requires more energy (such as gas and electricity) to be delivered across the network, a significant portion of which still dwells above ground, distribution via the subterranean network stays largely unaltered.

D. Automated Energy Efficiency Evaluation of Underground Space

For this reason, a number of software providers and manufacturers have developed energy simulation tools that may be used to analyze a building's efficiency digitally [15]. It has been established and proven that Building Information Modeling (BIM) may assist in the development of energy performance analyses and, as a result, a more environmentally friendly design [16]. Building information modeling (BIM) enables the integration of architectural, structural, electrical, mechanical, and lighting data into a single model. Because the models and information should be consistent throughout the whole construction process and only be produced once, it may help to reduce data loss. The definition of vocabulary and related words, procedures and exchange of knowledge, and the manner in which the data which have been created are kept and arranged are the components that make up a standardized BIM framework for relevant data. Due to its flexibility to integrate to a variety of digital platforms, the neutral IFC (Industry Foundation Classes) model is well-suited for use with BIM [16]. There has been a lot of study done recently to see how a Framework and an energy monitoring application may be used together to produce more energy-efficient structures. Building information modeling (BIM) models may be connected to energy simulation tool for the aim of conducting building comparative analyses and determining how Existing infrastructure can be used to construct a system. On their research, Researchers concentrated on evaluating the effectiveness of various kinds of wall materials with respect to the qualities they have on energy conservation. They used Revit for BIM modeling coupled to Autodesk Ecotect and Green Building Studio for the modeling. A Revit model is used in both experiments to generate a gbXML file, which is then imported into an energy simulation program for use in the study of energy performance consumption [16]. Various wall coverings have been tested at a four-story library to determine which ones are most efficient. By altering the kind of wall material fed into Ecotect software, they were able to approach an 8 percent reduction in electrical energy use [16].

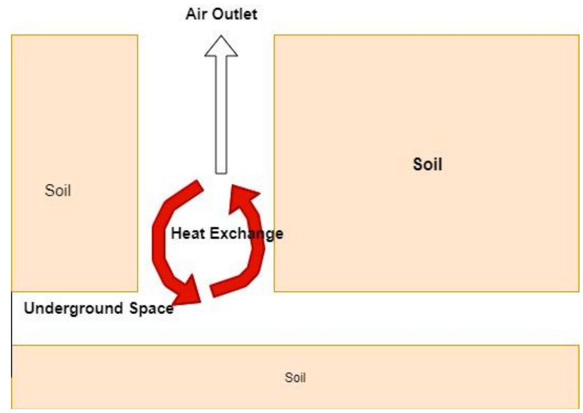

Fig ii: Underground space

A well-oriented structure might save up to £878 in energy costs over the course of its lifespan, according to Abanda and Byers' case study on an energy analysis of an energy analysis of the three-story home [12]. So far, both studies have been able to show that the orientation of the building and the kind of wall material used have an influence on energy consumption and consequently increase the building's energy efficiency. Additionally, they both felt that the use of BIM in the energy analysis helped to maximize the building's energy use [11, 12]. BIM connection to energy simulation software for energy analysis has recently been the subject of numerous researches in 2017. The BIM model was created using Autodesk Revit, and then it was exported to the Ecotect program in the gbXML format in order to conduct an analysis of the radiation from the sun and the energy demand of the structure. Using the results of the simulation analysis, the structure air - conditioning system system's monthly energy usage may be utilized to improve the building's energy efficiency. Using BIM technology, researchers have examined the study of residential buildings. The research was carried out with the help of Revit for the purpose of preparing the models, which was then sent over to Autodesk Green Building Studio in the form of a gbXML file for the purpose of doing an energy analysis. Energy analysis may now be completed more quickly and correctly thanks to a combination of BIM technologies and Revit's green building services [16].

Once the file has been exported from the BIM program, it can then be imported into the energy simulators where a number of different simulations may be run. According to the findings of their research, it is expected that integrating a BIM model to energy simulation tool delivers huge and sustainable improvements to the process of analyzing the performance of buildings in terms of energy saving. The design team's capacity to examine the design assumptions and make well-informed judgments was also enhanced by this method. To summarize, they concluded that the method helped speed energy simulation and get a more accurate outcome by providing more complete and precise data. Gourlis and Kovacic, on the other hand, found that in many situations, the shift from BIM to energy analysis software requires human adjustments that might influence simulation input data [17]. It is possible to improve green building performance while also lowering energy usage by using BIM technology [17].

IV. SIGNIFICANCE TO THE U.S

In highly populated U.S. cities, underground space is a growing public domain. It has the ability to enhance the urban environment by alleviating surface pressure, offering more room for the public transportation system, lowering noise and improving air quality, maintaining more green spaces in the city core, and shortening distances through improved functional concentration and effective space use [18]. Better subterranean spaces need a more methodical approach to design and evaluation. Accessibility and the immediate surroundings, direction and navigation, spatial ratios, interaction with the outside world, naturally occurring lighting, elements and colors, acoustics, and quality of air are some of the key variables that might have an impact on the design of a subterranean area. All these features are subjective, thus objective assessment is difficult.

V. FUTURE IN THE U.S.

An increasing number of initiatives are being made to introduce automation into the mining sector as businesses aim to use the technology to raise standards for efficiency and safety. The two most influential developments of our day are automation and digitalization. They have effectively disrupted every sector, including, for the most part, how we live, work, and see the world. Recent advances in autonomous robots offer the potential to bring this process to a successful end. The pace of acceptance of these new trends varies per industry, however. Compared to other businesses like the industrial and automotive industries, the mining industry has historically grown more slowly. Despite this, cutting-edge technology is revolutionizing the geotechnical sector. Through the utilization of a variety of potential urban future scenarios for 2050[18], automation will eventually be utilized to assist assess the performance, resilience, and robustness of present subsurface infrastructure technologies. The way infrastructure systems were planned, developed, built, then managed and maintained in the past will ultimately have a significant impact on how we live in 2050. Future pressures on the usage of the subsurface may be evaluated, and related implications for engineering geology can be assessed, by considering a number of changes, such as to metropolitan areas in terms of housing, retail, transit, food, water, energy, emissions, and waste - solid and water.

VI. CONCLUSION

This research examined the application of automation in civil engineering design with the goal of determining how well subterranean areas save energy. According to the findings of the study, the construction industry is always searching for methods to improve and boost its performance. As a consequence, the industry is increasingly turning to computers and information technology for assistance. Improving larger areas of the issue space in order to increase decision-support and decision-implication analytical skills; holistically incorporating optimization approaches; and combining all of these by leveraging virtualization. Geological and geotechnical engineers have the ability to take into consideration future demands for underground space. These engineers can also highlight probable engineering ramifications, which is particularly useful in regions that have often complex geological features. People may start to examine the existing techniques of using underground space as a result of this way of thinking in order to determine whether or not these methods are (or may be) suitable for future-proofing, considering whatever the future may hold. Using Building Information Modeling (BIM) is a rapidly expanding technology that has been proven and tried in the past to improve building energy performance evaluations, leading to a more energy-efficient structure. More reliable, accurate, and in-depth conclusions may be generated using the BIM platform, which also speeds up the energy analysis process, allowing for more efficient design at an earlier point in time. There is speculation that the use of artificial intelligence to the creation of automated civil engineering tools might result in significant improvements. Engineers may potentially have access to a great quantity of knowledge through expert systems, which can also give intelligent decision-making assistance. By analyzing and verifying designs, they might be of assistance in the process of design optimization.

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