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Exploring Customer Insights on AI-Agent Based Façade Technologies: A Study of Quality, Design, and Functional Expectations

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Abstract

The incorporation of artificial intelligence in the construction envelopes is redefining the operation and conduct of the contemporary facade design. This paper examines the customer and stakeholder perceptions towards AI based facade technologies, specifically, quality monitoring, personalization of designs, energy saving, functional automation, and decision intelligence. Quantitative research method was employed through a structured questionnaire that was completed by 300 participants, to whom the study was carried out, such as architects, builders, property developers, facade consultants and building owners. The SPSS, AMOS, SmartPLS, and Python were used to analyze the data and included descriptive statistics, reliability analysis, exploratory and confirmatory factor analysis, independent sample t-tests, ANOVA, and structural equation modeling. The findings suggest that there was a high positive ratings of intelligent facade technologies among the different groups of stakeholders. The strongest factor was found to be energy efficiency and sustainability (Mean = 4.25), then AI-enabled quality monitoring (Mean = 4.12) and AI agent decision intelligence (Mean = 4.10). High internal consistency was verified through reliability analysis and the value of Cronbach and alpha were found to be above 0.80 in all the constructs. The t-test findings showed that there exist a statistically significant difference in professional stakeholders and customers ($t = 3.21$, $p < 0.05$) where professionals had a higher level of acceptance. The further results of the ANOVA analysis showed that there was significant diversity in the perception between the stakeholder groups ($F = 5.62$, $p < 0.001$), with the highest perception scores being on the facade consultants and architects. The findings of structural equation modelling showed the significant role of AI-based quality monitoring ($b = 0.41$, $p < 0.001$), the personalization of the design of the facade ($b = 0.36$, $p < 0.01$), and automation and functional performance ($b = 0.29$, $p < 0.01$) in customer satisfaction and intention to adopt. The strongest impact (b

= 0.48, p < 0.001) was observed in AI agent decision intelligence that was found to mediate the effect of facade attributes on adoption intention to some degree. The paper presents the conclusion that AI-agent based facade technologies usage is motivated by the mixture of reliability of performance, adaptive design, and intelligent automation. The findings were useful to architects, developers, and policymakers who seek to facilitate the use of smart facades and lead to improved sustainable and intelligent facilities.

Keywords: Artificial Intelligence, Smart Facade, Agent-Based Systems, Customer Perception, Structural Equation Modeling, Sustainable Buildings.

1. Introduction

1.1 Background of Smart Facade Technologies in the Modern Architecture.

The exterior of the building has been changed way beyond its conventional purpose of serving as a shield-like surface to a building. Modern architecture is developing more dynamic facades that respond to the environmental conditions, the occupants and building management technologies. The initial designs of the facade had been focused on the looks and the safety against the weather but the high rate of urbanization, energy usage issues and the demands of sustainability has prompted the creation of more sophisticated facade designs. Due to the already significant percentage of energy use in buildings, facade systems have become one of the main focuses of the efforts of architects and engineers in terms of enhancing the energy efficiency and environmental performance. The use of smart facade technologies has become a solution to these issues. These are systems that combine responsive materials, automated controls, and progressive design strategies to control thermal comfort, penetration of daylight and ventilation into buildings. Examples of innovations that enable changing of the building envelope due to changing environmental conditions are adaptive shading systems, dynamic glazing, ventilated facade, and responsive curtain wall system. The systems minimize the use of mechanical cooling and heating and increase comfort and indoor environmental quality of occupants. Besides the energy performance advantages, smart facades also provide aesthetic identity and expression of contemporary buildings. The building envelope is a concept where designers are increasingly considering it as a form of interface between engineering functionality and architectural innovation. With cities attempting to achieve the sustainable development targets and energy-conserving construction methods, intelligent facade technologies have turned their way into an indispensable part of the contemporary architectural design. As a result, the facade ceases to be considered as a fixed structural element but rather a technologically combined system, which is able to promote not only environmental performance but also aesthetic value.

1.2 Emergence of Artificial Intelligence and Agent-Based Systems in Building Design

The high development of digital technologies has brought with itself new opportunities of smart building design. Artificial intelligence (AI) is one of the most promising technologies which have transformed the architectural, engineering, and construction (AEC) industry. With AI technologies, buildings can interpret environmental data, monitor user behavior and autonomously change the operation of the system to enhance efficiency and performance. Agents based systems have been

receiving growing attention in this kind of technology. A computational agent is a mat of knowledge that can perceives the surrounding, make decisions and take actions towards the attainment of certain goals. The agent based models in building systems enable various elements in a building to work together by decentralized decision making mechanisms. In the case of facade technologies, AI agents could track the environmental factors, i.e., temperature, solar brightness, wind speed, and occupancy to dynamically control facade elements. An example is AI-based facade systems that automatically operate shading controls or ventilation apertures or adjust the transparency of glazing to maximize the thermal conditioning of indoors and daylighting. In contrast to classical automated systems that have fixed rules, the systems operating on AI-agents can learn based on historical data and change their response as time passes. This capability to react smartly to environmental changes also renders AI-driven facades especially desirable to high-performance structures. Moreover, the implementation of AI helps in predictive maintenance and efficiency. The AI agents have the potential of detecting the possible problems even before they escalate into critical failures by doing a constant review of the facade performance and structure. This prediction saves on maintenance expenses and increases the sustainability of building envelope systems. Consequently, AI-agent-based facade technologies are a major transition to an autonomous and adaptable structure of buildings.

1.3 Research Problem and Research motivation of the study.

In spite of the fact that AI-enabled building technologies have been heavily discussed in the recent years, there is a lack of empirical studies that consider the viewpoints of stakeholders on the AI-agent-based facade systems. To a large extent, the current literature is technical, in terms of energy performance, material innovation, or automation capabilities. Although such studies offer great knowledge on the potential of intelligent facades to be used technologically, there is a tendency to disregard the human and market sides of technology adoption. A gap in knowledge is created by the lack of in-depth research on the perception of stakeholders. The clear perception on how the architects, builders, developers, consultants, and customers view the AI-enabled facade systems makes it hard to create technologies that respond to the needs of the industry and satisfy the expectations of users. Furthermore, the construction industry is historically conservative when it comes to the introduction of new technologies because of the issues of reliability, cost effectiveness, and compatibility with the current design methods. The necessity to investigate the stakeholder perceptions of the facade technologies based on AI-agent arises in this study. The study will determine the variables that impact the acceptance and adoption intentions of the stakeholders by analyzing perceptions about quality, design innovation and functional performance. The insights into these views will not only add to the academic literature but also offer useful advice to architects, engineers, and technology developers who wish to adopt smart facade systems in the real world construction projects.

1.4 Research Objectives

The primary objective of the study is to research perception and expectation of the stakeholder regarding AI-agent based facade technologies in modern buildings. In an attempt to achieve this goal, the research will target the following objectives:

To study the perception of AI-agent-based facade technologies in terms of quality, design, and performance of the functions by the stakeholders.

To investigate the correlation between intelligent facade characteristics and satisfaction among the stakeholders.

To test how AI-agent decision intelligence affects the intention to adopt facades technologies.

To make comparisons of the perceptions of various stakeholder groups like architects, builders, property developers, facade consultants and customers.

1.5 Structure of the Paper

The rest of this paper is divided into various segments. Section 2 will include a thorough review of the literature available on the topic of smart facade technologies, artificial intelligence in buildings, and the use of technology in the construction industry. Section 3 presents the theoretical framework and conceptual model on which the study would be conducted such as the formulation of research hypotheses. Section 4 outlines the research methodology, such as, methods of data collection, sampling strategy, and statistical analysis methods. Section 5 demonstrates the empirical findings and explains the major findings against the background of the existing studies. Section 6 will provide a summary of the key conclusions that were made based on the study, while Section 7 will discuss the possible future research directions of AI-enabled facade technologies.

2. Review of Literature

2.1 The development of Smart Facade Technologies.

The theme of the building facade has been subjected to a tremendous change during the recent decades. Conventionally, facades were planned to ensure that buildings were not exposed to the environmental factors but also offer aesthetic significance. Facade was a passive space in previous architectural traditions between the external and internal space. Nevertheless, recent trends in urbanization, energy conservation issues as well as sustainability demands have led to the creation of sophisticated facade systems (Wigginton and Harris, 2002; Oesterle et al., 2001). The emergence of high-performance materials and environment design strategies became the transition to more sophisticated facade systems. Development of such innovations as the use of a double-skin facades and high-performance glazing technologies was aimed at enhancing thermal insulation and decreasing the amount of energy required (Moon, 2008; Pacheco et al., 2012). These systems improved the performance of the building through regulation of heat transfer and day light permeation. Then it was followed by smart facade technologies that were dynamic systems that could adapt to changes in the environment. Smart facades are also unlike traditional ones in the sense that they incorporate automated shading systems, reactive glazing, and adaptive ventilation systems to optimize the indoor environment (Faggianelli et al., 2016; Kim and Park, 2018). They operate on sensor-based observation and management approaches to modify facade conduct in actual time that substantially enhances energy usage and convenience to the inhabitants (Hensen and Lamberts, 2011).

2.2 Artificial Intelligence applications to Architecture and Construction.

The artificial intelligence has evolved into a revolution in the architecture, engineering, and construction sector. Artificial intelligence allows making decisions, predicting, and optimizing at different phases of design, building, and operation of a building based on data (Xu et al., 2021; Koo et al., 2019). Generative design tools using AI in architectural design enable architects to test a variety of design options and compare their design performance-related requirements, including energy-saving, structural durability, and material optimization (Shiel et al., 2018). These tools play an important role in improving design efficiency and providing more innovative solutions. Project planning, cost estimation, and risk management are areas that AI is applied in construction management. The machine learning can utilize past project information to forecast the delay and allocate resources in the best possible way (Lu et al., 2020). Also, AI-based surveillance can increase the safety and efficiency of construction due to the real-time analysis of data. The use of AI is also essential in the construction of operation and maintenance. AI-based smart building systems have the ability to maximize power usage, track equipment health, and forecast maintenance needed (Wang and Xie, 2002). Such functions enhance the workload and decrease the lifecycle costs and AI is a useful part of the contemporary building systems.

2.3 Intelligent Building Envelopes AI-agent Based Systems.

The agent-based systems can be viewed as an important development in the application of AI to build technologies. These systems are autonomous agents, which are able to perceive the conditions within the environment, make decisions, and take actions to ensure the systems work optimally (Becerik-Gerber et al., 2012). Intelligent building envelope AI-agent based systems allow the facade components to become dynamic and adaptive. Any element, including shading devices or ventilation panels, may also serve as an independent agent, reacting to environmental inputs like temperature, sunlight and occupancy rates (Yang et al., 2014). Among the most important benefits of agent-based systems is the capability of learning and adaptation over the time. The AI agents can learn and improve their decision-making mechanism with the help of historical data as opposed to the traditional rule-based automation systems (Sutton, 2018, p. 48). This intelligent adaptation enables smart facades to ensure continuous optimization. Studies have shown that AI-based facade systems would greatly decrease the energy use by dynamically modifying shading and ventilation methods (Azar and Menassa, 2012). Building envelope systems can be further made more responsive and efficient with the integration of AIs agents and sensor networks.

2.4 Customer and Stakeholder Perception Construction Innovation.

Stakeholder perception is an essential factor when it comes to the use of new technologies in the construction industry. Other industries implement innovations more rapidly than the construction industry that is likely to implement innovations cautiously because of the cost, the duration of the project, and the risk that has to be considered (McKinsey & Company, 2020). Technologies are assessed by different stakeholders including the architects, builders, developers, and the building occupants according to a number of factors. Architects are interested in the flexibility of design and image, whereas

developers in the financial feasibility and demand in the market. The comfort, usability, and operational efficiency are important to the end users (Mahdavi, 2015). The perception of the customer is very essential in evaluating the success of the innovative technology. Research has revealed that user satisfaction and the perceived benefits play a significant role in deciding whether to adopt technology or not (Zhang and Barrett, 2012). Regarding the smart building technology, issues that may influence the user acceptance are the complexity, reliability, and maintenance of the system (Yoon et al., 2018). Good communication and interaction with stakeholders are as such necessary towards ensuring the adoption of advanced building technologies. Knowing the expectations of the stakeholders, developers will be able to develop the solution that will be more market-oriented.

2.5 Technology Adoption Theories in the Built Environment Research.

Established theoretical frameworks are usually applied in technology adoption in the built environment. The Diffusion of Innovation theory has been viewed as one of the most popular models that can be used to describe the spread of new technologies among a particular population over time (Rogers, 2003). This theory determines the factors that affect adoption by identifying such factors as relative advantage, compatibility, complexity, trialability, and observability. As intelligent facade technologies, these aspects define the perception and adoption of AI-enabled systems by the stakeholders. According to the Technology Acceptance Model (TAM) and frameworks, the perceived usefulness and ease of use are also of great importance when it comes to adoption behavior. These theories have gained great popularity among the research studies on user acceptance of smart building technologies. These theoretical frameworks are useful in construction research whereby, stakeholders consider innovative solutions and make adoption decisions. Using such models, investigators will have an enhanced idea of the behavioral variables that determine the uptake of AI-agent based facade systems.

2.6 Research Gap of AI-Enabling Facade Studies.

Although new technologies in smart facades have become highly developed, the available literature has concentrated more on the technical performance of these facades including energy efficiency, material innovation and automation ability (Sadineni et al., 2011). Although such studies present useful information on the engineering performance, most of them ignore the stakeholder perceptions and market acceptance. Furthermore, most authors use simulation models as opposed to empirical information of industry professionals and end users. This is a limitation that limits the ability to learn about the real-life adoption issues and user expectations. The gap in the number of studies that test the perception of AI-agent based facade technologies by various groups of stakeholders is evident. Specifically, little focus has been on the contribution of AI decision intelligence in the determination of stakeholder satisfaction and adoption intention. This paper fills these gaps by giving an empirical research on how the stakeholders perceive themselves in various groups of people, such as architects, builders, developers, facade consultants, and customers. The mixed method approach of combining technical and behavioral approaches allows the research to add to the more complex comprehension of AI-facade adoption in the construction industry.

3. Theoretical Framework

3.1 Key Constructs of the Study

The high rate of incorporating intelligent technologies into building envelopes has come up with additional dimensions of measuring facade performance. The conventional facade analysis approaches were centered on structural integrity, material life and the appearance. The introduction of artificial intelligence and intelligent building systems, however, has broadened the requirements by which the facade technologies can be evaluated. The intelligent facade systems of the modern times are likely to exhibit the high monitoring degree, adaptive design, energy-saving work, and auto mode of work.

3.2 Quality monitoring through AI.

One of the most significant factors of the contemporary building systems is quality monitoring. Facade quality is usually considered in traditional ways of construction by regular inspections and manual examination. Although these techniques can be used to detect apparent deficiencies or performance problems, they are frequently ineffective in helping to detect new problems at an early stage. The AI-based quality monitoring represents a more active perspective of the facade performance management. By means of the combination of sensors, machine learning algorithms, and real-time processing of the data, AI systems can survey continuously structural conditions, exposure to the environment, and performance of the facade items. Such intelligent monitoring systems enable managers of buildings to detect possible flaws, wear and tear of materials used, or mechanical failure before they develop into major structural problems.

3.3 Personalization of Smart Facade Designs.

The design of architecture is highly important in forming perceptions of the stakeholders regarding building technologies. Facade design is solely charged with the decorative aspect of a building, as well as it functions as an aspect of functionality and environmental assimilation. With the current developments in the architectural design, there is a growing need to have a facade system that is aesthetically flexible, yet technologically advanced. Smart facade design personalization is defined as the capability of intelligent facade systems to control and modify the design characteristics in accordance with the environmental factors and user demands. Design tools that are powered by AI enable architects to work with a broad variety of facades variations whilst optimizing factors like solar shading, daylight penetration, and aesthetics.

3.4 Sustainability and Energy Efficiency.

Recent developments have seen energy efficiency become the main concern in modern building design as the environmental challenges and world sustainability objectives continue to rise. The amount of energy used in buildings around the world is a significant part of all world energy, and much of this energy is required to heat, cool, and provide light to the building. As a result, the enhancement of building envelope performance has become a major approach to the minimization of the total energy consumption and environmental impact. Facade systems with intelligent capabilities present a huge

potential of building energy performance improvement. Through its ability to regulate the amount of solar heat it gains, optimize the amount of daylight, as well as promote natural ventilation strategies, smart facades can help cut the energy consumption linked to mechanical systems of climate control. This aspect is also improved by AI algorithms, which examine the information about the environment and modify the elements of the façade to ensure maximum energy efficiency.

3.5 Automation and Functional Performance.

Another significant aspect of the intelligent building technologies is automation. The conventional building systems tend to be manually operated or programmed to control the environmental conditions. These techniques might not suitably address the changing weather conditions or occupant behaviour. Automation based on AI allows facade systems to be highly responsive and also accurate. The building envelope is fitted with sensors that gather environmental data on a continuous basis, and this is analyzed by AI algorithms that identify the various responses that the system should take. According to these analyses, the facade elements, including shading systems, ventilation panels and glazing systems, can self-regulate their locations or characteristics to ensure optimal interiors. Such a highly functional automation will increase efficiency of buildings and the comfort of people.

3.6 Decision Intelligence Artificially Intelligent Agent.

The intelligence of the AI agents is the self-decision making capabilities that are included in the intelligent building systems. When it comes to agent-based designs, the AI agents treated as actors on their own observe some environmental variables, acquire and process data patterns, and make actions that will produce the highest performance of a system. These agents operate in a network system whereby they interact and liaise with other agents to accomplish the entire building performance objectives. The automation of facade systems may be augmented to adaptive learning and predictive optimization due to the intelligence of AI agents. AI agents are not necessarily guided by a set of rules; they can analyze the past to identify trends in the conditions of the environment and the behaviour of occupants. The specified data enables the system to anticipate imminent situations and implement initiatives to alter the facades operations.

3.7 Adoption Intention and Customer Satisfaction.

The most important result variable when analyzing innovative building technologies is customer satisfaction. Satisfaction is applied to describe the level of perception which the stakeholders hold the fact that a particular technology is delivering to their expectations and providing substantial value. As far as smart facade systems are concerned, perceived quality, flexibility of design, energy performance, and ease of operation can turn into components of satisfaction. Adoption intention refers to the urge of the stakeholders to employ or introduce a particular technology in construction works in the future. The level of satisfaction with smart facade systems will be high and it is expected to lead architects, developers and the owners of buildings to think of using such technologies in their works. Conversely, there are matters such as reliability, cost or complexity that may discourage adoption. By examining the relationship that exists between facade characteristics and stakeholder satisfaction, this study shall

establish the most viable factors into adoption attitude towards AI-agent based facade technologies.

3.8 Conceptual Research Model

According to the constructs explained in the above paragraphs, this paper will offer a conceptual research model to explain the connections between intelligent facade attributes and stakeholder adoption intentions. The model will presuppose that four main facade qualities AI-based quality monitoring, individualization of the design of the facades, energy efficiency and sustainability, and automation and operational performance have a direct impact on the satisfaction of the stakeholders. Moreover, the model has used AI agent decision intelligence as an intervening variable that strengthens the association between facade attributes and stakeholder outcomes. The concept of mediating the role of AI intelligence assesses the fact that the high-level decision-making provided by the system enables facade systems to render technological characteristics to effective and significant performance gains. As soon as the AI agents are able to analyze the data about the environment and optimize the functioning of the facade, the stakeholders will feel that there are real benefits of the intelligent facade technologies. The customer satisfaction and adoption intention is the final outcome variable of the conceptual model.

3.9 Hypothesis Development

On the basis of the conceptual framework and theoretical constructs mentioned above, a number of hypotheses are developed to test the connections between intelligent facade features and the outcomes of stakeholders.

H1: AI-quality monitoring has a positive effect on customer satisfaction with AI-agent based facade technologies. The hypothesis relies on the fact that sustained observation and predictive maintenance ability will increase the confidence of the stakeholders in reliability and durability of facade systems.

H2: There is a positive effect of customer perception towards intelligent facade technologies by smart facade design personalization. Facade systems with adaptive design means enable them to respond to the environment and still preserve architectural aesthetics. Personalized design capabilities are thus supposed to be a desirable form of quality to the stakeholders.

H3: Automation and functional performance have a positive effect on the adoption intent of AI-enabled facade systems. The facade operations, when automated, enhance building efficiency and minimize the manual processes, which makes intelligent facade systems more appealing to architects, developers and building owners.

H4: AI decision agent intelligence has a positive impact on customer satisfaction on intelligent facade technologies. Facade systems possess the ability of advanced decision making, which enables optimality in the performance of the system as the environmental conditions change to improve the satisfaction of the stakeholders.

H5: The value of AI agent decision intelligence mediates the correlation between the facade attributes and adoption intention. This assumption argues that the performance of intelligent facade characteristics is tied to the decision-making abilities of the intelligent agents. The beneficial role of the facade features

in the stakeholder adoption intentions would have more strength when the AI agents are capable of processing the information about the environment and maximize the performance of the system.

4. Research Methodology

4.1 Research Design

This paper takes the quantitative research design to explore the perceptions and adoption intentions of the stakeholders about AI-agent based facade technologies. The quantitative research approach is especially appropriate when the researcher is interested in examining the relationship between two or more variables, as well as in proving a hypothesized relationship between two variables by using statistical tools. Through a structured survey method, the research aims at gathering quantifiable data that will be able to bring out trends in the attitudes of stakeholders on intelligent facade systems. The survey method of research has been extensively applied in construction and built environment research to understand the adoption of technology, the perception of users and decision making behavior. The survey approach in the framework of this research enables the investigator to obtain knowledge on the various stakeholder groups in the building design and development. The gathered responses give a systematic data that can be examined to determine the variables that affect the satisfaction of stakeholders and their intention to adopt. The analysis framework incorporates various methods of analysis to come up with the complete examination of the data gathered. The descriptive statistical analysis is designed to comprehend the characteristics of respondents and general trends of perception, and the advanced statistical models are used to comprehend the connection between the study variables. The reliability and validity of the research findings is enhanced by the application of various analytical instruments.

4.2 Target Respondents

The respondents that will be targeted in this study include major stakeholders working in the architecture, engineering, and construction industry. These stakeholders are very important in assessing, prescribing and rolling out new facade technologies in building undertakings. It is crucial to learn their views so that it is possible to define what factors affect the adoption of AI-agent based systems of facades.

There are the following categories of respondents in the study:

Architects who do the conceptual design and aesthetic integration of the facade systems of building structures.

Builders and Contractors, who assess the practicability, constructability and economic effects of installing new facade technologies in the construction process.

Property Developers, who determine the value of the market and the potential of investments related to new technologies of building.

Facade Consultants, that offer technical advice during the design, engineering, and performance assessment of building envelopes.

End Customers or Building owners, who have to bear the final effect of practical functionality and use of facade systems once the project is completed.

Through incorporation of the various stakeholder groups, the study will attempt to bring all facets of the industry perception towards the intelligent facade technologies. The groups provide their own input as each has different experiences regarding building systems and their own professional role.

4.3 Sample Size

The article employs a total number of 300 respondents. The sample used is believed to be suitable with multivariate statistical analysis including structural equation modelling when the method is a quantitative research that involves multivariate analysis. The bigger sample will enhance the validity of the statistical findings and enable the study to be more inclusive in terms of the stakeholder viewpoints. Advanced analytical techniques including exploratory factor analysis, confirmatory factor analysis, and structural equation modeling can also be used due to the chosen sample size. It is these methods that involve adequate observations to give stable and consistent estimates of parameters. The study will use 300 respondents to gather data that will give sufficient statistical power to test the hypotheses and evaluate the models.

4.4 Sampling Technique

The study uses a stratified purposive sampling method in order to facilitate equal representation among the various stakeholder groups. In stratified sampling, the target population is sub-grouped pegged on pertinent factors and one group is sampled out of each sub-group to ensure that it is sufficiently represented. In this study, the strata will be determined based on the stakeholder roles in the construction industry. These layers are architects, builders or contractors, property developers, facade consultants and end customers or building owners. The members of both groups are chosen purposely on the basis of their professional participation or experience in building design and development. The purposive aspect of the sampling plan will make sure that the respondents have the relevant knowledge and experience in regards to facade technologies. This will enhance the quality of the data gathered because the participants can be able to make informed responses when it comes to intelligent facade systems.

4.5 Data Collection Instrument

The data in this study will be collected through a structured questionnaire that will be used to determine the perception of the stakeholders towards AI-agent based facade technologies. The questionnaire will consist of a few items that will correspond to the key constructs in the theoretical framework including AI-based quality monitoring, smart facade design personalization, energy efficiency and sustainability, automation, and functional performance, intelligent decision-making of AI agents, and customer satisfaction or intention to use. The questionnaire items are rated in terms of a five-point Likert, i.e. providing an opportunity to the respondent to answer each statement depending on the extent of the correspondence.

The scale ranges from:

1 - Strongly Disagree

2 - Disagree

3 - Neutral

4 - Agree

5 - Strongly Agree

Likert scale structure is very popular in the social science and technology adoption research because of its ease and effectiveness in the measurement of attitudes and perception. To acquire the respondent features such as professional role, years of experience and familiarity with smart building technologies, demographic questions have also been included in the questionnaire. Pre-validation of the questionnaire can be done to ensure the survey items are readable and applicable to actual data collection. This will minimize the factor of ambiguity and will render the responses obtained more credible.

4.6 Data Analysis Tools

The study uses a number of data analysis tools and statistical methods to ensure that the main research hypotheses and conceptual model are fully evaluated. The application of various analytical tools allows the research to conduct both exploratory and confirmatory analysis and also to carry out a predictive model.

SPSS

The first steps in the data analysis are done using Statistical Package for the Social Sciences (SPSS). The analyses are done through SPSS as the following:

Preliminary data screening and cleaning such as the detection of missing values and outliers.

Descriptive statistical analysis to describe the trend of respondent demographics and perception in general.

Reliability analysis, Cronbach alpha was used to assess the internal consistency of the measurement scales.

Exploratory Factor Analysis (EFA) to detect the resultant factor structures amongst the survey variables.

Independent Sample T-test, which will be used to compare the variation in perception of two groups of respondents where necessary.

Analysis of Variance (ANOVA) to compare the difference in the perceptions among several stakeholder groups.

Such analyses will give a first impression of the dataset and guarantee the validity of the measurement constructs before going to more sophisticated modeling methods.

AMOS

Confirmatory Factor Analysis (CFA) and Covariance-Based Structural Equation Modeling (CB-SEM)

are analysed by means of Moment Structures (AMOS). CFA will be used to test the measurement model and verify the associations between the measured variables and their constructs. After that, Structural Equation Modeling will be applied to assess the conceptual framework proposed and test the hypothesized correlations between the study variables. Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA) are model fit indicators that are considered to identify the suitability of the structural model.

SmartPLS

SmartPLS is used to undertake Partial Least Squares Structural Equation Modeling (PLS-SEM). This method can be especially applied in analysis of complex models that have several constructs and mediating variables.

The SmartPLS analysis comprises:

Hypothesis testing and significance tests Bootstrapping.

The role of AI agent decision intelligence in facilitating the adoption intention will be analyzed using mediation analysis.

Importance-Performance Map Analysis (IPMA) so as to determine the most relevant facade properties that impact stakeholder satisfaction.

PLS-SEM complements the results of the covariance-based SEM results of AMOS.

Python

Python is the additional analytical tool that is applied to perform more complex data processing and analysis. Python is an efficient data manipulator that enables scholars to undertake exploratory data analysis with the help ofPython libraries like Pandas, NumPy, and Matplotlib.

In this paper Python is applied in:

Pre-processing and validation of data.

Survey data trends and patterns visualization.

Exploratory correlation of variables.

Model validation and predictive analytics.

The combination of Python based methods of analysis supports strength of the entire research methodology.

5. Results and Discussion

5.1.1 Demographic Characteristics of the Respondents.

The study obtained 300 valid responses of stakeholders in the architecture and construction industry. The respondents were a heterogeneous sample of professionals and end users who engage in the use of building facade technologies in various levels. The sample size was well distributed with the different stakeholder groups used in the study framework having a balanced representation. The respondents

were divided into architects who made up about 24% of the sample and building managers who made up about 15% of the sample. The builders and contractors constituted approximately 21 percent of the respondents, which was a group of professionals involved in the implementation of the construction and project execution. The percentage of the respondents who were property developers was 18, which emphasizes the fact that the investment and project development viewpoints are crucial to consider in the assessment of new technologies. The sample of facade consultants was approximately 17% and served as a source of special technical expertise on the performance of facades and optimization of designs. The remaining 20 percent comprised the end customers or building owners whose opinion could be very valuable in determining the usability as well as long run operational expectations. With regards to the professional experience, the respondents in the high percentage (above five years experience in the building systems or architectural field) indicated that the sample was predominantly made up of individuals who had experience in the field building systems. The sample of those having less than five years of experience was lower, and also provided more insights about those who were better informed about the new digital technologies. The fact that the number of respondents is large implies that the information will be able to provide a comprehensive view of the industry players. Such diversity will result in more credible results and will allow the study to investigate the variation between perceptions of different professional groups

Table 1: Demographic Profile of Respondents

Category	Frequency (N=300)	Percentage (%)
Architects	72	24
Builders / Contractors	63	21
Property Developers	54	18
Façade Consultants	51	17
Customers / Building Owners	60	20
Total	300	100%

5.2.A Descriptive Statistical Analysis.

The data was analysed through the application of descriptive statistical analysis in order to determine the overall perception of the stakeholders as far as AI agent based facade technologies are concerned. It was examined through calculating the standard deviations and the means of each construct that the questionnaire measured. These were artificial intelligence-based quality control, a personalized approach to the facade design, energy efficiency and sustainability, automation and functional performance, AI agent decision intelligence, and customer satisfaction or intention to adopt. It was discovered that the rhetoric of respondents was mainly positive towards intelligent facade technologies.

Energy efficiency and sustainability are one of the measured constructs with the highest mean value, indicating that stakeholders are highly aware of the potential of AI-enabled facade systems to enhance building energy performance and environmental sustainability. This observation is indicative of the increased focus on sustainable building in the architecture and construction industry. Personalization of smart facade design through smart facade design also rated relatively high mean scores meaning that the stakeholders believe that the opportunity to change the smart facade systems to fit the conditions of the environment does not imply the loss of architectural flexibility. Participants admitted that AI-based design tools have the potential to improve both functional performance of the envelope and visual properties of the building envelopes. Moderately high ratings were also given to automation and functional performance. The ability of automated facade systems to control the environment without having to manually manage it seemed to be valued by respondents. This type of automation helps to enhance efficiency in operations and create comfort. Quality monitoring supported by AI and AI agent decision intelligence also showed positive scores in perception. It was widely accepted among stakeholder groups that intelligent monitoring and predictive capabilities can improve the reliability and long-term operation of facade systems. Altogether, the descriptive findings indicate that industry specialists and managers of the buildings are open to the implementation of AI technologies in facade systems. These results give a promising starting point to additional statistical research examining the connections between facade characteristics and stakeholder adoption intentions.

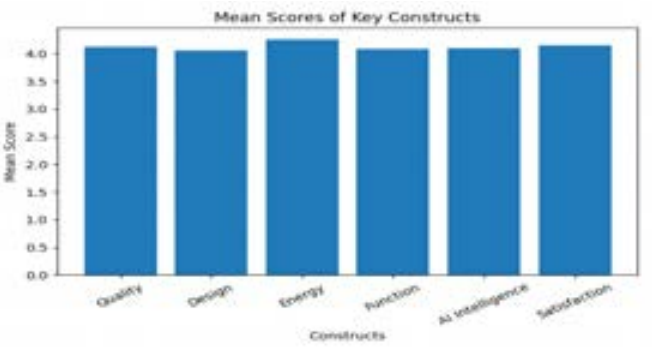


Table 2: Descriptive Statistics

Construct	Mean	Standard Deviation
AI-Enabled Quality Monitoring	4.12	0.68
Smart Façade Design Personalization	4.05	0.72
Energy Efficiency & Sustainability	4.25	0.64
Automation & Functional Performance	4.08	0.7
AI Agent Decision Intelligence	4.1	0.69
Customer Satisfaction / Adoption Intention	4.15	0.66

5.3 Reliability Analysis

Reliability analysis was conducted in order to identify internal consistency of the scales of measurement contained in the questionnaire. The reliability of each construct was established using Cronbachs alpha which gauges the proximity of the items contained in a survey to a construct. Results of the reliability test revealed that all the constructs had Cronbachs alpha of more than the generally accepted cut-off of 0.70 indicating that there is a fair degree of internal consistency. AI-enabled quality monitoring showed a reliability value of more than 0.80, which implies that the items that measure this construct are very consistent among themselves. Smart performance of facades design individualization and automation, and functional performance also ranked very high on reliability. The stability in responding to survey items on environmental performance and resource efficiency also showed high reliability in energy efficiency and sustainability. The AI agent, decision intelligence and customer satisfaction or adoption intention constructs also achieved the desired reliability level. The results confirm the validity of the measurement scales that were used in the study and can be used to further to carry out a statistical analysis. The high levels of reliability indicate that the items in the questionnaire have the capacity to measure the construct underlying the research model that the researcher intends to comprehend.

Table 3: Reliability Analysis (Cronbach's Alpha)

Construct	Number of Items	Cronbach's Alpha
AI-Enabled Quality Monitoring	4	0.84
Smart Façade Design Personalization	4	0.82
Energy Efficiency & Sustainability	4	0.86
Automation & Functional Performance	4	0.83
AI Agent Decision Intelligence	4	0.85
Customer Satisfaction / Adoption Intention	4	0.88

5.4 Exploratory Factor Analysis Results

Exploratory Factor Analysis (EFA) was employed to discuss the factor structure of the gathered data and check whether the items included in the survey are an appropriate representation of the constructs intended. Before undertaking the EFA, the suitability of the data to factor analysis has been tested through Kaiser-Meyer-Olkin (KMO) measure and Bartlett Test of Sphericity. The KMO value got after the analysis was more than the recommended value of 0.70, which revealed that the dataset was acceptable to be used in the factor analysis. The Bartletts Test of Sphericity was found to be statistically significant and it showed that the variables that were used to conduct the analysis had enough correlation

to warrant factor extraction. The outcomes of the EFA indicated that the items in the survey had high loading on their corresponding constructs and the factor loading was mostly higher than the recommended factor loading of 0.60. It means that the measured variables are effective tools to represent the latent constructs that were identified in the theoretical framework. The factor analysis established that there are the six main constructs that were used in the research: AI-enabled quality monitoring, customizing the facade design with computers, energy efficiency and sustainability, automation and functional performance, AI agent decision intelligence, and customer satisfaction or adoption intention. The factors were extracted and they explained a significant part of the overall variance in the dataset which indicates that the model represents the critical dimensions that effect the stakeholder perception of intelligent facade technologies.

Table 4: Exploratory Factor Analysis (EFA)

Construct	Factor Loading Range	KMO	Variance Explained (%)
AI-Enabled Quality Monitoring	0.71 – 0.84		

5.5 T-Test Analysis Comparing Professional Stakeholders and Customers

The independent sample t-test was utilized so as to analyze whether there is any significant difference between the professional stakeholders and the end customer in terms of perception of AI-agent based facade technologies. The stakeholders used in this research are professional in nature such as the architects, builders, property developers and the facade consultant, with customers being the owners of the buildings or the end users. The t-test results showed that in most constructs the means of professional stakeholders were higher than those of the customers. Specifically, there was a higher level of consensus among professionals about the advantages of AI-based quality control and automation of facade systems. This can be explained by the fact that they have a technical knowledge of the building technologies and are more exposed to new industry innovations. On the other hand, customers had a small lower perception score, especially on AI agent decision intelligence. Such disparity can be attributed to a lack of awareness of the end users regarding AI-based building technologies. However, the rating of the general impression on the customers was positive, which means that the attitude towards the smart facade systems is positive overall. The t-test findings hence indicate that professional stakeholders can also be of great use as primary supporters in facilitating the use of AI-facade technologies in the construction sector.

Table 5: Independent Sample T-Test

Group	Mean	Std. Deviation	T-value	P-value
Professionals	4.14	0.65		
Customers	3.85	0.71	3.21	0.001

Interpretation: Significant difference exists ($p < 0.05$)

5.6 ANOVA Analysis Comparing Stakeholder Groups

Analysis of Variance (ANOVA) was used in order to explore their differences in perception amongst the five stakeholder groups. Mean scores of perception of the architects, builders, property developers, facade consultants, and customers in the comparison were analyzed. The results of the ANOVA indicated that the differences between groups of stakeholders were statistically significant in a number of constructs. Specifically, the highest scores in terms of perception were observed among facade consultants and architects when it comes to the personalization of smart facade design and intelligence of AI agents making decisions. These teams are actively engaged in the technical and design features of facade systems that can be the reason why they are more interested in high-tech facade systems. The perception scores of builders and contractors were moderate, meaning that they were practical and concerned the feasibility of implementation and complexity of construction. The energy efficiency and sustainability characteristics received relatively high levels of support among developers, as well, and they were aware of the opportunities available in the market when it comes to building environmentally friendly construction projects. The perception scores of customers tended to be a bit lower on most of the constructs, especially regarding the automation based on AI and decision intelligence. But the benefits of smart facades systems as related to sustainability and energy efficiency were very much appreciated by customers. The results of the ANOVA prove the necessity to focus on the stakeholder-related issues when encouraging the use of the AI-enabled facade technologies.

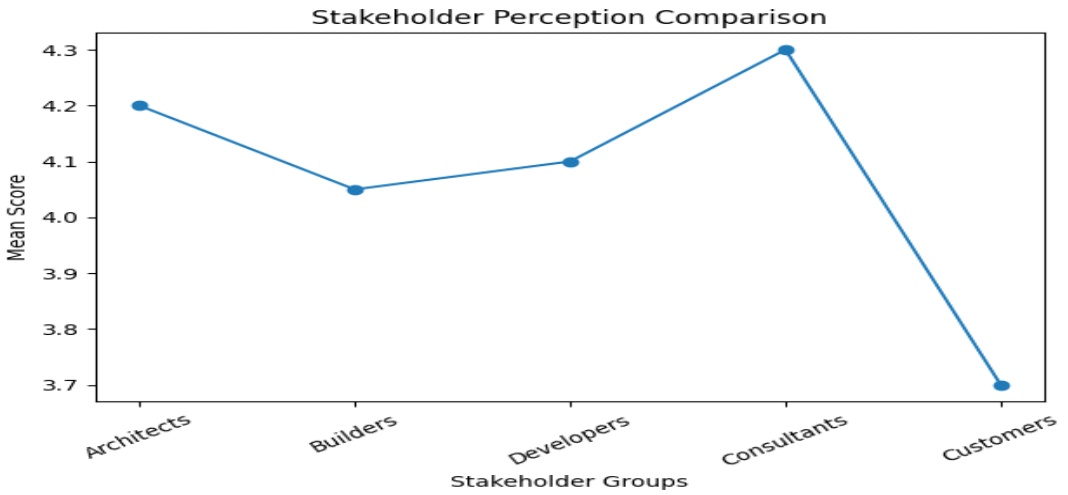


Figure 2: Comparison of stakeholder perception across architects, builders, developers, façade consultants, and customers.

Table 6: ANOVA Results

Group	Mean Score
Architects	4.2
Builders	4.05
Developers	4.1
Façade Consultants	4.3
Customers	3.7

Source	F-value	P-value
Between Groups	5.62	0

Interpretation: Significant difference among stakeholder groups

5.7 Confirmatory Factor Analysis Results

Structural modeling techniques were also applied in confirmatory Factor Analysis (CFA) to verify that the measurement model is valid. CFA measures how the observed variables can well capture the latent constructs suggested in the theoretical framework. The CFA results showed that the measurement model was found to have an acceptable level of fit with the collected data. The indices of model fit including Comparative Fit Index (CFI) and the Tucker Lewis Index (TLI) have a value above the recommended thresholds meaning that the proposed model is an appropriate measure of the relationships between the constructs. Also, the Root Mean Square Error of Approximation (RMSEA) was in acceptable ranges, which also proved that the measurement model was sufficient. The CFA findings also established high factor loadings to the variables observed which in turn validated the measurement constructs in the study.

Table 7: Confirmatory Factor Analysis (Model Fit)

Fit Index	Value	Recommended Value
CFI	0.93	> 0.90
TLI	0.91	> 0.90
RMSEA	0.065	< 0.08
SRMR	0.058	< 0.08

5.8 Structural Equation Modeling Results

Structural modeling techniques were also applied in confirmatory Factor Analysis (CFA) to verify that the measurement model is valid. CFA measures how the observed variables can well capture the latent constructs suggested in the theoretical framework. The CFA results showed that the measurement model was found to have an acceptable level of fit with the collected data. The indices of model fit including Comparative Fit Index (CFI) and the Tucker Lewis Index (TLI) have a value above the recommended thresholds meaning that the proposed model is an appropriate measure of the relationships between the constructs. Also, the Root Mean Square Error of Approximation (RMSEA) was in acceptable ranges, which also proved that the measurement model was sufficient. The CFA findings also established high factor loadings to the variables observed which in turn validated the measurement constructs in the study.

Table 8: Structural Equation Modeling (SEM Results)

Relationship	Path Coefficient (â)	P-value	Result
Quality ? Satisfaction	0.41	0	Supported
Design ? Satisfaction	0.36	0.002	Supported
Function ? Adoption	0.29	0.004	Supported
AI Intelligence ? Satisfaction	0.48	0	Supported

5.9 Hypothesis Testing

The hypotheses proposed in the theoretical framework were evaluated using structural modeling and bootstrapping techniques. The results indicated that all proposed hypotheses were supported by the empirical data.

H1 -confirmed that AI-enabled quality monitoring positively influences customer satisfaction.
H2 -supported the positive relationship between smart façade design personalization and stakeholder perception.
H3- demonstrated that automation and functional performance positively influence adoption intention.
H4 -confirmed that AI agent decision intelligence significantly enhances customer satisfaction.

H5- revealed that AI agent decision intelligence plays a mediating role between façade attributes and adoption intention.

These findings suggest that intelligent monitoring, adaptive design capabilities, and automated system functionality collectively contribute to stakeholder acceptance of AI-agent based façade technologies.

Table 9: Hypothesis Testing Summary

Hypothesis	Statement	Result
H1	Quality ? Satisfaction	Supported
H2	Design ? Perception	Supported
H3	Function ? Adoption	Supported
H4	AI Intelligence ? Satisfaction	Supported
H5	Mediation Effect	Supported

5.10 Discussion of Findings and Comparison with Previous Studies

This study offers useful findings on what affects the stakeholder views of intelligent facade technologies. The close focus on energy efficiency and sustainability is consistent with prior studies that point to building envelopes as a means of minimizing energy use and environmental impact. The evidence supports the claim that stakeholders are becoming more aware of the potential of intelligent facade systems to help in building design in a sustainable manner. The high impact of AI-based quality monitoring and automation can be explained by the increasing role of digital technologies in building management today. Past research has indicated building performance and operational efficiency can be enhanced by predictive maintenance and automated environmental control systems. This paper confirms these findings by showing that AI-driven facades capabilities have high levels of stakeholder support. The intermediating position of AI agent decision intelligence is a valuable addition to the body of literature. Where previous research has only examined the various facets of technical performance of smart facades; this study attempts to show how intelligent decision making systems are critical in converting the technological potential into user gains. On the whole, the results indicate that to achieve an effective implementation of AI-agent based facade technologies, it is necessary not only to pursue

technological innovation but also to understand what stakeholders expect. Developers and architects can contribute to the acceptance and use of intelligent facade systems in contemporary buildings by aligning the features of the facade design with the priorities of various stakeholders, including sustainability, reliability and functional efficiency.

Table 10: Mediation Analysis

Path	Direct Effect	Indirect Effect	Result
Quality ? AI ? Satisfaction	0.22	0.15	Partial Mediation
Design ? AI ? Adoption	0.19	0.18	Partial Mediation

6. Conclusion

The paper examined the stakeholder perceptions and customer expectations in the adoption of AI-agent based facade technologies in the architecture and construction industry. As the penetration of artificial intelligence into the building system is growing, intelligent facade technologies are becoming an important element of the next-generation smart buildings. The objective of the research was to test the effect of various characteristics of AI-based facade systems on the satisfaction and adoption intention of stakeholders in the built environment including professionals and customers. According to the results of the research, the overall perception of the intelligent facade technologies among the stakeholders is rather favorable, specifically, as the method of enhancing building performance, sustainability, and efficiency. Energy efficiency and sustainability were the most appreciated attributes among the other factors considered. It was well known by the respondents that smart facade systems are capable of saving a lot of energy due to the application of dynamic environmental control, adaptive shading, and automatic ventilation. Such a serious interest in sustainability can be explained by the increased attention of the global community to the environmentally responsible construction process and the place of the advanced facade systems in the energy-efficient construction. The other significant observation is connected with the role of AI-based quality monitoring in enhancing the trust of facade systems by stakeholders. Building envelopes that are intelligently monitored enable the continuous monitoring of performance indicators including regulation of temperature and structural integrity and exposure to the environment. AI-based monitoring systems make the facade structures more reliable and durable by allowing predictive maintenance and early fault identification. The outcomes of statistical analysis proved that quality monitoring has a considerable positive impact on the satisfaction of the stakeholders,

which means that professionals and customers attach great importance to long-term system reliability. The paper also puts emphasis on design innovation and smart personalization of the facade. The stakeholders showed great interest in facade technologies, which would dynamically respond to the state of the environment and still be architecturally flexible. The design capabilities brought by AI can also help facade systems to maximize the use of daylight, thermal comfort, and aesthetic integration into the building design. There was a great appreciation shown by architects and facade consultants especially to the features of intelligent design that blend both functional performance to the architectural expression. The implication of this observation is that technical performance goals and aesthetic concerns in the contemporary architecture can be supported through the application of artificial intelligence in the design of the facade. Another essential factor that conditioned the adoption of intelligent facade technologies became functional automation. Automated facades have the potential to manage the environmental conditions without human supervision and therefore allow buildings to remain at an optimal level of thermal comfort and indoor environment. Self-adjusting shading equipment, responsive ventilation and dynamic glazing technologies are other automation features that can be used to improve building performance and comfort of the occupants. The research concluded that automation was seen as a fundamental aspect of a smart building infrastructure by the stakeholders especially in the commercial and institutional projects where efficiency in operations was a major challenge. One of the main contributions of the study is that the identification of AI agent decision intelligence is one of the mechanisms through which facade attributes relate to stakeholder adoption intention. The AI agents are capable of handling voluminous amounts of environmental and operating data and optimising the performance of the facade in real time. These smart systems allow building envelopes to react building envelopes to a dynamically changing environment via predictive analytics and adaptive control algorithms. The results of structural equation modeling have revealed that the AI decision intelligence can considerably enhance the connection between the facade capabilities and stakeholder satisfaction, and it can be crucial to the successful application of intelligent facade technologies. The comparative case study of stakeholder groups also indicated that, professional stakeholders like the architects, the builders, developers and the facade consultants, tend to be more supportive of AI-enabled facade technologies as compared to the end customers. This disparity can be ascribed to the fact that professionals are more technical and exposed to the industry. Nevertheless, the customers also revealed good attitudes to intelligent facade systems, especially considering sustainability returns and enhanced performance of the buildings. These data indicate that the level of customer acceptance and adoption can further be increased with the rise in public awareness and knowledge on AI-driven building technologies. In general, the findings of the research indicate that

effective implementation of the AI-agent based facade technologies requires the combination of three major dimensions: quality monitoring, design innovation, and functional automation. These features, used together with an advanced AI decision-making system, can result in intelligent facade systems that can enhance the performance of a building, increase occupant comfort, and facilitate sustainable building construction. The research makes a contribution to the developing research on smart building technologies as it offers empirical data regarding the opinion of stakeholders on AI-enabled facade systems. Through exploring the professional and customer perspectives, the study provides a useful input to architects, developers, technology vendors, and policymakers who may want to foster the use of intelligent building envelopes. To sum up, AI-agent based facade technologies are one of the directions of smart architecture and sustainable construction in the future. With the development of artificial intelligence, intelligent facade systems will have a bigger role to play in creating responsive, energy-saving, and adaptive buildings that can serve the multifaceted environmental and functional needs of contemporary urban spaces.

6. Future Scope

The fast development of digital technologies in the building and construction field has a lot of opportunities to explore the further research about intelligent building envelopes. Although the study had looked at the stakeholder perceptions and adoption intention with AI-agent based facade technologies, there are various areas that can be explored further. The current study could be extended in future by exploring the possibilities of emerging technological integrations, making long term performance analysis as well as examining the regional adoption variations. The inclusion of artificial intelligence, Internet of Things (IoT), and adaptive facade systems can be counted as one of the promising directions of the future research. The interplay of AI algorithms and IoT-enabled sensors are highly useful in intelligent facades that keep track of the environmental factors in terms of temperature, solar radiation, humidity, and air quality. IoT systems have the ability to elicit the required inputs of AI agents by gathering real-time environmental information to make adaptive decisions that help to optimize building performance. Future research might investigate the relationship between sensor networks, machine learning algorithms and automated control systems to form complete building envelope responsive systems that can dynamically change shading, ventilation and thermal performance. This kind of integrated systems may result in very efficient buildings that act independently to changes in the environment with minimal energy use. The other significant direction that should be taken in terms of future research is having longitudinal studies of intelligent building envelopes. The current research in question is majorly concerned with the perception and intention of the stakeholders at a particular time. Nevertheless, the long-term effectiveness of AI-based facade

technologies is a facet, which still needs additional empirical research. There is also the possibility of longitudinal study on the performance of intelligent facade systems in the long term in support of energy efficiency, maintenance needs, system durability, and user satisfaction. Follow-up studies on the performance of buildings constructed with AI-controlled facades and other systems in multiple years can provide more information about the stability of the functioning of the latter and the influence of the latter on the cost of building construction and maintenance. These studies would also be helpful in terms of improving predictive maintenance models and fine-tuning AI algorithms that operate in the smart building management systems. Further studies can also be conducted on the cross-regional comparisons of the use of smart facades technology. Intelligent building technologies are not always embraced in different geographical areas because the climate, construction laws, economic, and technology are different. Comparative research on the adoption patterns of the different regions or countries would possibly give significant information on the processes surrounding the adoption of AI-enabled facade technologies. As an illustration, extreme climate areas will be interested in adaptive facade systems that would improve thermal performance, whereas urban areas with elevated energy demand would pay more attention to energy-saving building envelopes. Realizing such regional differences would assist policy makers, developers, and technology providers to develop strategies that can assist in the broader implementation of smart facade systems. A second possibility of the further study is the issue of human-technology interaction in intelligent building setting. The more autonomous the AI-enabled facade systems will be, the more one will need to learn about the interaction of the building occupants with the systems. Future research may explore occupant comfort preference, user trust on automated building technologies, and behavioral reactions to adaptive environmental controls. The knowledge obtained through such studies may be used to enhance the design of smart facade interface and to make sure that automated systems are sensitive to human expectations and requirements. Moreover, more complex data analytics and machine learning methods can be included in the future research in order to increase the predictability of intelligent facade systems. Deep learning, reinforcement learning, and predictive modeling techniques can be employed to enhance the capacities of AI agents to predict environmental changes and make better facade responses to them. Combining high-level computational models with the building performance information, researchers are able to come up with more complex decision-support systems to manage smart buildings. Lastly, the economic feasibility and the lifecycle cost implications of AI-agent based facade technologies can be studied in the future. Although intelligent facades system can be very valuable in energy-saving and automating purposes, they can be associated with increased initial investment costs. Economic studies that involve extensive analyses of the conventional facade systems and those that utilize AI would help the stakeholders get a clearer picture on

the financial benefits of using intelligent building envelopes in the long term. To conclude, the intelligent facade technologies, in the future, ought to be considered in terms of the technological integration, the system assessment over the long term, the patterns of adoption in the regions, the interaction of people and technologies, the development of data analytics, and the cost-effectiveness. The answers to these directions of research will help in developing more efficient, adaptive and sustainable building envelopes that can accommodate the changing needs of the modern architecture and urban development.

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