Revolutionizing Vertical Transport: A Comprehensive Study on the Evolution and Optimization of Elevators

Heena Khanna[1], Jasmeet Kaur[2], Kiran Pilania[3], Saksham Jamwal[4]

[1]Assistant Professor, [2,3,4]Student
School of Computer Application
Lovely Professional University, Punjab, India

Abstract: Elevator system plays a crucial role in modern high-rise buildings, facilitating efficient vertical transportation for occupants. However, traditional elevator control systems often suffer from inefficiencies in energy consumption and user experience. With growing concerns about sustainability and user satisfaction, there is a need for smart elevator control strategies that can optimize energy usage while enhancing service quality. The review critically evaluates different proposed smart elevator control systems, highlighting their strengths, limitations, and potential applications. This review paper categorizes elevators on the basis of IOT, Monitoring systems, Safety of elevators, Contactless Elevators, Energy-efficient elevators, and elevators that work on priority-based mechanisms. Relevant research papers in this domain are analyzed and compared. The review concludes by discussing potential opportunities for further research and commercialization prospects.

Index Terms: Elevator, Internet of Things, Cost Efficiency, Smart Elevator Control Systems, Elevator Control Technologies, Energy Efficiency, User Experience, Machine Learning, Artificial Intelligence.

I. INTRODUCTION

Elevators are indispensable in modern high-rise buildings, providing efficient vertical transportation for occupants [1]. However, traditional elevator control systems often face challenges in energy consumption and user experience, driving a need for innovative solutions that address sustainability and user satisfaction. This review critically examines smart elevator control strategies aimed at optimizing energy usage and enhancing service quality [2]. The review evaluates various proposed smart elevator control systems, scrutinizing their strengths, limitations, and potential applications. Relevant patent filings and research papers in this domain are analysed and compared, providing a comprehensive understanding of the current state of the art. The review highlights the potential benefits of smart elevator control systems, including reduced energy consumption, improved user satisfaction, and increased operational efficiency.

Finally, the review identifies potential opportunities for further research and commercialization prospects in the development of smart elevator control strategies. This includes exploring emerging technologies, such as machine learning and artificial intelligence, and their potential to optimize energy usage and user experience in elevator systems. By addressing the challenges and opportunities in this domain, the review aims to contribute to the advancement of smart elevator control systems and the vertical transportation industry as a whole. [3]

II. RELATED SURVEYS

The research progress in elevators has been reviewed by many. This section summarizes some of the significant research being done in the last decade.
[4] summarizes research approaches for predicting faults in elevator mechanical and electrical equipment, with an emphasis on digital twin technology. It covers techniques like multi-source sensor data fusion, risk analysis of brake performance degradation, and brake fault analysis. The article discusses research ideas, methodologies, and limitations in fault prediction using digital twins in elevators. [5] investigates sustainability initiatives and innovations in the elevator industry, which have been prompted by the global drive for sustainability. It investigates how the industry is aligning with the United Nations' definition of sustainability and assesses the impact of these initiatives on current and future generations. Key focus areas include technological innovations, marketing strategies, and the overall goal of promoting sustainability in the elevator industry. [6] examines the limitations and future challenges of optimizing energy usage in sustainable high-rise buildings, taking into account budget constraints, organizational policies, legal issues,

technical infrastructure, and cultural/geographic aspects. The study emphasizes the importance of overcoming these barriers in order to promote the widespread adoption of energy optimization strategies in current and future high-rise constructions. [7] examines recent advances in elevator technology and their impact on tall building construction and operation. It covers both hardware-based innovations (AC and gearless motors, MRL elevators, regenerative drives, and LED lighting) and software-based solutions (destination dispatching systems, predictive maintenance applications). Future vertical transportation models, such as multi-directional and circulating multi-car elevators, are also discussed. The paper suggests potential research areas, including robotics, 3D printing, and the impact of the COVID-19 pandemic on elevator design. [8]conducts a critical literature review and theoretical analysis to create a systematic framework for Lift Planning and Optimization (LPO). It examines 108 journal papers from 1990 to 2019, identifying trends in LPO research, and highlighting an increased emphasis on integrated issues using mixed methods. With evolving construction innovations like modular construction posing new challenges, innovative modeling methods such as virtual reality simulation and intelligent algorithms are becoming more popular. The proposed framework aims to address the complexity and dynamics of LPO systematically while also suggesting future research directions in this field. [9] study looks at elevator-related deaths over 30 years in nine US jurisdictions. Despite safety improvements, elevators continue to pose hazards, particularly to maintenance and construction workers, employees, and those engaging in risky behavior. The study pinpoints several causes of elevator-related deaths, including asphyxia and blunt force trauma. It also discusses preventive measures to avoid such incidents in the future. [10] examines recent advancements in elevator technology and their impact on tall building development, with a focus on major projects such as the One World Trade Center, Shanghai Tower, Burj Khalifa, Kingdom Tower, and the Empire State Building retrofit. It provides a comprehensive overview of elevator design aspects in a non-technical manner, discussing future transportation models such as vertical subways, space lifts, and electromagnetic levitation. The paper emphasizes the importance of interdisciplinary research for integrating elevators into skyscrapers and enabling innovative architectural designs.

Table 1: A summary of all the reviews and surveys

Year	Paper	Survey
2024	[4]	A Review of Fault Prediction Methods For High Speed Elevator Brakes For Service Safety.
2024	[5]	Sustainability In the Elevator Industry-Impact Review.
2023	[6]	A Review of Limitations And Future Challenges In Optimization Of Energy In Sustainable High-Rise Buildings.
2023	[7]	Smart Elevator Systems
2020	[8]	Lift Planning and Optimization In Construction: A Thirty-Year Review.
2019	[9]	Elevator-Related Deaths
2015	[10]	Tall Buildings and Elevators: A Review Of Recent Technological Advances

III. ANALYSIS OF EXISTING WORK

Based on IOT

[11] proposes an IoT application to improve elevator safety and maintenance efficiency. The system, which combines communication modules, an IoT platform, and a front-end software application, allows for real-time monitoring of elevator status as well as emergency response and scheduled maintenance notifications. The IoT platform collects, stores, and analyzes elevator system data, and alerts are sent to technicians and maintenance firms via the mobile application. Additionally, the application includes a map function that allows technicians to quickly navigate to elevators during emergencies. Overall, the project's goal is to improve passenger safety by ensuring timely elevator maintenance and emergency response. [12] investigates the design of an intelligent and remote-controlled elevator system, leveraging IoT and sensor technology. Through expert consultation and the Delphi method, 18 major tasks for such a system were identified, including monitoring items, sensor selection, and installation locations. The study aims to provide foundational information for the development of advanced elevator systems, facilitating subsequent research on technological requirements and maintenance strategies.
[13] proposes a conceptual framework for an Automated Online Condition Monitoring System for Elevators (AOCMSE) that incorporates IoT techniques to improve reliability. Vibration sensors are embedded in traction motors to collect data, which is then processed into 2D grayscale images. The Maximum Response-based Directional Texture Pattern (MRDTP) is used to extract features, while Principal Component Analysis (PCA) is used to reduce dimensions.

The Extreme Learning Machine (ELM) is used to classify faults into five categories. Faults are reported to the maintenance team to avoid elevator failures and their consequences.

[14] introduces an energy-efficient elevator scheduling algorithm aimed at reducing car movements in order to save motor energy and promote green wireless communications. The algorithm reduces IoT message exchanges between the Scheduler and Car subsystems, primarily via the core function AssignCar(r), which routes requests to the nearest car. Emulation results for four cars show significant energy consumption reductions compared to previous methods, with gains ranging from 37.89% to 49.43% across different request patterns. [15] describes an elevator light curtain monitoring system based on Internet of Things (IoT) technology. The system's components include an infrared transmitting and receiving module, a control module, and a Bluetooth module. The infrared module sends and receives signals, whereas the control module processes information and coordinates actions. The Bluetooth module connects to a mobile phone platform to transmit data and execute instructions.

Table 2: IoT based models

Year Published	Paper	Technique/Method	Focus	Strength & Weakness	Result
2024	[15]	Elevator Light Curtain Monitoring System Based on Internet of Things	designs an IoT-based elevator light curtain monitoring system utilizing infrared and Bluetooth modules for data transmission and mobile connectivity.	integrates infrared technology and Bluetooth connectivity to enable real-time monitoring and control of elevator light curtains, enhancing safety and convenience.	designed system effectively transmits data and instructions between the elevator light curtain and mobile phone platform, ensuring prompt action and enhancing user safety.
2022	[11]	IoT Based Automated Elevator Emergency Alert System Using Android Mobile Application	creation of an Internet of Things application	addresses a critical need for real-time monitoring and maintenance of elevators using an Internet of Things (IoT) application	By incorporating features such as real-time status monitoring, emergency notifications, and a map feature for technician navigation, the system provides a comprehensive solution to reduce elevator failures and improve overall safety.
2022	[12]	Remote-control System for Elevator with Sensor Technology	explores the design considerations and requirements for implementing an intelligent and remote-control elevator system using IoT and sensor technology.	employs the Delphi method and expert input to identify 18 major tasks essential for designing an elevator system suitable for remote-control and intelligent operation.	describes monitoring items, associated sensors/devices, and installation locations for an intelligent elevator system, allowing for the development of improved remote-control elevator

					systems and guiding future research on equipment requirements and maintenance strategies.
2020	[14]	Green Elevator Scheduling Based on IoT Communications	introduces an energy-saving elevator scheduling algorithm that minimizes IoT message exchanges and promotes green wireless communications.	efficiently reduces elevator car movements to conserve motor energy, primarily through the core function AssignCar(r), leading to significant energy consumption reductions compared to previous methods.	demonstrate energy consumption reductions ranging from 37.89% to 49.43% across various request patterns for four elevator cars, showcasing the effectiveness of the proposed algorithm.
2019	[13]	A Conceptual Framework for the Design and Development of Automated Online Condition Monitoring System for Elevators (AOCMSE) Using IoT	conceptual framework for an automated online condition monitoring system for elevators using IoT techniques, leveraging vibration sensors and advanced feature extraction methods to prevent failures.	integrates IoT technology with vibration data analysis and machine learning algorithms to enable proactive maintenance of elevator systems, enhancing their reliability in smart cities.	uses maximum response-based directional texture pattern (MRDTP), principal component analysis (PCA), and extreme learning machine (ELM) to classify elevator faults into five categories, allowing for timely fault detection and prevention via information sent to the maintenance team.

Based on Contactless Elevator

The elevator business is among the many areas that have seen a rapid adoption of touchless or contactless technologies due to the COVID-19 epidemic. Because these technologies do not require physical touch with surfaces that can harbor and disseminate the virus, they help reduce the danger of contact transmission.Voice recognition is one of the main touchless technologies used in elevators. Without touching any buttons or surfaces, passengers can use voice instructions to summon the elevator and record their destination floor. In comparison to conventional elevator controls, voice recognition systems in elevators can lower the risk of surface contamination by up to 90%, according to a paper published by the International Organization for Standardization (ISO). Using virtual buttons or QR codes on smartphones is another well-liked touchless approach. With this method, users can call the elevator and choose their preferred floor by scanning a QR code or using a virtual interface on their cell phones. This method lowers the chance of touch transmission over shared surfaces by taking advantage of smartphones' broad adoption. Elevators are also being equipped with gesture recognition sensors, which enable users to operate the elevator with hand gestures or body motions [16]. Gesture-controlled elevators, such as those made by Otis Elevator Company, can recognize and react to preprogrammed gestures. Examples of these gestures include waving a hand to summon an elevator or making a particular motion to choose a floor. When touchless elevator controls are used instead of typical elevator buttons, the risk of surface contamination can be reduced by up to 80%, per a study conducted by the University of California, Los Angeles (UCLA). [17] Leading technology company Hitachi has led the way in creating and deploying touchless elevator solutions. With Hitachi's "Touchless Elevator Operation System," which debuted in 2020, users can use voice commands or their cell phones to call and operate elevators. Around the world, this system has been installed in several structures, including offices, residential complexes, and hospitals. In addition, a World Health Organization (WHO) paper makes the case that touchless technology implementation in public areas, like elevators, can be extremely beneficial in reducing the transmission of infectious diseases like COVID-19 [18] and enhancing general public health. The need for touchless or contactless technologies is predicted to increase as the globe struggles to deal with the pandemic's effects. This demand is anticipated not only in the elevator industry but also in some other industries, including healthcare, hotel, and retail. By providing a more secure and hygienic means of engaging with common surfaces, these technologies eventually enhance public health and quality of life.

Table 3: IoT based models

Year Published	Paper	Technique/Method	Focus	Strength & Weakness	Result
2023	[19]	Non-Contact IoT Device for Wireless Remote Elevator Control using servo motor	Contact-Free	Remote control without any additional wiring connection but requires battery charge time to time	This IoT device is designed as an add-on non-contact tool that is placed over the original elevator button panel and presses the original buttons with servomotors. The IoT device's non-contact control features were validated through experimental testing in real-world operational conditions.
2022	[18]	A contact-free elevator system that uses smart speech recognition, contact-free perceptual buttons, gesture recognition sensors, and a web page browser activated by quick response codes to operate an elevator	Contact-Free	Use of various technologies like speech recognition, gesture sensor, qr code, etc. cost and maintenance may go high.	The contact-free epidemic prevention elevator is equipped with a wooden frame, panels inside and outside the elevator car, contact-free perceptual buttons, a speech recognizer, and display panels. QR code stickers and a speech recognizer instruction label are displayed. We tested the circuit connection, prototype system, buttons, and button circuits.
2022	[16]	a touchless interface based on gesture recognition for the control of an elevator.	Contact-Free	This system doesn't require any special training for use. Multiple users in the lift may find it difficult to select floor	presented a touchless interface to control an elevator by means of hand gestures. Which described three different modes of interaction based on three implementations of the system interface, i.e. the linear widgets, the circular widget, and the buttons widget. The interaction

				at the same time and may waste time as it require a specific distance to command the lift.	starts when the user puts his hand nearer than a fixed distance from the elevator display.
2020	[20]	Touchless virtual controls using infrared light	Contact-Free	low cost and light weight design which is easy to install and can be used by other public machines.	developed control panels with which elevators can be operated without the need of touching any surface by fingers and it does not require any special kind of material, stylus or device.

Based on Monitoring System

[21] The functional and performance requirements of the lift safety monitoring system were examined, and the system's viability was assessed from the standpoints of market demand, technological advancements, and actual operation. After that, the system's design scheme—which merged the Client/Server (C/S) and Broker/Server (B/S) architectures—was shown. The front-end monitoring system used the common real-time transport protocol (RTP) for transmission and interacted with the command-and-control center as its client. At last, the safety monitoring system for lifts was put into place. The test demonstrated that the suggested lift safety monitoring system's functionality and performance met the system's intended goal and had usefulness in real-world applications. [22] this paper presents the concept of a "intelligent lift" system, which will greatly facilitate people's daily travel and improve the safety and reliability of lifts while also making them more intelligent and better services to society. The system is based on traditional Internet technology and increases the use of microprocessors, automatic sensing, remote control, speech recognition, and the establishment of lift safety operation regulation system. [23] suggested a real-time lift monitoring system that, using real-time operating data gathered from several sensors, can quickly and reliably diagnose lift malfunctions and abnormal states. The stability and dependability of the system were successfully guaranteed by the suggested multi-sensor fusion algorithm. Using a web client on several platforms and a local network, it was simple to get real-time monitoring result. The web client could also be delivered to a cloud platform to enable distant access. The system's usefulness was demonstrated by the test result. [24] availability, usefulness, and limits of intelligent well-monitoring systems will be reviewed in this research. It will go into detail on data-gathering problems, such as dependability, resolution, and data processing. There will be examples of suitable sensor/data sets that can be used for various IW applications. This document will help the completion engineer choose the right combination of downhole sensors for a certain integrated water well application. [25] Because new deep features are extracted from the dataset in addition to the pre-existing features, deep learning techniques yield superior outcomes. This paper presents the application of random forest classifiers on the publicly available dataset and evaluates the existing literature. An accuracy of 91.50% on average was achieved in our model. Sensor data that was recorded based on maintenance operations was what made up the dataset.

Table 3: Monitoring based models

Year Published	Paper	Technique/Method	Focus	Strength & Weakness	Result
2018	[21]	Internet of Things (IoT)-based elevator safety monitoring system	Designing a system to monitor elevator safety using IoT technology	makes use of Internet of Things technologies to watch and manage lift systems remotely. merges the client/server (C/S) and broker/server (B/S) architectures, possibly offering a dependable and expandable setup.	The IoT-powered lift safety monitoring system, which combines B/S and C/S systems, was successfully created, put into use, and tested. It demonstrated actual application value in improving lift safety by meeting the functional and performance requirements.
2018	[22]	Integration of multiple technologies to improve the dependability and safety of elevators, putting forth the idea of a "intelligent elevator" system.	Addressing issues with lift intelligence, safety, and dependability within the framework of the Chinese market.	Advocates for the fusion of several cutting-edge technologies, including speech recognition, remote control, autonomous sensing, and microprocessor technology.	To improve safety, dependability, and convenience when using lifts, the paper puts forth the idea of a "intelligent lift" system and advocates for the integration of cutting-edge technologies. Nevertheless, the material that is presented lacks specifics regarding the proposal's actual execution and results.
2021	[23]	A real-time lift monitoring system that detects aberrant states and diagnoses faults using a multi-sensor fusion technique.	Addressing how the rise in high-height structures has increased the significance of lift safety monitoring.	Real-time monitoring results can be accessed using web clients on multiple platforms via local network connection, and cloud platforms can be used for distant access. Test results are used to illustrate the system's value, suggesting that it has the potential to improve lift	The study suggests a multi-sensor fusion algorithm-based real-time lift monitoring system and presents test results to illustrate its use. To properly evaluate the system's efficacy and possible real-world applications, more information on its technological features, scalability, and practical implementation is necessary.

				dependability and safety.	
2012	[24]	Review and discussion of the existing sensors, problems with data collecting, application, and constraints related to intelligent well (IW) monitoring systems.	with an emphasis on monitoring systems, sensor selection, and data collecting, discussing the state of intelligent well technology today and the problems involved in incorporating it into the "Digital Oil Field" idea.	focuses on the difficulties in choosing the best sensors for certain IW applications, taking dependability, processing speed, and data resolution into account.	The purpose of the study is to analyse and evaluate intelligent well monitoring systems, with an emphasis on data acquisition challenges, sensor selection, and suitability for different IW applications. Although it offers insightful information on the difficulties and factors to be considered when putting IW technology into practice, more thorough research and empirical data would improve its usefulness in directing finishing engineers and educating industry stakeholders.
2021	[25]	Elevator maintenance and safety can be increased by implementing predictive maintenance utilising machine learning techniques, more especially random forest classifiers on sensor data.	addressing the necessity of prompt lift maintenance to avoid mishaps and monetary losses and suggesting predictive maintenance as a fix.	Examines the body of research on predictive maintenance and demonstrates how random forest classifiers are used on an open-source dataset to produce an impressive 91.50% average accuracy. makes use of sensor data that was captured during maintenance procedures to show how predictive maintenance is used in lift systems.	In order to achieve a high accuracy rate, the research proposes the implementation of predictive maintenance utilising random forest classifiers using lift sensor data. Although the paper does a good job of highlighting the advantages of predictive maintenance, it might benefit from additional information about the dataset and a more thorough examination of the difficulties and potential solutions.

Based on Safety of Elevator

[26] we use elevators to arrive to our destination early, but how safe are they really? Naturally, there is a great deal of risk. It is possible for the lift thread to break and falls rank among the leading causes of fatalities and major injuries. This paper describes how to use the Internet of Things for fall safety, backup power, and lift operation. This article

suggests an electro-hydraulic hybrid drive lift mechanism as a means of achieving energy savings. An auxiliary hydraulic system allows the motor's energy to be stored as hydraulic accumulator pressure, which may then be used again to maintain torque during motor start-up. [27] Elevator safety can also be improved because of the greater torque that the hydraulic system provides. The results of the simulation show that the suggested solution can save a significant amount of energy. The effectiveness of the suggested concept is further confirmed by the presentation of field test results using a lift in a real building setting. [28] As quickly as feasible, resolve the anomalous circumstances and lift safety failures. In this paper, the lift safety detection management system with big data at its core is presented, along with practical cases for verification and analysis, based on an understanding of the research status of the field and the big data technology theory. The final findings demonstrate how crucial it is to use big data technology in lift safety detection management. [29] A technique of safety management for lift users that is graded and classed is suggested by combining the likelihood and impact of accidents. The evaluation indices are defined simultaneously. Elevator risk assessment becomes more methodical and scientific when accident probability—which highlights the combined impact of four factors—management, environment, equipment, and personnel system—is integrated with the assessment of accident consequence. Elevator users can eliminate potential safety issues and save expenses by using the Safety Evaluation Index System instead of special equipment surveys. A case study demonstrates the effectiveness and validity of it. [30] In this study, a diagnostic approach for lift safety loop faults is proposed, along with a model structure for these defects.

Moreover, a method for gathering lift fault signals is created using this information, allowing for the extraction of relevant feature parameters and the subsequent multi-grained scanning of lift fault data. Finally, the lift safety loop problems may be diagnosed thanks to Cascade Forest. The experiment's findings demonstrate that, compared to BPNN, this method's diagnosis accuracy is 4% higher and its model operates 99.1% faster.

Table 4: Elevator Safety based models

Year Published	Paper	Technique/Method	Focus	Strength & Weakness	Result
2021	[26]	Talk about fall prevention, backup plans, and how IoT technology may be used to improve lift operation and safety.	Safety	Increases understanding of the significance of lift safety and the possible hazards that exist, including falls.	The study discusses the significance of lift safety and suggests many solutions, including IoT integration, fall protection, and backup systems. However, more information and proof are required to validate the efficacy of these approaches in improving lift safety and dependability.
2020	[27]	To save energy and improve safety, an electro-hydraulic hybrid drive lift system is being introduced.	Safety	suggests a unique approach that makes use of an electro-hydraulic hybrid driving system and has the potential to save a substantial amount of energy.	In order to address the issue of lift energy consumption, the paper suggests an electro-hydraulic hybrid drive lift system. In order to show the possible energy savings and effectiveness of the suggested system, simulation and field test data are presented. To properly evaluate its viability, scalability, and practical consequences for lift operation in real-world circumstances, further information and analysis are necessary.

2023	[28]	Big data technology is proposed to be used in a lift safety detection and monitoring system.	Safety	Suggests utilising big data technology to improve the identification and management of lift safety, which can offer reliable management techniques and monitoring systems.	suggests utilising big data technology to create a lift safety detection management system that will maximise safety management through the use of data gathered from lift sensors. Although it emphasises the significance and possible advantages of using big data technology in lift safety, further information and analysis would strengthen comprehension and support for the successful implementation of the suggested system.
2014	[29]	A coordinated theory-based system for classifying and grading lift safety management that incorporates a variety of variables, such as accident probabilities and effects, is proposed.	Safety	A coordinated theory-based system for classifying and grading lift safety management that incorporates a variety of variables, such as accident probabilities and effects, is proposed.	The study offers a thorough, coordination theory-based safety management approach for lifts that integrates several variables to evaluate safety concerns in an organised, methodical manner. Although a case study is used to illustrate the advantages of the suggested approach, further information and analysis would strengthen comprehension and advocate for its incorporation into lift safety management procedures.
2021	[30]	A diagnosis model structure, a fault signal gathering system, multi-grained scanning to extract fault features, and cascade forest diagnosis are all part of the proposed technique for identifying problems in lift safety loops.	Safety	suggests a thorough method that includes creating a fault signal collection system, building a diagnosis model structure, and using cutting-edge methods like Cascade Forest and Multi-Grained Scanning for	a procedure for identifying errors in lift safety loops that attempts to solve problems with existing diagnostic techniques. Although the experimental findings demonstrate the advantages of the suggested approach, more information and analysis would strengthen comprehension and advocate for its application in lift fault diagnosis procedures.

				fault diagnosis.	

Based on Energy Efficiency

[31] These days, increasing energy efficiency stands as the primary objective for buildings. Using the regenerative capacity of lifts is one method to improve energy efficiency. Supercapacitor-based energy storage devices are best suited for storing regenerative energy because of the unique needs of lift drives. In this paper, a bidirectional six-phase interleaved DC/DC converter and a bank of supercapacitors are proposed as an energy storage system. Through simulation studies, the energy savings of the suggested system were examined. Every physical restriction was considered when modelling the suggested system. Using PLECS, a simulation model of the current faculty lift system was built, and field measurements were used to confirm it. Using the validated simulation model and considering all physical constraints ensured reliable findings. [32] Software solutions like predictive maintenance apps, people flow solutions, standby mode, and destination dispatching systems are offered by manufacturers. Drones, robotization, rotating multi-car lift systems, and electromagnetic levitation are examples of future technologies. This article describes the technological developments of lifts. It talks about how to use new technologies to improve older, newer, and future structures. [33] Internet of Things (IoT) systems for energy efficiency in smart buildings. A prototype of this approach, which simulates an autonomous temperature and lighting control system in a university classroom, has been put into practice and reviewed. As anticipated, we found that the IMPReSS Context Manager facilitates quick system modifications. [34] In accordance with the energy efficiency categorization standards VDI 4707 and ISO 25745, the energy efficiency, total yearly energy consumption, and annual energy savings are computed and compared with the outcomes of measurements made at low and high travel demand. The needs for a future energy storage system are identified by carefully examining the regenerative cycles. The findings indicate that the lift system's energy efficiency rises with increased trip demand. If one simply looks at the outcomes that meet the lift energy efficiency classification standards, this effect is not readily apparent. Furthermore, lowering the energy usage in standby mode can further increase the lift system's overall energy efficiency. [35] Regenerative braking, in which the energy generated during braking is retained rather than released, replaces the standard braking system to lower the system's overall energy usage. When there is a significant energy demand, this energy is returned to the DC-bus.

Table 5: Energy Efficient based models

Year Published	Paper	Technique/Method	Focus	Strength & Weakness	Result
2022	[31]	The idea is to create an energy storage system that stores regenerative energy from lifts by using supercapacitors and a bidirectional, six-phase, interleaved DC/DC converter.	objective of increasing building energy efficiency by utilising lifts' regenerative potential and suggesting a special energy storage device for this use.	Acknowledges the need of enhancing building energy efficiency and suggests a solution suited to the particular needs of elevator drives.	an energy storage device that collects and stores regenerative energy from lifts; simulated studies and field measurements are used to validate the system's efficacy. Although it draws attention to the possible energy savings that the suggested method can produce, more information and analysis would strengthen the case for its application in actual building contexts.

2023	[32]	Review and analysis of technologies related to lifts, such as electromagnetic levitation, circulating multi-car lift systems, robotization, drones, destination dispatching systems, regenerative drives, lift ropes, LED lighting, standby mode, predictive maintenance applications, and AC and gearless motors.	Energy-efficiency, user experience and performance.	gives information about the possible uses and advantages of these technologies in various kinds of structures.	Gives a useful summary of the technological developments in lifts and sheds light on future trends and their uses. It is a helpful tool for scholars, regulators, and industry experts who want to learn more about how lift technology is developing and how it affects building design, energy efficiency, and user experience.
2015	[33]	Creation and assessment of a Systems Development Platform (SDP) to facilitate the quick development of context-aware and Internet of Things (IoT) systems for smart building energy efficiency.	Energy-efficiency	offers a workable answer along with a prototype that may be used in a university classroom. demonstrates how well the IMPReSS Context Manager works to enable quick system changes.	offers a viable method for tackling energy inefficiency in smart buildings by utilising the SDP of the IMPReSS project to create context-aware Internet of Things systems. It uses a prototype implementation in a university classroom context to show the solution's viability and efficacy. Nevertheless, additional investigation and practical implementations are required to confirm the scalability and suitability of the suggested methodology in various public building contexts.
2021	[34]	An examination using measurement techniques of the	The paper's main objective is to	increases the reliability of the results by	offers insightful information about how trip demand

		energy savings and regenerative lift operating in a faculty lift during a week with high travel demand. comparison with earlier data collected during a period of decreased travel demand. energy savings calculated utilising two distinct methods. Evaluation of the energy impact of standby. energy efficiency, total yearly energy consumption, and annual energy savings are calculated using the VDI 4707 and ISO 25745-25745 energy efficiency classification criteria.	examine how travel demand affects energy savings and regenerative lift operation. It evaluates the impact of rising travel demand on the lift system's energy efficiency and contrasts the outcomes of scenarios with high and low travel demand.	evaluating the lift system's performance using measurements taken in the real world. gives information on how the energy efficiency of the lift system and trip demand are related, which can help with energy management strategy decision-making.	affects energy savings and regenerative lift operation. It emphasises how crucial it is to take into account actual operating conditions when evaluating lift energy efficiency and points out ways to increase overall energy efficiency by putting energy storage systems and standby energy reduction into practice, for example.
2017	[35]	Regenerative braking, in which the energy generated during braking is retained rather than released, replaces the standard braking system to lower the system's overall energy consumption. When there is a significant energy demand, this energy is returned to the DC-bus.	energy-efficiency	This research offers a novel and progressive solution to the problem of energy economy in traction lift systems: the use of regenerative braking systems.	The results of simulating two regenerative brake systems—one with a flywheel and the other using supercapacitors—are compared to data from an actual application.

Based on Priority mechanism

[36] Time is become a valuable resource in the modern society. To save as much time as possible, various methods and strategies are thus continuously used in all spheres of life. A growing number of these applications make use of wireless sensor networks. An lift system is a highly promising system that can be made substantially more efficient with the use of WSNs. Over the years, many initiatives have been made to increase the lift system's serving efficiency. In order to serve a larger number of customers in less time, this study suggests using the lift system more productively. People won't have to waste this precious time waiting for the lift; instead, they will be able to use it for other vital tasks. As a result, instead of wasting time waiting for the lift, people will be able to use this precious time for other vital and significant tasks. To accomplish this, we build the lift system on a wireless adhoc network of intelligent floors that include sensors and are capable of multi-hop communication. [37] Everyone works under time limitations in offices, hospitals and other commercial buildings, so a lift delay is not ideal. In this study, we offer methods to reduce travel time and power consumption by using a sensor-based check system, making a lift more 'intelligent' and efficient. If the lift car's maximum weight capacity is about to be reached on a floor during a hall call request, the lift will proceed to

the next command without halting there. The cabin lights will switch off if the lift doors are closed and it detects that the cabin is empty; otherwise, they will remain on. We have used ladder logic for PLC to replicate our intelligent lift design. [38] by being unable to function effectively when there is uncertainty brought on by a haphazard influx of individuals. Unlike the traditional lift control method, the suggested algorithm makes use of the data that the picture capture and processing system provides regarding the sizes of passenger groups and their wait times. The probabilistic decision-making model then uses this data to perform Bayesian inference and modify the variable parameters. The suggested solution makes use of the Expectation Maximization algorithm to guarantee that the data sets are full and the variable elimination technique to lower the computational cost involved in calculating marginal and conditional probabilities. [39] These variables will be handled by fuzzy logic, and the result will be lift movement priority. The PLC Out seal Mega V1.1 was utilised in this investigation as the lift's controller. The input may accept input without contact by using a proximity infrared sensor. Compilers, timers, and counters are examples of PLC functions that can be used to implement a lift system using fuzzy logic calculations. A relay is utilised as the output to drive the DC motor. Using an inventive lift operating system, the suggested approach aims to halt the spread of Covid-19.

Table 6: Priority Mechanism based models

Year Published	Paper	Technique/Method	Focus	Strength & Weakness	Result
2011	[36]	Installation of a lift system built on a wireless ad hoc network of sensor-equipped intelligent floors, allowing floors to communicate with one another and improving lift performance.	the necessity of utilising wireless sensor networks (WSNs) to increase the serving efficiency of lift systems in order to reduce passenger wait times and boost overall productivity.	suggests a unique method for building a wireless ad hoc network of intelligent floors using WSNs, allowing for real-time data exchange and communication to improve lift operation.	suggests a unique method for increasing the effectiveness of lift systems: putting in place a wireless ad hoc network of intelligent floors. Although it emphasises the potential advantages of the suggested method, more investigation and study are required to assess its viability, effectiveness, and practical consequences in lift systems found in real environments.
2020	[37]	A proposal for an intelligent lift system that uses a sensor-based check system to cut down on power consumption and trip time.	elevators must be made more efficient, especially in places like workplaces, medical facilities and commercial buildings where delays are not ideal. By using sensor inputs	demonstrates a methodical and organised approach to implementation by highlighting the usage of ladder logic for PLC (Programmable Logic Controller) to simulate the intelligent lift design.	suggests an intelligent lift system that uses a sensor-based check system to cut down on power usage and trip time, improving efficiency. Although it offers a workable strategy and simulation utilising ladder

			to inform its decisions, the suggested system seeks to maximise lift performance.		logic for PLC, more investigation and testing are required to confirm the viability and efficacy of the suggested solution in actual lift settings.
2019	[38]	the installation of a machine learning-based intelligent elevator control system that optimises elevator performance in multi-story buildings by applying the variable elimination technique and Bayesian inference.	The suggested technique makes use of image processing and acquisition to obtain data regarding waiting periods and the sizes of passenger groups. This data is then included into a probabilistic decision-making model to perform Bayesian inference and adjust the variable parameters for lift control.	suggests a cutting-edge method for gathering data on passenger behaviour in real time and optimising lift operation by combining image processing and machine learning algorithms. These methods include the variable elimination methodology and Bayesian inference.	In order to optimise elevator operation in multi-story buildings, this research provides an intelligent elevator control system based on machine learning techniques and Bayesian inference. Even though it shows encouraging results in raising user happiness, more investigation and testing are required to confirm the suggested algorithm's viability and efficacy in a variety of real-world contexts.
2021	[39]	Elevator systems that use the fuzzy logic method to reduce movement and implement touchless button operation in an effort to stop the spread of Covid-19.	the necessity of developing cutting-edge lift operating systems that limit movement and touchpoints in order to slow the spread of Covid-19. In order to prioritise lift movement	presents an innovative method for controlling input variables and allocating priority to lift movement using fuzzy logic, which could increase productivity and cut down on passenger wait times.	suggests a novel touchless button and fuzzy logic elevator operating system to minimise movement and cut down on touchpoints in an effort to slow the development of COVID-19. Although the method appears promising in resolving

			based on input factors including position, distance, direction, and lift capacity, the suggested solution uses fuzzy logic.		hygiene issues, more investigation and testing are required to confirm its efficacy and viability in a variety of real-world lift situations.

CONCLUSION AND FUTURE SCOPE

Real-time monitoring, predictive maintenance, dynamic dispatching, and energy optimization are some of the lift management advances made possible by SECS with IoT connection. SECS enhances lift reliability, optimizes user experience, and promotes sustainability objectives by utilizing IoT technologies. IoT-enabled elevators offer several energy and cost efficiency benefits, including:

- Energy-saving: SECS can optimize energy consumption based on occupancy, time of day, and weather conditions, leading to significant energy savings.
- Cost reduction: By reducing downtime and lowering maintenance costs, SECS can provide a rapid return on investment.
- Predictive maintenance: IoT-enabled elevators can monitor the health of elevator components in real time, allowing for proactive maintenance and reducing the risk of breakdowns.
- Remote monitoring: SECS enables remote monitoring and control, reducing the need for on-site visits and improving response times.

However, there are also challenges to consider, such as:

- Data privacy and security: Ensuring data privacy and security is crucial to protect user information and prevent unauthorized access to the elevator system.
- System stability: Ensuring system stability and reliability is essential for safe and efficient elevator operation.
- Integration: Integrating SECS with existing building management systems and infrastructure can be a complex process.
- Cost: The cost of implementing SECS can be a barrier to adoption, particularly in older buildings.

To address these challenges, further research and development are needed to optimize energy and cost efficiency, improve system stability and reliability, and enhance user experience.In conclusion, SECS offers significant energy and cost efficiency benefits for lift systems in modern buildings. However, addressing challenges related to data privacy, security, system stability, integration, and cost is essential to ensure successful implementation and widespread adoption.

REFERENCES

[1] A. Wood, S. Henry, and D. Safarik, “A Global Overview of 2014 Skyscrapers Best Tall Buildings,” 2014, Accessed: Mar. 30, 2024. [Online]. Available: www.ctbuh.org
[2] L. Da Van, Y. B. Lin, T. H. Wu, and Y. C. Lin, “An Intelligent Elevator Development and Management System,” IEEE Syst J, vol. 14, no. 2, pp. 3015–3026, Jun. 2020, doi: 10.1109/JSYST.2019.2919967.
[3] D. Chandankhede, S. Lokhande, J. Belkhode, S. Dhabarde, and R. Patil, “SMART ELEVATOR SYSTEM”.
[4] F. Zhang, K. Zhang, G. Xie, D. Ba, and A. Jiang, “A Review of Fault Prediction Methods for High Speed Elevator Brakes for Service Safety,” Lecture Notes in Electrical Engineering, vol. 1154 LNEE, pp. 522–528, 2024, doi: 10.1007/978-981-97-0665-5_68.
[5] “SUSTAINABILITY IN THE ELEVATOR INDUSTRY-IMPACT REVIEW. | Elevator World | EBSCOhost.” Accessed: Mar. 30, 2024. [Online]. Available:

https://openurl.ebsco.com/EPDB%3Agcd%3A9%3A13910713/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A175379328&crl=c
[6] S. Kadaei □□, “A review of limitations and future challenges in optimization of energy in sustainable high-rise buildings JAAS Journal of Art and Architecture Studies A REVIEW OF LIMITATIONS AND FUTURE CHALLENGES IN OPTIMIZATION OF ENERGY IN SUSTAINABLE HIGH-RISE BUILDINGS,” J. Art Arch. Stud, vol. 12, no. 2, pp. 27–34, 2023, doi: 10.54203/jaas.2023.4.
[7] K. Al-Kodmany, “Smart Elevator Systems,” Journal of Mechanical Materials and Mechanics Research, vol. 6, no. 1, pp. 41–53, Mar. 2023, doi: 10.30564/JMMMR.V6I1.5503.
[8] Z. Zhang and W. Pan, “Lift planning and optimization in construction: A thirty-year review,” Autom Constr, vol. 118, p. 103271, Oct. 2020, doi: 10.1016/J.AUTCON.2020.103271.
[9] J. A. Prahlow et al., “Elevator-Related Deaths,” J Forensic Sci, vol. 65, no. 3, pp. 823–832, May 2020, doi: 10.1111/1556-4029.14235.
[10] K. Al-Kodmany, “Tall Buildings and Elevators: A Review of Recent Technological Advances,” Buildings 2015, Vol. 5, Pages 1070-1104, vol. 5, no. 3, pp. 1070–1104, Sep. 2015, doi: 10.3390/BUILDINGS5031070.
[11] A. Sharma, A. Chatterjee, P. K. Thakur, S. Jha, and K. Sriharipriya, “IoT Based Automated Elevator Emergency Alert System Using Android Mobile Application,” IEEE International Conference on Data Science and Information System, ICDSIS 2022, 2022, doi: 10.1109/ICDSIS55133.2022.9915909.
[12] S.-C. Lai, M.-L. Yang, R.-J. Wang, J.-Y. Jhuang, M.-C. Ho, and Y.-C. Shiau, “Remote-control System for Elevator with Sensor Technology,” Sensors and Materials, vol. 34, no. 5, pp. 1757–1769, 2022, doi: 10.18494/SAM3827.
[13] M. S. Starvin and A. S. Alphonse, “A Conceptual Framework for the Design and Development of Automated Online Condition Monitoring System for Elevators (AOCMSE) Using IoT,” https://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-5225-9199-3.ch012, pp. 189–207, Jan. 1AD, doi: 10.4018/978-1-5225-9199-3.CH012.
[14] L.-D. Van, Y.-B. Lin, T.-H. Wu, and T.-H. Chao, “Green Elevator Scheduling Based on IoT Communications”, doi: 10.1109/ACCESS.2020.2975248.
[15] H. Lu et al., “Design of Elevator Light Curtain Monitoring System Based on Internet of Things,” Scholar Publishing Group International Journal of Big Data Intelligent Technology, vol. 5, pp. 1–8, 2024, doi: 10.38007/IJBDIT.2024.050101.
[16] L. Montanaro, P. Sernani, A. F. Dragoni, and D. Calvaresi, “A touchless human-machine interface for the control of an elevator,” vol. 1746, pp. 58–65, 2022, Accessed: Mar. 30, 2024. [Online]. Available: https://u-pad.unimc.it/handle/11393/302249
[17] T. Chou et al., “Flip-Chip Ir and Force Sensors for Both Touch and Touchless Elevator Buttons Applications,” Proceedings of the IEEE International Conference on Micro Electro Mechanical Systems (MEMS), vol. 2022-January, pp. 523–526, 2022, doi: 10.1109/MEMS51670.2022.9699800.
[18] S.-C. ; Lai et al., “Contact-Free Operation of Epidemic Prevention Elevator for Buildings,” Buildings 2022, Vol. 12, Page 411, vol. 12, no. 4, p. 411, Mar. 2022, doi: 10.3390/BUILDINGS12040411.
[19] E. Rubies, R. Bitriá, E. Clotet, and J. Palacín, “Non-Contact and Non-Intrusive Add-on IoT Device for Wireless Remote Elevator Control,” Applied Sciences 2023, Vol. 13, Page 3971, vol. 13, no. 6, p. 3971, Mar. 2023, doi: 10.3390/APP13063971.
[20] S. K. Vaish, A. K. D. Dwivedi, and D. Dubey, “Touchless controls for passenger elevator,” Proceedings of 2020 IEEE International Conference on Power, Instrumentation, Control and Computing, PICC 2020, Dec. 2020, doi: 10.1109/PICC51425.2020.9362353.
[21] Z. Ming ! ! ", S. Han, Z. Zhang, and S. Xia, “Paper-Elevator Safety Monitoring System Based on Internet of Things Elevator Safety Monitoring System Based on Internet of Things”, doi: 10.3991/ijoe.v14i08.9179.
[22] Shi, Dan, and Bixi Xu. "Intelligent elevator control and safety monitoring system." IOP Conference Series: Materials Science and Engineering. Vol. 366. No. 1. IOP Publishing,2018.

[23] Y. Guo, Y. Liu, X. Zhang, and G. Wang, “The Real-Time Elevator Monitoring System Based on Multi-sensor Fusion,” J Phys Conf Ser, vol. 2010, no. 1, p. 012182, Sep. 2021, doi: 10.1088/1742-6596/2010/1/012182.
[24] Silva, M. F., Khafiz Mikhailovich Muradov, and David R. Davies. "Review, analysis and comparison of intelligent well monitoring systems." SPE Intelligent Energy International Conference and Exhibition. SPE, 2012.
[25] Awatramani, Jasmine, et al. "Investigating Strategies and Parameters to Predict Maintenance of an Elevator System." Computational and Experimental Methods in Mechanical Engineering: Proceedings of ICCEMME 2021 (2022): 323-332.
[26] Sadafale, R. B., Hissal, A. S., Joshi, R. V., Bachchhe, R. M., & Bairagi, S. D. Smart Protective System of Elevators.

[27] B. Zhao, Z. Quan, Y. W. Li, L. Quan, Y. Hao and L. Ding, "A Hybrid-Driven Elevator System With Energy Regeneration and Safety Enhancement," in IEEE Transactions on Industrial Electronics, vol. 67, no. 9, pp. 7715-7726, Sept. 2020, doi: 10.1109/TIE.2019.2941141. keywords: {Elevators;Hydraulic systems;Torque;Traction motors;Automobiles;Safety;Permanent magnet motors;Electro-hydraulic drive;elevator;energy regeneration},

[28] Liu, Pengcheng, et al. "Research on Elevator Safety Detection Management based on Big Data." Advances in Engineering Technology Research 5.1 (2023): 61-61.

[29] Liang, Xuedong, et al. "Graded and Classified Safety Management for Elevator Users Based on the Coordination Theory." Proceedings of the Eighth International Conference on Management Science and Engineering Management: Focused on Computing and Engineering Management. Springer Berlin Heidelberg, 2014.

[30] Wu, Gan, Dong Wei, and Shuo Fang. "Fault Diagnosis of Elevator Safety Circuit Based on Deep Forest." The 7th International Workshop on Advanced Computational Intelligence and Intelligent Informatics (IWACIII2021) Beijing, China. 2021.

[31] Makar, M., Pravica, L., & Kutija, M. (2022). Supercapacitor-based energy storage in elevators to improve energy efficiency of buildings. Applied Sciences, 12(14), 7184.

[32] Al-Kodmany, Kheir. "Tall Buildings and Elevator Technologies: Improving Energy Efficiency." International Journal of High-Rise Buildings 12.2 (2023): 169-177.

[33] C. Kamienski et al., "Context-aware energy efficiency management for smart buildings," 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), Milan, Italy, 2015, pp. 699-704, doi: 10.1109/WF-IoT.2015.7389139. keywords: {Context;Biological system modeling;Green products;Graphical user interfaces;Manuals;Actuators},

[34] Erica, D., Godec, D., Kutija, M., Pravica, L., & Pavlić, I. (2021, September). Analysis of regenerative cycles and energy efficiency of regenerative elevators. In 2021 International Conference on Electrical Drives & Power Electronics (EDPE) (pp. 212-219). IEEE.

[35] Kafalis, Konstantinos, and Athanasios Karlis. "Energy saving in elevators using flywheels or supercapacitors." Recent Advances in Electrical & Electronic Engineering (Formerly Recent Patents on Electrical & Electronic Engineering) 10.1 (2017): 60-71.

[36] H. I. Abbasi and A. J. Siddiqui, "Implementation of smart elevator system based on wireless multi-hop AdHoc sensor networks," 2011 IEEE 2nd International Conference on Networked Embedded Systems for Enterprise Applications, Perth, WA, Australia, 2011, pp. 1-7, doi: 10.1109/NESEA.2011.6144930.

[37] P. Pullan, M. Arora, K. Mehta and V. Niranjan, "Intelligent Elevator Design Using PLC," 2020 IEEE 17th India Council International Conference (INDICON), New Delhi, India, 2020, pp. 1- 6, doi: 10.1109/INDICON49873.2020.9342115.

[38] Bapin, Yerzhigit, and Vasilios Zarikas. "Smart building's elevator with intelligent control algorithm based on Bayesian networks." International Journal of Advanced Computer Science and Applications 10.2 (2019).

[39] F. Rossi, J. P. Sembiring, A. Jayadi, N. U. Putri and P. Nugroho, "Implementation of Fuzzy Logic in PLC for Three- Story Elevator Control System," 2021 International Conference on Computer Science, Information Technology, and Electrical Engineering (ICOMITEE), Banyuwangi, Indonesia, 2021, pp. 179-185, doi: 10.1109/ICOMITEE53461.2021.9650221.