ENHANCING ENVIRONMENTAL, SOCIAL, AND GOVERNANCE (ESG) PERFORMANCE THROUGH BUILDING AUTOMATION SYSTEMS (BAS)

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Abstract. The integration of Environmental, Social, and Governance (ESG) principles with Building Automation Systems (BAS) has emerged as a critical strategy for enhancing sustainability in building operations. ESG has emerged as a global framework for assessing corporate sustainability, while BAS facilitates real-time monitoring and control of building systems. Therefore, this study aims to examine the integration of Environmental, Social, and Governance principles with Building Automation Systems to enhance sustainability in building operations in the Sri Lankan context. The research uses a mixed-methods approach, involving a questionnaire survey and semi-structured interviews with professionals in sustainability, facilities management, and BAS engineering. The Relative Importance Index was used to analyse ESG-related issues, while qualitative data from interviews provided insights into strategies for integrating BAS with ESG principles. The findings show that BAS significantly improves environmental sustainability by optimising energy use, reducing operational costs, and improving system efficiency. However, its social and governance contribution is limited due to manual oversight and privacy concerns. Key ESG challenges, such as air pollution and energy inefficiency, were identified, especially in Sri Lanka. Addressing these challenges requires policy reforms, stakeholder engagement, and ethical practices. The study bridges the gap between technological advancements and ESG principles, offering practical recommendations for integrating technology with broader sustainability frameworks.

Keywords. ESG; Building Automation System (BAS), Organisational Performance, Smart Building Technology, Operational Efficiency

1. Introduction

ESG (environment, social and governance), established in 2004, has been widely applied in Europe, America, and other developed countries as a framework incorporating environmental, social, and governance factors in investment decisions and ownership (Li et al., 2021). As a result of the increasing emphasis on sustainable and responsible business practices, there has been a substantial rise in the number of companies that measure and disclose ESG data in recent years (Amir & Serafeim, 2017). According to Fatimah et al. (2023) ESG metrics are crucial in addressing resource depletion and environmental challenges, as evidenced by strategic initiatives like the Sustainable Development Goals and climate action plans. To evaluate sustainability, ESG scores have become widely acknowledged indicators, and researchers and administrators employ them to evaluate the progress of organisations in sustainable development (Clément et al., 2022). Reliable, transparent, and trustworthy sustainable data analysis and reporting are essential for the attainment of ESG objectives, as they provide stakeholders with a quantifiable perspective on a company's ESG performance (Jonsdottir et al., 2022). Further to the author, the primary focus of institutional investors is the quality of ESG data, emphasizing comparability, dependability, and precision. However, the challenges posed by inaccuracies in ESG reporting are significant, as companies frequently encounter difficulty in comprehending the requirements and generating comprehensive reports.

Xiao & Fan (2014) stated that modern buildings utilise advanced technologies like BAS (building automation system) for intelligent real-time monitoring and control, storing records of temperature, flow rate, humidity, pressure, power, control signals, and equipment states in a vast database. BAS enables real-time monitoring and control by integrating a variety of building systems, such as HVAC, lighting, security, and fire safety, into a centralised platform (Himeur et al., 2022). While ESG provides a framework for investment decisions by rating ESG factors, a building automation system (BAS) controls and monitors all systems in real time over the internet (Yang et al., 2020). Despite the clear advantages of BAS, challenges remain in fully utilizing its capabilities for ESG-focused sustainability efforts. Integrating BAS with ESG principles can enhance transparency in sustainability initiatives, improve data accuracy for ESG

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reporting, and support companies in achieving environmental sustainability certifications like LEED and BREEAM (Brounen, Marcato, & Op't Veld, 2021). While the existing literature acknowledges the significance of ESG indicators in assessing sustainability and corporate performance and highlights the potential of BAS for real-time monitoring and control, there remains a lack of comprehensive research that effectively integrates ESG principles with BAS capabilities to enhance overall building sustainability. Therefore, this study aims to bridge the gap between technological advancement and societal well-being by examining ESG and BAS capabilities. The paper structure begins with an introduction to the study and followed by a literature review on ESG, BAS, and integration of BAS and ESG. The paper then presents the research methodology and findings, and the final section of the paper presents the conclusion of this research.

2. Literature Review

2.1 BUILDING AUTOMATION SYSTEM (BAS)

Building automation systems are a popular choice in the buildings industry due to its capacity to reduce energy consumption, simplify building operations, and improve customer satisfaction by monitoring and maintaining comfortable requirements (Domingues et al., 2016). Ren et al. (2023) have introduced BAS as a mindset of smart buildings, which facilitates the building's smartness. Additionally, the system necessitated an appropriate connection between system components and external sources, such as the cloud. BASs are deployed in modern buildings, particularly public and commercial buildings such as malls, factories, domestic domains, and enterprise buildings, to monitor and control real-time data. They analyse vast amounts of data that are retained in the system (Domingues et al., 2016; C. Fan et al., 2015).

BAS utilise various sensing methods like CO2 concentration, temperature, zone airflow, occupancy levels, and daylight levels to maintain comfort and reduce errors and costs (Vandenbogaerde et al., 2023). Sensors, in conjunction with actuators, enable control systems to function, either directly managing sensor information or being controlled by a supervisory layer. Informative sensors aid in mapping essential data for building model calibration, and the design of control and monitoring schemes for detailed building modelling is a research area (Aste et al., 2017)

2.2 ESG FRAMEWORK

An ESG framework is a method that assesses the value of a company by evaluating its performance on non-financial factors, which includes environmental impact, social responsibility, and governance practices (Park et al., 2022). It is imperative for investors to assess corporate behaviour and prospective financial performance using ESG factors. These three factors are crucial for investment analysis and decision-making processes, as they enable the assessment of the sustainability and social impact of business operations (Brounen et al., 2021). According to Park et al. (2022), the ESG index has emerged as a highly significant indicator of a company's non-financial performance, and it has become the new standard to base investment decisions on the ESG index.

Each of the three pillars in the ESG framework serves a distinct yet interconnected function. The environmental pillar assesses a company's endeavours to protect the environment, which includes mitigation of climate change and reduction of carbon emissions, pollution control, management of waste generated during the production process, efficient use of energy and water, and emphasis on diversity and deforestation (Radzi et al., 2023). The social pillar focuses on company's relationships with stakeholders, employees, customers, communities, and suppliers. It encompasses areas such as labour standards, employee well-being, workplace

diversity and inclusion, human rights, and community engagement (Brounen, Marcato, & Op't Veld, 2021). Strong social policies not only enhance a company's public image but also drive innovation and employee productivity. The governance pillar relates to internal practices and policies that drive corporate decisions and accountability. Key areas include board diversity and structure, executive compensation, anti-corruption measures, shareholder rights, and transparency in reporting. Governance is foundational to ethical management and risk mitigation (Radzi et al., 2023).

2.3 ESG-RELATED ISSUES

2.2.1 Environmental Issues

Sri Lanka aims to become a 100% sustainable energy-dependent nation by 2050, aligning its economic strategies with global trends (Koswatte et al., 2024). Despite being a middle-income developing nation, Sri Lanka faces challenges such as land degradation, pollution, inadequate water resource management, diminishing biodiversity, coastal erosion, and poor industrial waste handling. Buildings account for over 40% of the world's energy use, 42% of its CO2 emissions, and 30% of its freshwater use (Fan & Fang, 2023). To decrease energy and water use, benchmarking energy and water use has become a top priority for governments and relevant agencies. Around 51% of Sri Lanka's energy demand is fulfilled from renewable resources but faces higher energy costs compared to other Asian countries (Koswatte et al., 2024). Small- and medium-sized enterprises (SMEs) continue to face barriers due to a lack of funding, knowledge, technology, and motivation.

Sri Lanka ranked as the 80th worst CO2 emitter in the world in 2019, with carbon emissions of 20.8 million MtCO2e. Air pollution in Colombo is a major concern, with Colombo's air quality reaching 169 on the index in December 2022 (Koswatte et al., 2024). Sri Lanka is seventh among the world's worst unmanaged plastic offenders, and waste management in the country has become a severe concern due to rising garbage production and a lack of extensive, well-resourced waste management infrastructure. Over 60% of Sri Lanka's municipal solid waste is organic and biodegradable, but managing hazardous waste is difficult due to a lack of technical expertise (Fernando & Tsuji, 2024).

2.3.2 Social Issues

Sri Lanka's constitution ensures the right to join a trade union, with 2,074 registered trade unions operating in various sectors. However, child labour remains a significant issue, with 43,714 children involved in it (Mudalige, 2023). The country has established the National Policy on Elimination of Child Labour to combat this problem. Work environments in Sri Lanka suffer from issues such as noise, insufficient lighting, and overcrowding, with safety measures often lacking. Sustainability reporting in Sri Lanka has gained less attention than in other countries. Gender-based discrimination and equal rights are also challenged, particularly in the workplace. Women face barriers due to family and social factors, and employers may not be willing to hire them. The International Labour Organisation (ILO) is working to address these issues through social dialogue and developing tools to create a more conducive environment (Dissanayake et al., 2019).

Poverty in Sri Lanka has increased due to economic growth, social protection issues, and the COVID-19 pandemic. The poverty rate reached 14.3% in 2019, with 14.3% of the population living below the national poverty line. Poverty has increased since 2019, reaching 12.7 in 2020 and doubling between 2021 and 2022 (Baffes et al., 2021). To make a more inclusive and prosperous society, there is a need to improve social protection, tackle poverty and inequality, and encourage digital transformation. Traditional methods of supply chain management face

challenges like uncertainty, cost, complexity, and vulnerability. Innovative management processes, such as large-scale smart infrastructure and intelligent automation in SCM (Supply Chain Management), are necessary to address these issues (Abeyrathne & Gunawardana, 2023).

2.3.3 Governance Issues

In order to foster investor confidence and trust, organisations must guarantee transparency in their operations. This encompasses the provision of stakeholders with information that is comprehensive, accurate, and easy to understand. Additionally, this contributes to the improvement of stakeholders' reputations and the mitigation of misunderstandings. Consequently, the aforementioned issues pertain to each of the ESG pillars and their current conditions within an organisation, enumerating areas of concern to mitigate their effects (Sellhorn & Wagner, 2022).

2.4 ACHIEVING ESG THROUGH BAS IMPLEMENTATION

Environmental, Social, and Governance (ESG) goals are increasingly integral to corporate strategies, particularly in the built environment sector. BAS has emerged as a key enabler in achieving these goals by optimizing energy efficiency, enhancing occupant well-being, and supporting transparent governance practices.

On the environmental front, BAS contributes significantly to environmental sustainability by managing HVAC, lighting, and energy systems to reduce carbon emissions and energy consumption (Wang et al., 2012). Smart sensors and predictive analytics embedded within BAS allow for real-time monitoring and adaptive control, resulting in substantial energy savings and compliance with green building standards such as LEED and WELL (Ali et al., 2020).

From a social perspective, BAS enhances indoor environmental quality (IEQ), which influences occupant health, comfort, and productivity. Intelligent lighting and air quality systems can adjust to user preferences and occupancy patterns, promoting well-being (Spengler & Chen, 2000). Moreover, BAS supports inclusivity through adaptive technologies that respond to diverse needs, including accessibility features for people with disabilities.

On the governance front, BAS provides detailed operational data that can be used for ESG reporting and regulatory compliance. This data transparency strengthens stakeholder trust and facilitates data-driven decision-making (Pérez-Lombard et al., 2008). Moreover, the integration of cybersecurity features into BAS platforms ensures the protection of sensitive data, aligning with governance best practices.

Despite these benefits, challenges such as high implementation costs, interoperability issues, and the need for skilled personnel persist (Baharetha et al., 2024). However, advancements in IoT and cloud computing are rapidly addressing these barriers, making BAS a viable and strategic tool for ESG achievement.

3. Methodology

The study was conducted in two phases, focusing on the Sri Lankan context. To integrate ESG and BAS and address existing issues related to ESG factors within Sri Lanka, data were gathered from the ESG and BAS industry practitioners during phase I. Additionally, the perspectives of experts in the ESG and BAS practices were collected in phase II to determine the significance of ESG and to formulate recommendations through BAS. A questionnaire survey was identified as the most appropriate data collection method for Phase I. Quantitative data on existing issues and qualitative data on the opinions of individuals were collected using an online questionnaire. 30 responses were received from the 40 distributed questionnaires and chosen for the analysis. Simple random sampling was chosen as the sampling technique due to its requirement

of a single random selection and a restricted comprehension of the population. The questionnaire predominantly consisted of closed-ended questions and a few Likert scale questions to identify the issues in ESG implementation in Sri Lankan building practices.
Moreover, in Phase II of the study, interviews were conducted with experienced expert professionals in Sri Lanka to acquire expert knowledge on ESG and BAS. The literature review identified the matters that served as the foundation for the interviews, which were conducted to gather more comprehensive qualitative information. Eight (08) semi-structured interviews were conducted with experts in ESG practices to determine the most effective strategies for integrating ESG and BAS.
The profiles of the selected experts are provided in Table 1.

Table 1: Profile of the Experts

Expert	Designation	Years of experience in the profession	Years of experience in BAS
E1	ESG group head	16 Years	10 Years
E2	Head of Facilities Management	14 Years	4 Years
E3	Health and Safety Officer	5 Years	2 Years
E4	Head of Facilities Management	10 Years	10 Years
E5	Sustainability Manager	10 Years	2 Years
E6	Operations manager	12 Years	8 Years
E7	Facilities executive	7 Years	1 Years
E8	Project Manager	10 Years	5 Years

The questionnaire survey was analysed using both statistical and manual content analysis, with RII used for the evaluation of issues. Content analysis was used for interview data analysis since most of the data consisted of opinion evidence.

Relative Importance Index (RII)=$\sum w/A*N=(1n1+2n2+3n3+4n4+5n5)/5*N$; (0 ≤ RII ≤ 1)
where the symbols indicate:
W: weight was given to each delay factor by the respondent within the range {1, 2, 3, 4}, multiplied by the number of respondents {$n1$, $n2$, $n3$, $n4$} for each factor.
$n1$ = number of respondents who strongly disagree.
$n2$ = number of respondents who disagree.
$n3$ = number of respondents who neither agree nor disagree.
$n3$ = number of respondents who agree.
$n4$ = number of respondents who strongly agree.
A: highest weight (in this study: 5).
N: overall number of respondents (in this study: 30).

4. Results

4.1 QUESTIONNAIRE SURVEY RESULTS

4.1.1 Profile of the Respondents

The questionnaire was distributed to professionals who are involved in sustainability, facilities management, and BAS engineering, as this survey is intended to identify issues related to ESG factors and BAS integration within organisations. The respondents' profiles are illustrated in Figure 1.

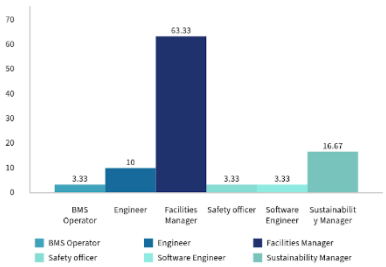

Figure 1: Respondents' profile

Considering the understanding of the respondents regarding the ESG rating, the survey reveals that 40% of respondents have average knowledge about ESG ratings, with 13.3% having very high knowledge, 30% having high knowledge, and 16.7% having low knowledge. The majority of respondents do not have high knowledge on ESG, with over half having average and low knowledge. In the analysis of the ESG performance of the respondents' organisations, the majority of them (76.7%) exhibit a high level of performance in ESG. Additionally, 20% of the organisations exhibit ordinary performance, and 0.3% exhibit very high performance.

4.1.2 ESG Related Issues and Reasons

The study measured ESG-related issues identified through literature review and used a relative importance index (RII) analysis to rank them based on their relative importance. Respondents valued each question based on the level of condition of each factor in their organisation using a five-point Likert scale.

Environmental Issues

Table 2: Environmental issues

Factor	RII	Rank	Reference
Air pollutants	0.587	1	Lucy Pérez et al., 2022
Impact and dependence on ecosystems	0.500	2	Brounen et al., 2021
Impact and dependence on biodiversity	0.467	3	Brounen et al., 2021
GHG emissions	0.460	4	Brounen et al., 2021
Biodiversity and ecosystems; rehabilitation	0.427	5	Lucy Pérez et al., 2022
Energy efficiency	0.340	6	Brounen et al., 2021
Waste management (water, solid, hazardous)	0.313	7	Lucy Pérez et al., 2022
Water usage management	0.307	8	Lucy Pérez et al., 2022
Innovation in environmentally friendly products and services	0.300	9	Brounen et al., 2021
Hazardous-materials management; circularity	0.267	10	Brounen et al., 2021

According to the survey findings, the RII values for environmental factors are within the range of 0.267 to 0.587. The most pressing concern is the discharge of air pollutants, while hazardous waste disposal is the least pressing concern. The majority of organisations have effective hazardous material management systems, which suggests that these factors are not a concern when evaluating RII. As per the respondents, the production process, energy consumption, and

high-intensive machinery are the primary causes of environmental issues in organisations. Building conditions and tenant restrictions are beyond the control of certain organisations, resulting in energy and water waste. Nature can be negatively impacted by the use of harmful materials in apparel, such as cotton and leather, which result in the devastation of habitats and the cutting down of trees. Burning fuels and inefficient fixtures contribute to greenhouse gas emissions during transportation to destination sites. Land development destroys natural habitats, necessitating reforestation initiatives to mitigate the environmental impact. Low energy efficiency is primarily due to the presence of antiquated machinery and fixtures, as well as building envelopes. Organisations frequently furnish waste to CEA-registered outsiders for decomposition and recycling, as the quantity of collected waste, particularly food waste, is a cause for concern. The demand for lighting, heating, and ventilation, as well as the additional consumption of electricity for decorations, all contribute to an increase in energy consumption during peak seasons with an increase in visitors and decorating. Higher energy consumption and greenhouse gas emissions are the consequence of the extended operational hours, increased appliance utilisation, and strain on HVAC systems.

Social Issues

Table 3: Social Issues

Factor	RII	Rank	Reference
Programs for reduce poverty	0.486	1	Lucy Pérez et al., 2022
Discrimination, diversity	0.450	2	Brounen et al., 2021
Forced and compulsory labour	0.407	3	Brounen et al., 2021
Community impacts (How a company affects the well-being and development of the communities in which it operates)	0.340	4	Brounen et al., 2021
Opportunity	0.280	5	Brounen et al., 2021
Equality	0.253	6	Lucy Pérez et al., 2022
Training and education	0.240	7	Lucy Pérez et al., 2022
Customer privacy, satisfaction	0.230	8	Lucy Pérez et al., 2022
Workforce freedom of association	0.200	9	Lucy Pérez et al., 2022
Customer health and safety	0.140	10	Brounen et al., 2021
Workplace health and safety	0.133	11	Brounen et al., 2021
Child labour	0.121	12	Brounen et al., 2021

The survey results indicate that the RII values for social pillar factors range from 0.121 to 0.486. These factors include poverty reduction programs, discrimination and diversity, community impact, opportunity, equality, training and education, customer privacy and satisfaction, workforce freedom of association, customer health and safety, and workplace health and safety related issues. The most critical issue is privacy reduction programs, while the least critical issue is child labour. In relation to the reasons for social issues mentioned, the majority of respondents have indicated that the primary cause of crimes and safety concerns is the failure of employees to adhere to policies and procedures during their work. Additionally, in order to maintain positive social practices, it is essential that management and employees maintain effective communication.

Governance Issues

Table 4: Governance Issues

Factor	RII	Rank	References
Bribery and corruption	0.513	1	Brounen et al., 2021
Incentives	0.287	2	Brounen et al., 2021
Board diversity and structure	0.280	3	Brounen et al., 2021
Stakeholder engagement	0.240	4	Brounen et al., 2021
Supply chain management	0.213	5	
Capital allocations	0.193	6	Lucy Pérez et al., 2022
Codes of conduct and business principles	0.173	7	Brounen et al., 2021
Business ethics, data security	0.167	8	Lucy Pérez et al., 2022
Accountability	0.165	9	Brounen et al., 2021
Fairness of executive pay	0.160	10	Brounen et al., 2021
Transparency and disclosure	0.153	11	Brounen et al., 2021
Shareholder rights	0.140	12	Brounen et al., 2021

The survey results indicated that the RII values for governance factors varied from 0.140 to 0.513. Bribery and corruption were the most critical issues identified, while shareholder rights were the least critical. From the respondents' perspective, the majority of organisations adhere to their governance factors manually, which means that they have acknowledged the possibility of errors such as duplication and reporting.

4.1.3 Building Automation System Contribution to Enhance ESG Performance

The BAS contribution to improving ESG performance is assessed in Figure 2 below based on the respondents' viewpoints. Evaluations were conducted separately for each of the three pillars: Environment, Social, and Governance.

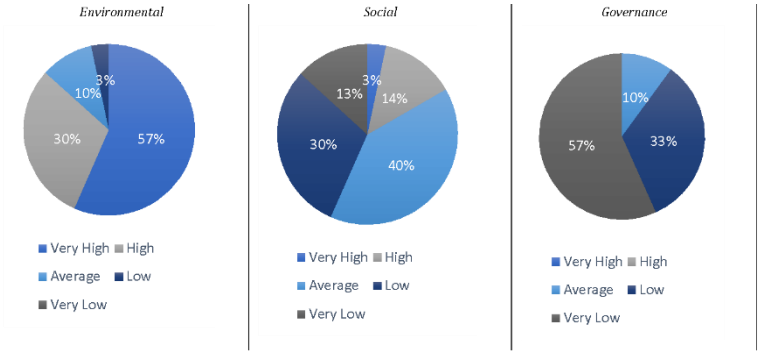

Figure 2: Building Automation System Contribution to Enhance ESG Performance

BAS has been approved by the majority of respondents (57%), with 30% indicating that it has a high contribution to improving environmental performance. The majority of respondents (40%) believed that BAS makes an average contribution to improving social performance while 30% of respondents reported that it makes a low contribution and 13% reported that it is very low. A vast majority of respondents (57%) agreed that BAS makes a very low contribution to improving governance, while 10% stated that it averagely affects the governance performance.

4.2 EXPERT INTERVIEW ANALYSIS

4.2.1 Importance of ESG in the Context of Building Operations

Organisations are increasingly aligning with the Triple Bottom Concept, which focuses on profit, people, and planet. This approach is necessary to address environmental pollution, human rights, resource decay, and compliance with rules and regulations. E2 suggested that

organisations should consider their environmental, social, and governance aspects in order to improve their performance. E3 emphasized the importance of reducing energy usage, waste, and chemicals in their operations. Following ESG principles can help reduce these impacts by implementing energy-saving, less waste, and eco-friendly products, leading to sustainability growth. Governance requirements under this framework can help identify factors that align with each ESG pillar, reducing fraud risks, complying with regulatory compliances, reducing legal disputes, and aligning with sustainability. E3 also highlighted the importance of enhancing brand reputation and trust within stakeholders. Even during crisis times, companies can manage risk and maintain stakeholder trust by facilitating efficient resource management, cost savings, and reducing environmental impacts.

E5 and E6 emphasized the importance of integrating ESG principles into daily operations to examine resource usage, waste generation, and emissions. By monitoring these factors, areas for advancement can be identified and eco-friendly solutions like recycling, leveraging natural light, and recovering energy become feasible. Facility management should shift from resource consumption to exploring reuse possibilities during building construction and maintenance, resulting in a lower environmental footprint. E6 advocated for adopting more energy-efficient technologies, renewable energies, and waste reduction methods to achieve sustainable practices and save costs. Risk management is crucial in this context, as companies can provide proactive solutions for potential risks such as increasing costs due to taxes or high material prices. E7 mentioned that engaging with these factors can attract investors, improve financial performance, and build a strong reputation that attracts customers and talent. Establishing a framework that effectively identifies, assesses, and mitigates risks related to environmental, social, and governance factors helps companies adhere to ESG standards and promote sustainability programs aligned with business objectives.

4.2.2 Strategies to Enhance ESG Factors Through BAS

Environmental Pillar

Experts agreed that BAS can significantly improve environmental factors. E1 stated that they implemented an ESG framework for their organisation, which they followed for around 10 years without using ESG words specifically. After implementing BAS, they saw significant energy savings, with their local factory reducing energy consumption by over 50% compared to an Indian factory with the same capacity. The local factory's performance doubled compared to the Indian factory. E3 also noted that BAS helped to reduce manpower by connecting AC and lighting systems and scheduling them automatically. They also have used BAS to support energy-related tasks, such as meter readings and comparing results. E6 and E8 reported that BAS helped to reduce sudden breakdowns by providing early detection alarms on system errors, allowing staff to take proactive maintenance activities. This led to less breakdowns and efficient system operations, reducing unfrozen costs. In conclusion, BAS implementation positively impacts energy-efficient technologies in facilities, contributing to a more sustainable and efficient environment.

Social Pillar

The BAS system is unable to integrate with the majority of social factors, as per all eight specialists. E1, E2 stated that the company already possess legitimate documents and ongoing data records, and there is no necessity to incorporate these data into the BAS system. E2 clarified further, stating, "A BAS is a controlling and monitoring system. We have installed a motion sensor near the door, and when a person approaches, the sensor sends a signal to the system. We have programmed the system to automatically open the door when the relevant sensors send a signal, and the door open automatically. Also, the system will automatically

activate in accordance with the time signal if the lights are scheduled to be on at 6:00 p.m. But maintaining a database is merely a computerisation procedure. We can enter data into the BAS and access historical data."

Governance Pillar
According to all eight experts most of governance factors cannot integrate with BAS system. E3 further mentioned, "Specially these factors have some kind of privacy level. If we connect with BAS at least BAS operator can achieve to the details. Always we should consider privacy when consider these factors connect with BAS."

Refer Table 5 for the guideline to Enhance ESG performance through BAS.

4.4 DISCUSSION

This study intended to explore strategies for enhancing ESG (Environmental, Social, and Governance) performance through the application of Building Automation Systems (BAS). Empirical findings strongly confirms that BAS significantly contributes to environmental performance, particularly in reducing energy consumption, operational costs, and improving building efficiency aligns closely with the existing literature that highlights BAS as a key enabler of environmental sustainability (Radzi et al., 2023). BAS achieves this by integrating with HVAC, lighting, and energy management systems, facilitating automated control, real-time monitoring, and proactive maintenance. However, a deeper comparative analysis between the literature and empirical results reveals a clear deviation in the system's impact on the social and governance pillars. While literature suggests BAS has the potential to support broader ESG outcomes (Chungath, 2023), practical evidence shows limited influence beyond environmental aspects. Socially, BAS offers indirect benefits such as improving indoor air quality, comfort, and safety, yet it does not address deeper issues like diversity, labour standards, or training elements critical to social sustainability. In the governance realm, although BAS could theoretically promote transparency and accountability through data-driven insights (Brounen, Marcato, & Op 't Veld, 2021), experts and respondents confirm that privacy concerns and system limitations restrict its integration with sensitive governance functions. Most governance practices remain manual, lacking digital oversight through BAS. This discrepancy underscores the need for either enhancing BAS capabilities or incorporating complementary technologies to enable a more holistic ESG implementation in building operations.
While BAS may not directly address all Social and Governance challenges, it can play a significant role in supporting these pillars through enhanced workplace conditions, transparency, and operational efficiency. Some experts have recommended the development of a dedicated database for tracking and automating social and governance factors, which could further strengthen the contribution of BAS in these areas.

5. Conclusion

This study explored the integration of Environmental, Social, and Governance (ESG) principles with Building Automation Systems (BAS) to enhance sustainability in building operations, highlighting BAS's significant role in improving environmental performance through energy efficiency, waste reduction, and operational cost savings. However, its impact on social and governance factors, such as poverty reduction, diversity, and ethical governance, remains limited due to the need for human oversight and privacy concerns. Key ESG-related challenges in Sri Lanka, including air pollution, energy inefficiency, and governance issues like bribery, were identified, emphasizing the need for integrated strategies combining technological innovation with policy reforms. While BAS effectively supports environmental sustainability, addressing

social and governance challenges requires broader stakeholder engagement and ethical practices, underscoring the importance of a holistic approach to achieving ESG goals and fostering sustainable development.

Table 5: Guideline to Enhance ESG performance through BAS

Environmental	**Social**	**Governance**
Monitoring • Real-time monitor of power usage (kWh), diesel usage, and gas usage to identify consumption patterns and potential inefficiencies. • Continuously monitor emissions from emission sources like generators, incinerators, and kitchen exhausts using sensors and generating reports for regulatory compliance and improvement tracking. • Check alerts to identify malfunctioning equipment and leaks (gas) for early intervention and maintenance. • Monitoring and analysing energy consumption data for all subsystems in detail, allowing for targeted optimization. • Monitor historical data and gain a clear picture of power consumption and abnormal increases. • Analyse energy consumption by various parameters (system, location, machinery, time) with accurate details and efficiently. • Monitoring air quality in HVAC vents using sensors. • Integrating condensate water recycling with BAS (potentially high cost). • Utilise sensors to monitor water usage and detect leaks in real-time. • Measuring collected waste by type (cardboard, plastic) and entering data into the BAS for trend analysis and identify waste management strategies.	• Feed data collected on things like training, satisfaction feedback and monitor drawbacks and improvements. • Monitor parameters like CO2 level, lighting level, humidity level and control optimal condition. • Program with fire controls, fire alarms.	• Program to generate reports through the system. • can continue a database. • Feed data and keep a database to monitor patterns, trends, variation (for factors like policies, maintenance records, agreement data, supply chain related data)

• Develop a system to identify the composition of regenerated materials in products received from suppliers to inform purchasing decisions. • Creating a database to track monthly chemical usage and identify more sustainable alternatives. Controlling • Integrate occupancy and daylight sensors to automatically adjust HVAC and lighting systems based on real-time conditions. • Automatically increasing fresh air intake when CO2 levels exceed set points. • Setting alarms for exceeding pollutant levels and filter replacements. • Setting irrigation system based on sensor data (soil moisture, timing). • Scheduling HVAC systems and lighting operate based on occupancy and operational needs. • Optimizing equipment usage through scheduling (e.g., schedule on/off times). • Programming maintenance schedules into the BAS system to generate reminders and alerts for overdue tasks. • Prepare water bills and keeping detailed records. • Connect the garbage chute system to the BAS for automated waste segregation and bin replacement alerts. • Facilitate for data collection process of incident reports preparation. • Monitoring and controlling parameters like CO2 and lighting levels. • Program maintenance schedules into the BAS to generate reminders and alerts for overdue tasks,		

ensuring equipment operates efficiently.		

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