Digital Twin and Data Visualisation for Collaborative Workspaces(1st)

HOSSAIN, Mohataz <http://orcid.org/0000-0002-1885-8692>

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COLLECTIVE FUTURES

CRITICAL-CREATIVE PERSPECTIVES ON THE BUILT ENVIRONMENT IN BANGLADESH

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74/B/1 Green Road
RH Home Centre (Level 3)
Suite No. 232-239
Tejgaon, Dhaka 1215
Phone: (+8802) 223374560, 223374564
Mobile: (+880) 1917733741
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Contents

THEME 08

LANDSCAPE, ECOLOGY AND INFRASTRUCTURE

THEME 09

COMPUTATION AND TECHNOLOGY

END NOTE

REFERENCES

INDEX

EMBRACING TECHNOLOGY AND SUSTAINABILITY IN THE BUILT ENVIRONMENT

Eshrar Latif
[Theme Editor]

The advent of the Internet of Things (IoT), Building Information Modeling (BIM) digital twins, adaptive facades, renewable technologies, and batteries is changing how cities and citizens, buildings and occupants are perceived, monitored, and managed. Some emerging Bangladeshi scholars have critically discussed some of these developments in the context of Bangladesh.

Kazi Najeeb Hasan focuses on the prospect of Smart Cities in Bangladesh. The smartness of a city is not about retrofitting digital interfaces to optimize the operation of the urban environment, but the key goal is to use Information and Communication Technologies (ICT) and data to improve the quality of life of its citizens by addressing key urbanization challenges. The smart city creates urban intelligence by acquiring data from cameras, recording devices, physical infrastructures linked to various sensors, and connected cars and homes. Some immediate advantages are the optimization of urban services such as transport and waste management, reduction of crime, and improved air quality. However, with every data being captured, there is a fear of creating an Orwellian reality where citizens are at risk of increasing surveillance and intervention aided by the internet of things and artificial intelligence. Moreover, some argue that smart cities undermine qualitative values such as culture, memory, and beauty in supporting essentialist parametric values.

Dr Mohataz Hossain discusses the prospects of digital twins in the decarbonisation of the built environment in Bangladesh, focusing on works places. A digital twin is the virtual representation of an object that accurately represents the physical object. In the built environment context, the physical object is a building. Digital twins are linked to Building Energy Management Systems (BEMS) and various sensors and internet of things (IoTs) to control building parameters to attain any set objectives. For example, suppose the aim is to reduce carbon emissions without comprising human thermal comfort. In that case, the system will try to optimize the passive and active strategies, and it can also suggest changes in occupants' behaviour. The long-term data gathered from digital twins can be used to identify the performance gap of the building and to indicate optimisation of HAVAC and fabric parameters and occupants' behaviour patterns. Digital twins can be very useful in Bangladeshi garment industries where fire safety is an increasing concern. Digital twins will be able to pick up any abnormal hot spot in the building and can provide early warning of imminent fire risk.

Sarah Shuchi talks about the implementation of Building Information Modeling (BIM) in the construction sector of Bangladesh. In many countries, BIM has existed for over two decades. It is mandatory for builders and contractors to apply BIM Level 2 in all public sector projects in the UK. The obvious benefits of BIM are waste minimization and conflict detection between various building systems. BIM also helps optimize geometry and enables rapid design iterations. However, in many cases, BIM-based buildings are precast, prefabricated, and modular. Therefore, the implementation of BIM in Bangladesh will also be strengthened with the development of the modular construction industry. Since GIS and BIM represents urban and building scale information, respectively, an effort is now going on to integrate both into a common platform to provide building and geospatial information. It is highly likely that GIS, BIM, and Digital Twin will be integrated to provide a wealth of static and dynamic information.

Manal Anis explores the role of building facades not as an active high-tech element but as a passive element that can offer hygrothermal comfort by controlling airflow. Manal explores the passive and intelligent use of bamboo to prove his point. Bamboo expands and contracts by adsorbing and releasing moisture, and bamboo's expansion and contraction can be utilized to a certain extent to control envelope apertures if designed carefully. Controlling the size of apertures may control air movement through the building. However, the potential of hygric and thermal capacity of materials such as bamboo, wood, and cellulose-based materials are far beyond controlling envelope apertures. Moisture buffer capacity of hygric mass can be utilized to control relative humidity fluctuation in museums and places where high moisture load

9.2

DIGITAL TWIN AND DATA VISUALIZATION FOR COLLABORATIVE WORKSPACES

▶ Mohataz Hossain

Abstract This chapter demonstrates the potential of implementing the concepts of digital twins and real-time data visualization for a collaborative and climate-resilient workspace environment in Bangladesh. It indicates how these concepts can be integrated into existing and new buildings with the help of Building Energy Management System (BEMS) and low-powered Internet of Things (IoT) technologies. Firstly, the chapter includes field evidence and computer-simulated data of the working environments of three factories in Bangladesh revealing the system gaps among building envelope design, environmental conditions, workers' perceptions and building management. Secondly, it compares them with case studies in a developed country where digital twin, BEMS, and IoT technologies are already being implemented and real-time data visualizations are being used by both building users and managers to ensure a collaborative, comfortable, and safe working environment. Thirdly, while digital twins, i.e., a digital representation of existing physical buildings and cities, are being implemented in developed countries, this chapter contextualizes these concepts for built environments in tropical Bangladesh through an analytic diagram and illustrates how the real-time data visualization of the indoor environment, workers' feedback, and work efficiency with smart displays can ensure an energy-efficient, collaborative, and climate-resilient working environment. The chapter ends with outlining possible future collaborations and potentials towards climate-resilient and zero-carbon societies.

The Concept of Digital Twin for Workspaces

Bangladesh, the second-largest exporter of garments in the world, is a country where skilled labour is a significant resource for national income. A recent study showed that 81 percent of the country's revenue comes from clothing exports, with garment factories in Bangladesh alone contributing up to 20 percent of the Gross Domestic Product (GDP) (Sabir 2021). Over 7,000 garment factory buildings have been built to create productive working environ-ments where skilled workers labour to produce export quality products (Hossain 2018). In addition to the larger agriculture (40.6%) and manu-facturer sector (20.4%), the service sector (39%) includes transportation, education, food, utilities, retail trade, banking, health services, and hospitality (Alamgir 2021).

While assessing climatic scenarios, this country is located in the tropics, experiencing seasonal variations with mostly hot-dry or hot-humid days. Recent empirical studies have demonstrated that factory workers had reported their health issues, discomforts, and low workplace productivity in this tropical climate due to inconsistent thermal environments (Hossain 2018). The climate emergency and net-zero targets across the globe are also key considerations that would impact the design of the workspaces for the workers to keep them comfortable, safe, healthy, and productive.

In the current revolutionary era of technologies, the Internet of Things (IoT), which is considered to be a network of electronic devices integrated with wireless sensors, has made a huge enhancement in moving towards the concept of smart city environment (Sethi and Sarangi 2017). Moreover, sensor technologies are being used to better understand how different forces interact within workspaces and, thus new pre- and post-occupancy sensors may change their design strategy (Madlener 2021). Lehrer and Vasudev (2011) demonstrated the advantage of real-time energy monitoring and interactive data visualization towards a cost-effective workspace environment. Where many developed countries with varied climates are utilizing Building Energy Management System (BEMS) and IoT to enhance the environmental and energy performance of their buildings, Bangladesh has not fully taken advantage of these digital technologies in improving the workplace environments. To fully embrace digital technology, it is crucial to leverage zero-carbon technology to design climate-resilient workplace environments.

This chapter aims at exploring the concepts of digital twin and interactive data visualization as ways of improving our existing workspaces for a more collaborative and comfortable indoor environment. Based on literature reviews and empirical evidence, it attempts to show a link among existing issues, selective precedents, and future scope of digital technologies focusing on workspaces. It concludes by outlining a few recommendations for designers, stakeholders, and policymakers to keep the workspaces collaborative and climate-resilient and to develop net-zero carbon societies by 2050.

Limitations within the Workspace Environment of Bangladesh

Since Bangladesh experiences hot and humid climates, buildings and existing workspaces tend to rely on hybrid environmental-control systems with natural ventilation, mechanical air flow, ceiling fans, and air-conditioning to keep the indoor environment comfortable for occupants. However, occupants have less control over their environmental comfort within large open planned workspaces including office spaces due to divergence in perceived comfort levels, less awareness of their potential for individually adapting to higher comfort levels, and few choices on manoeuvring windows, fans, air conditioning (AC) etc., (Hossain et al. 2017). For instance, workers labour in multi-storied garment factories with limited controls on their adaptive thermal comfort since environmental variables, varied comfort, health, and adaptive behaviour are not perceptible to building managers and other occupants (Hossain 2018). Factories tend to obtain only work efficiency data, for instance, production per hour, using a large display board with manual handwriting. Floor managers can monitor the work-efficiency charts and take actions for underperforming workstations to improve their per-hour work efficiency. However, what are the actions being taken to improve workers' health and immediate environmental conditions? Can these be monitored and visualized in real-time? Are workers and managers educated enough to know how to take effective actions to read those environmental parameters? Can architects and engineers come forward to collaborate to improve this condition?

> *We feel uncomfortable due to high indoor temperature while working at our workstations. We don’t know how to control our environment which also makes us tired and affects our work efficiency – a statement from one of the garment workers collected by the author during a focus group discussion (Hossain 2018).*

Figure 1 and figure 2 show a localized high temperature of workspaces evident by a thermal image collected by the author from one of the three case study garment factories during 2015. One of the building managers said:

> *We are aware of workers’ low productivity and thermal discomfort. We added more ceiling fans. But we could not improve their working environment without knowing about the feasible solutions.*

A few research efforts and publications reveal encouraging intentions on part of the building owners and designers towards improving workspace conditions to eventually help workers to keep themselves healthy and work efficiently. Health, safety, and well-being of workers from the service sector also depend on their working environment (Alamgir 2021). However, there are not only divergences between occupants’ and building managers’ activities towards making the environment comfortable but also a lack of integration of technologies within the buildings and architectural elements, such as windows, doors, shading devices, and mechanical ventilation, each of which has a direct impact on the indoor environment.

Figure 1: Workspace of a Garment Factory

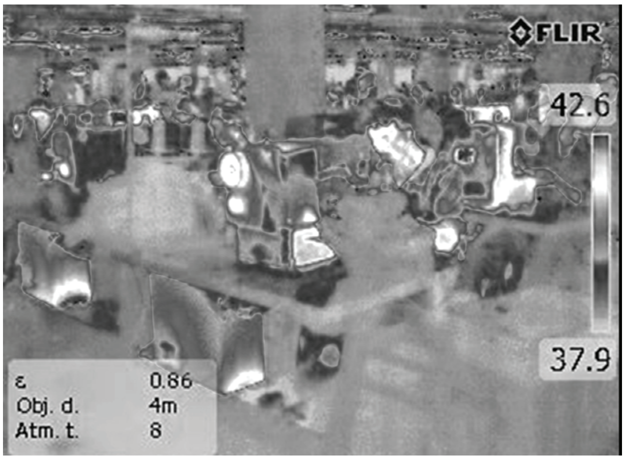

Figure 2: Realtime evidence of thermal environment of a workspace.

Digital Twin and Interactive Data Visualization

“Digital twin” is often interpreted as a buzzword that may create confusion in various industrial sectors. It is mainly a virtual representation of a physical or non-physical environment in the real world. For the building design sector, in simple terms, it refers to the virtual presentation of an existing building and physical community where energy demands and performance are predicted, monitored, visualized, and forecasted through validations with real-time data from the existing building site with climatic context. Computer-aided simulation tools and artificial intelligence (AI) are applied to model existing building forms with the site and context to estimate energy performance (TechUK 2021). The data may include average temperature, humidity, airflow rate, incident solar radiation, solar gain, heat gain or loss within the building envelope or spaces, electrical energy, water use, gas demand, etc.

To prevent extreme climate scenarios, human-caused emissions of carbon dioxide (CO_2) have to be reduced by about 45 percent from 2010 levels by 2030, reaching 100 percent net zero from 1999 to around 2050—as per the UK and Europe's commitment to global climate action of the Paris Agreement (Shepheard 2020). Considering this Net Zero 2050 objective, the digital twin concept is being embraced as a part of the ecosystem in many countries. For instance, digital twins are already being implemented in the UK, enabling the delivery of the net-zero goals with a special focus on reducing social inequalities and incorporating research and design as a long-term strategy in the building industry as well as within government policy (TechUK 2021). TechUK's Digital Twins Working Group (DTWG) has produced a report where it showed how the Cambridge Center for Digital Built Britain (CDBB) is working with industries and stakeholders to implement this concept at the national level as a part of the National Digital Twin Programme (NDTP). This concept is in its initial phase. The relevant case studies in the UK include the digital twin of a prominent Scottish building created by IES Ltd for planning the project and monitoring the environmental and energy performance. This project, an initiative of the Scottish government's vision of a net-zero society by 2045, has incorporated Building Information Modelling (BIM), Intelligent Control and Analysis (iSCAN) and BEMS (IES Ltd 2020). Another example of a large-scale digital twin project is entitled “SCENe: Trent Basin,” developed by the University of Nottingham in the UK, to visualise the real-time energy data of a housing community next to the River Trent. As a part of data visualization and public engagement, a 147-inch touch screen is positioned in the community hub room where people can learn about energy use and interact with the digital screen to monitor the design for their benefit (IES Ltd 2018). These case studies indicate how integrating the digital twin and human interaction to visualise real-time data benefits both users and the buildings' manager to increase their awareness about building energy efficiency and adaptive behaviour.

While digital twin technology strives to forecast and monitor computer-based simulated data, smart technologies such as IoT and BEMS are being utilized in many developed countries to monitor and manage the environmental and energy performance of built environments. One of the advantages of these technologies is the ability to visualise real-time data on a digital display screen—that is how building engineers or managers can monitor the energy performance of the whole building, for instance, the air temperature, relative humidity, CO_2 levels, ventilation rates, and energy consumption, by simply sitting at their workstations with computers or remotely accessing the data from smart devices (Hossain et al. 2020). With the advancement of technology and computer software, some of these data visualization methods are turning out to be very user-friendly and interactive. For instance, a user can interact with a touchscreen display and see the environ-mental and energy data in a more legible manner and provide real-time feedback of their perceived comfort, picking either "comfortable, neutral or uncomfortable" as feedback options. Consequently, occupant engagement with a building can be converted into an effective approach to control their workspace environment. A user-controlled working environment is not a new idea for air-conditioned workspaces where occupants can use a remote control to change the temperature and fan speed of the AC. However, smart technologies and data visualizations mentioned earlier are beyond those traditional ways of controlling the workspace environment.

There are many precedents in developed countries and diverse climatic regions, where IoT and BEMS are simultaneously used to visualise real-time environmental data. A notable example is the offices of ARUP located in Iidabashi in Tokyo, Japan, which has a humid subtropical climate, where the working environment has been used as a testbed to deploy IoT as the central technological transformation with a vision for a comfortable and healthier workplace. In this office, real-time environmental performance data are visualized at the office entrance on a dashboard. This helps occupants to be aware of the environmental performance at various points on the architectural floor plans. As a collaborative strategy, half of the staff have no fixed workstations, but instead have the freedom to pick the location of their workstations within the office floor (Katsumoto 2018). The workstations are designed with various differentiations such as private booths and workstations with or without views and daylight. The IoT dashboard also helps them to identify the most environmentally comfortable area (Katsumoto 2018). Some of the workstations are designed with a large table in such a way that they can initiate group discussions and collaborative working culture for greater work efficiency. A recent study in London showed that it may be viable to incorporate low-energy IoT devices to improve students' learning environments and teachers' workspaces (Hossain et al. 2020). As a result, occupants are more aware of their behaviour and its impact on environmental and energy performance.

However, the real challenge is whether all existing and new building designs are ready to adopt these advanced concepts and whether they can be climate-resilient and sustainable enough to meet the net-zero future. Will the technology itself be energy efficient and integrated enough so that the occupants, building managers, and other relevant stakeholders benefit from these smart technologies to work collaboratively? How far is Bangladesh from that collaborative future?

Integrating Digital Technology to Enhance Workforces in Bangladesh

Since skilled workers and their productivities are the key strength of the workspaces in Bangladesh, integration of these digital technologies for a comfortable environment and climate-resilient built environment would potentially enhance productivity and the health and well-being of workers. If national legislation and policies are

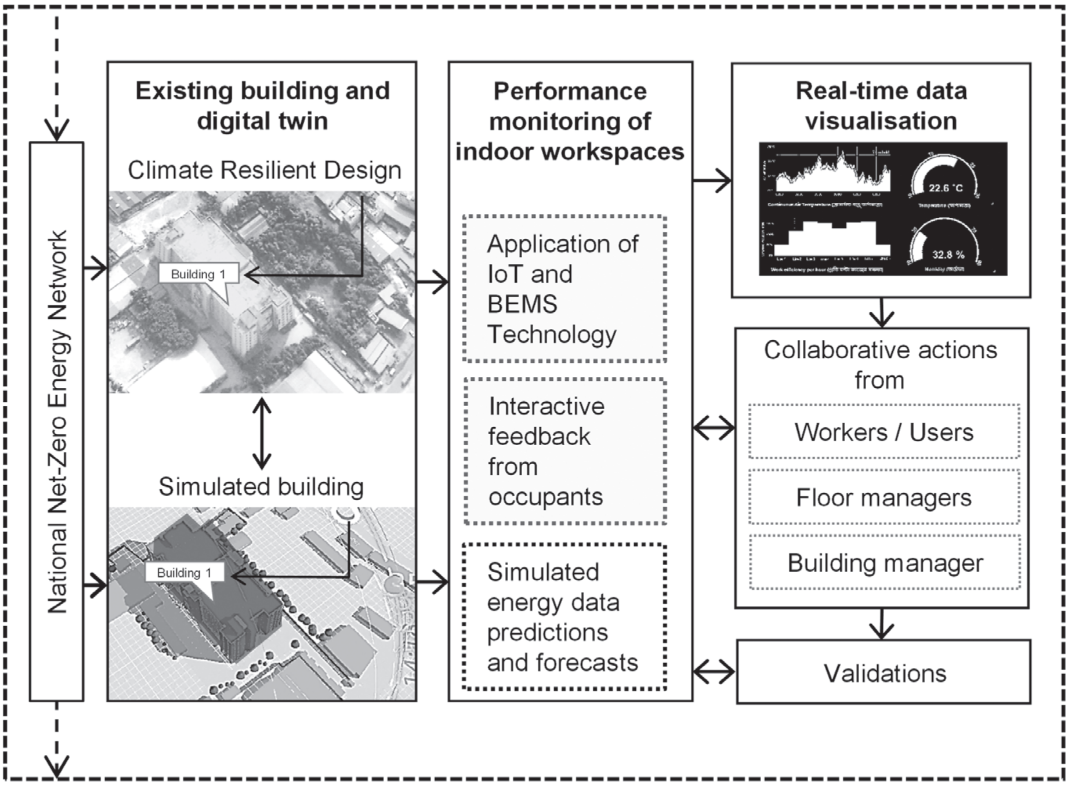

Figure 3: Conceptual Framework- collaborative and risilient workplaces.

developed towards a net-zero future by 2050 in Bangladesh, the main hurdles will be contextualising these digital technologies along with regional ethos within the building industries and workforce for a coherent decarbonisation process. Designing and retrofitting for climate-resilient buildings will be another dimension through which emerging technology and workers' comfort can be integrated with anticipation of extreme climatic scenarios. As adopted by developed countries such as the UK, a national route plan of the decarbonisation process from macro to micro levels of governance can be the starting point to implement this.

As referred by Kerrigan (2021), the key steps can be creating a baseline for Digital Twin, optimising environmental control and operations, retrofitting existing and new building stocks, designing a local electric energy grid , and integrating renewable energy generations. However, additional steps may be required for a developing country, such as Bangladesh, to make the digital twin concept feasible by incorporating all socio-economic challenges.

A Digital Twin for Bangladesh

Based on the basic requirement of a digital twin and collaborative technology network, figure 3 has been developed by the author. It endeavours to illustrate a conceptual framework for collaborative and resilient workspaces that could be adapted in the context of Bangladesh. Firstly, the implementation of a digital twin can be instigated at the government level, where the country can create a national net-zero energy network. Each domestic and non-domestic building can be connected under a national energy surveillance network to maintain net-zero compliance. Secondly, each building should be designed and/or retrofitted as a zero-carbon building that can cope with extreme climatic scenarios and should have a digital twin (figure 3) with integrated digital technologies to monitor and deliver detailed energy data of the workspaces including real-time environmental data. Thirdly, this information should be visualized by workers, users, and managers with a provision for interaction so that environmental quality can be collaboratively controlled. All other

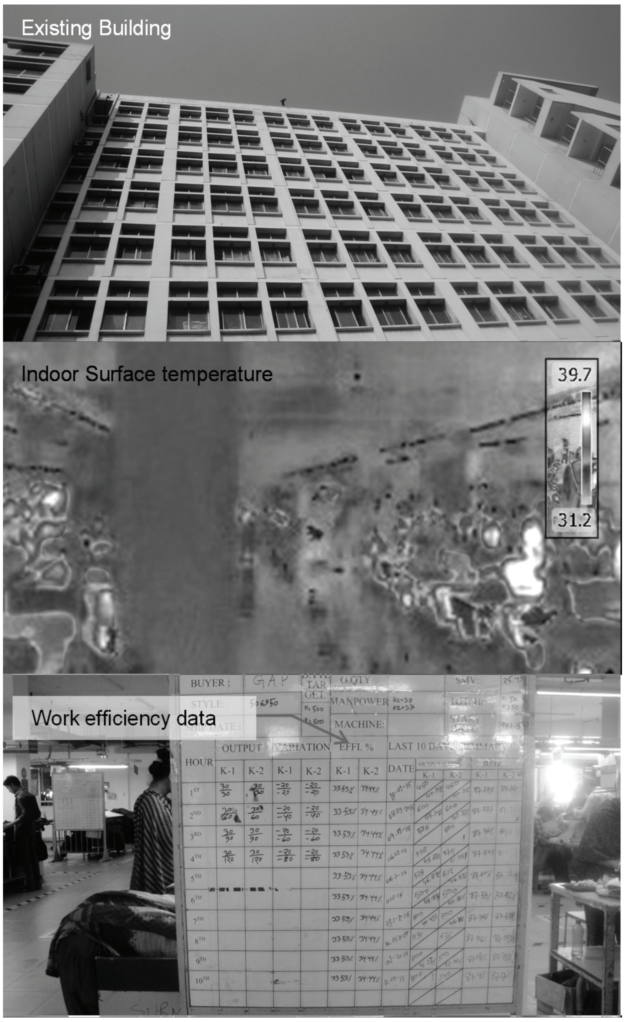

Figure 4: Existing practice of data visualization.

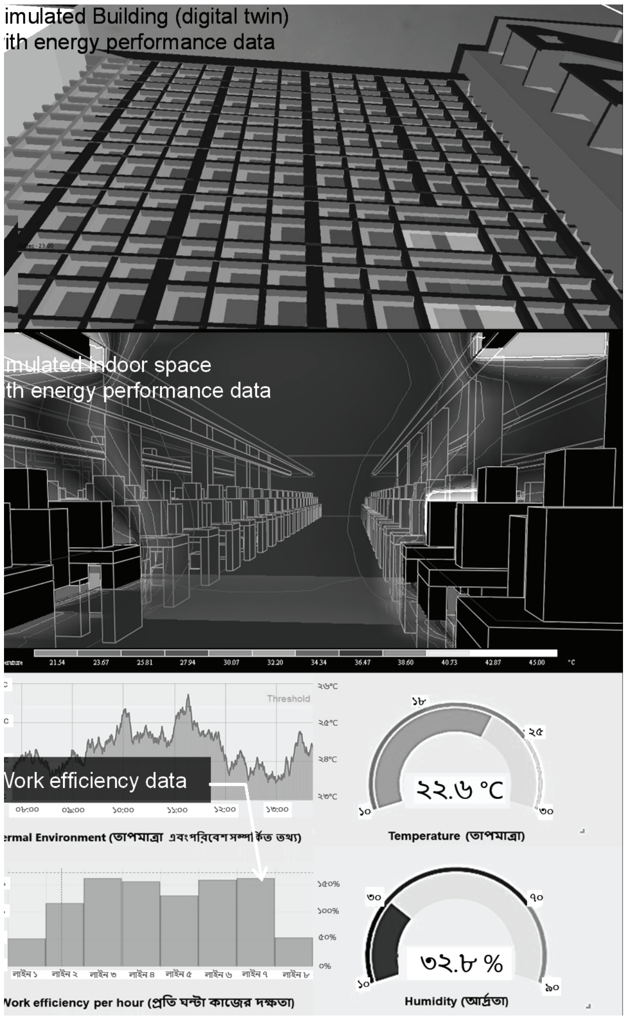

Figure 5: Digital twin and realtime data visualization.

adaptive measures can be undertaken by them so that their comfort, health, and well-being are ensured. These actions can also be fed back to the digital twin to adjust and validate the simulated data (figure 3). Thus, a collaborative approach can be continuously adjusted along with the diurnal variations of climate and available natural environmental resources, such as natural ventilation, solar heating, and renewable energies to enable employees to work effectively.

Figure 4 shows one of the studied buildings: a thermal image of indoor workspace and the existing practice of logging work-efficiency data on a display board. In contrast, figure 5 attempts to portray how the same information could have been visualized with the help of digital twin and data visualization technologies where simulated incident solar radiations on building envelope, indoor thermal environment, and digital data visualization are incorporated. As a first step to incorporate the vision of collaborative and digital workspaces into the agenda of national development, the government should step forward to create a liaison with all relevant stakeholders who will play major roles towards achieving that goal.

Further Recommendations

Digital technology, including AI, is emerging very fast, and the concept of a workspace is transforming too. However, the skilled workforce in Bangladesh should be valued and better utilized in the service of the country's economy, and the rational embrace of the digital twin with interactive data visualization technologies will be an effective way to enhance the workforce. The immediate actions from the Bangladesh government and relevant stakeholders can be:

- initiate action plans and legislation for decarbonising existing and new building stocks with a special focus on climate resilience, occupant health, comfort, and well-being
- conduct comprehensive feasibility studies for implementing the digital twin concept in Bangladesh
- propose “digital twin baseline” for both existing and new workspace designs
- retrofit existing workspaces for decarbonisation
- set up an IoT and smart technology-based environmental control and monitor strategies
- integrate these concepts within the curriculum of higher education and professional development for architects, designers, and engineers
- implement pilot projects to identify challenges
- promote a collaborative working culture among workers and relevant stakeholders.

Bangladesh’s next steps towards zero-carbon society development should be allied to the global Smart Cities and Net-Zero 2050 agenda. The United State’s policymakers have already applied incentive-based policies, including emission charges and tax subsidies, to resolve many environmental issues (US Environmental Protection Agency 2021). Similarly, the Bangladesh government can apply incentives and penalties to stakeholders for implementing digital twin policy. Based on the regional feasibility studies, further research and practice should continue to implement digital twins for data visualization and collaborative working environments. Consequently, the future of workspaces and the economic development of Bangladesh during the next 50 years depends on our collective and collaborative movements towards utilizing renewable energy and digital technologies.

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