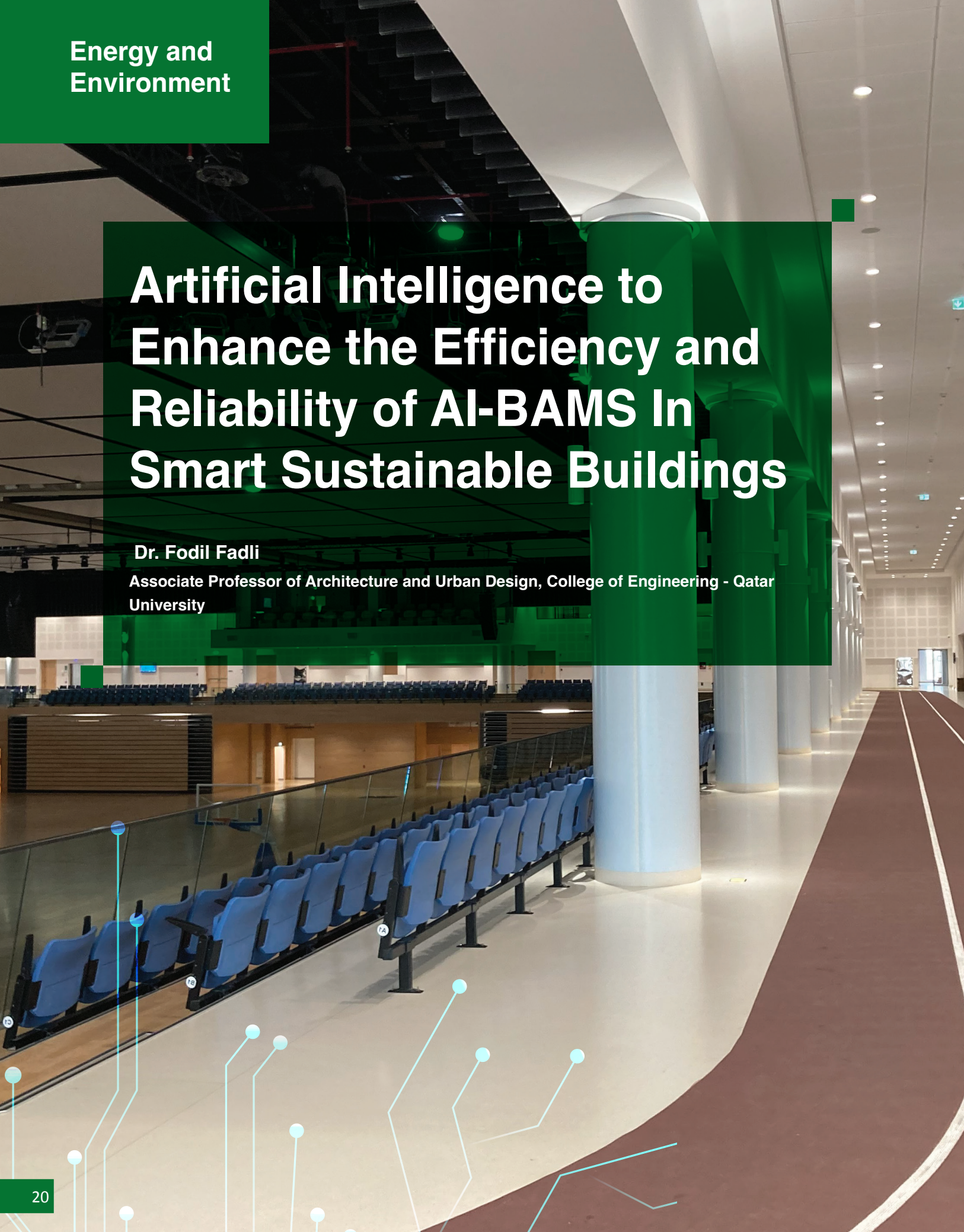

Artificial Intelligence to Enhance the Efficiency and Reliability of AI-BAMS In Smart Sustainable Buildings

Dr. Fodil Fadli

Associate Professor of Architecture and Urban Design, College of Engineering - Qatar University

Dr. Fodil Fadli

Our world is facing a tremendous challenge of Climate Change initially labelled as “Global Warming” which recently shifted to the alarming “Global Boiling.” This has brought in a lot of negative impact to our natural and built environment. We, as humans, cause major damages to our planet and environment due to our lifestyle and the exaggerated consumption rates of energy, water, and other resources. Since, we consume large amounts of energy and water, we produce large amounts of CO2, in turn, which damages the environment.

Over the last few decades, we have witnessed a major global rise in urban populations accounting to almost 75% of the world population. Energy consumption in buildings has become a critical issue, currently accounting for approximately 35% of the total global energy use.

In order to mitigate those negative impacts and deliver resilient solutions to promote smart sustainable buildings and cities which would provide environment-friendly processes and tools through the legacy of the SPORTE.3Q research project led by Dr. Fodil Fadli [LPI] and his Qatar University-based research team and the Cardiff University collaborating research team. The SPORTE.3Q Research project provided multitude of relevant and impactful research outputs such as the highly-cited journal paper: “AI-big data Analytics for Building Automation and Management Systems: A Survey, Actual Challenges and Future Perspectives.”

The aforementioned unique study highlighted the importance of designing, developing and implementing powerful AI-based Building Automated Management Systems [AI-BAMS]. AI-BAMS development is highly important but also very challenging due to frequent fluctuations in energy demand over the daily, weekly, monthly seasonal and yearly usage.

The digitization of building modelling platforms and tools such as Generative Twins [Composition of Generative Artificial Intelligence with powerful Digital Twins Models] aims to enable real-time Building Automated Management Systems inclusive of Energy Management Modules (EM2), forecasting and prediction tools such as the SPORTE.3Q Computational Urban Sustainability Platform [CUSP] model as shown in Figure 1. Initially developed by Cardiff University collaborating team members, it has been enhanced and adjusted to the Qatar context

through the SPORTE.3Q project. The upgrade and adaptation opted for the use of Generative Digital Twin technology alongside IoT devices and advanced data-driven algorithms. This offers substantial upgrades in Building Automation and Energy Modeling, Management and Optimization, Servicing, Maintenance, and Energy-Efficient Smart Sustainable Building Design together with an unprecedented users-machines/buildings real-time interaction [Figure 2].

AI-BAMS have the potential to provide all the necessary tools and functionalities for analyzing, operating, and managing buildings, whether they are simple mono-functional or complex multi-functional structures. However, in practice, these systems primarily focus on controlling, managing and operating heating, ventilation, and air conditioning (HVAC) systems. Consequently, several critical tasks remain the responsibility of the operator, such as evaluating building performance, detecting unusual energy consumption, identifying efficiency improvements, and ensuring user security and privacy. In order to address these gaps, the integration of Artificial Intelligence (AI), Machine Learning (ML) and Big Data Analytics (BDA) has emerged as a promising solution. These advanced technologies offer tailored, innovative approaches that are well-suited for modern and futuristic building automated management systems. Moreover, AI-enabled tools can assist operators in:

1. Analyzing Meta Data sets generated by interconnected equipment, tools and platforms.
2. Making informed, timely, intelligent decisions to enhance building performance.
3. Enabling real-time users-machines/buildings interaction.

This breakthrough innovation developed over the study [legacy of SPORTE.3Q project] provides a thorough systematic development of the application of AI and Big Data Analytics in BAMS. It explores diverse AI-driven tasks, including load forecasting, energy needs and consumption, water management, indoor environmental quality monitoring, and occupancy detection.

The first part of the study elaborates on a detailed taxonomy to examine existing frameworks and platforms. A comprehensive analysis was conducted on various aspects, such as learning processes, building environments, computing platforms, application scenarios and users-machines/buildings interaction. An in-depth exploration follows, highlighting current challenges and future perspectives in the field. The outcomes of the study focused on real-world applications of AI and Big Data Analytics in BAMSs. It presented three types of buildings and facilities as pilot studies (including the A07 Multi-Purpose Sports Hall building in Qatar University), showcasing their utility in:

- Detecting energy anomalies in diverse buildings typologies such as domestic, educational and offices.
- Optimizing energy and water use and performance in sports facilities.
- Predicting energy, water and occupational load and forecasting potential health risks to the users.

To conclude, this innovative study explores and lists futuristic perspectives and delivers unique guidance to improve and upgrade the efficiency and reliability of AI-BAMSs for Smart Sustainable Buildings. To sum-up, SPORTE.3Q team developed an innovative AI-based framework that reached well its aims to reduce energy consumption by approx. 40% and water usage by approx. 20%, leading to substantial CO2 reductions and cost savings based on the developed modeling and simulation. This pioneering research project [SPORTE.3Q] and derived studies enabled a vision that supports and encourages Qatar's renewable energy potential by helping increase its revenue and decreasing gradually its reliance on natural resources, that are currently reaching up to 60% of Qatar's national economic income. The plus-value is mainly generated through expanded endeavors such as a variety of environmental (reduced GHG emissions), social (improved health, community connections) and contextual (improved comfort) benefits. These goals and targets align well with the Qatar National Vision 2030 strategy and goals.

The AI-enabled BAMS framework consists of different components for real-time measurement, analysis and prediction that provide an end-to-end management solution, from water and energy production to end-user demand/consumption management in sports facilities and stadia, and potentially expandable

to other buildings typologies, urban districts and cities. Innovative computational tools and artificial intelligence techniques leveraging simulation, neural and genetic algorithms reasoning have been utilized to optimize operation scenarios as a major legacy of the tournament's stadiums, facilities and precincts. SPORTE.3Q innovated by designing, developing and applying a pioneering AI-based platform to enable futuristic Smart Sustainable Buildings in the follow-up proposed and recently awarded research project SPORTE.4AI.

The SPORTE.3Q project team comprises of multidisciplinary experts from College of Engineering in Qatar University and Cardiff University, UK. From Qatar University, the team includes Dr. Fodil Fadli (Lead Principal Investigator), Associate Professor of Architecture and Urban Design, Prof. Nader Meskin, Professor of Electrical Engineering, Dr. Ahmad M. Ahmad, Assistant Professor of Architecture and Urban Planning, Dr. Yassine Himeur, Research Associate (former), Eng. Mariam Elnour, Research Assistant; and Architect. Hamdi Ahmed Mohammedsherif, Research Assistant. Representing Cardiff University, the team includes Prof. Yacine Rezgui (Professor), Dr. Ioan Petri (Associate Professor), and Eng. Andrei Hodorog (Research Assistant), from the School of Engineering and BRE Trust Centre on Sustainable Engineering. This collaboration integrates expertise in sustainable architecture and urban design, sustainable engineering, electrical engineering, computer science and artificial intelligence to advance the project's objectives.

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For more about the project:

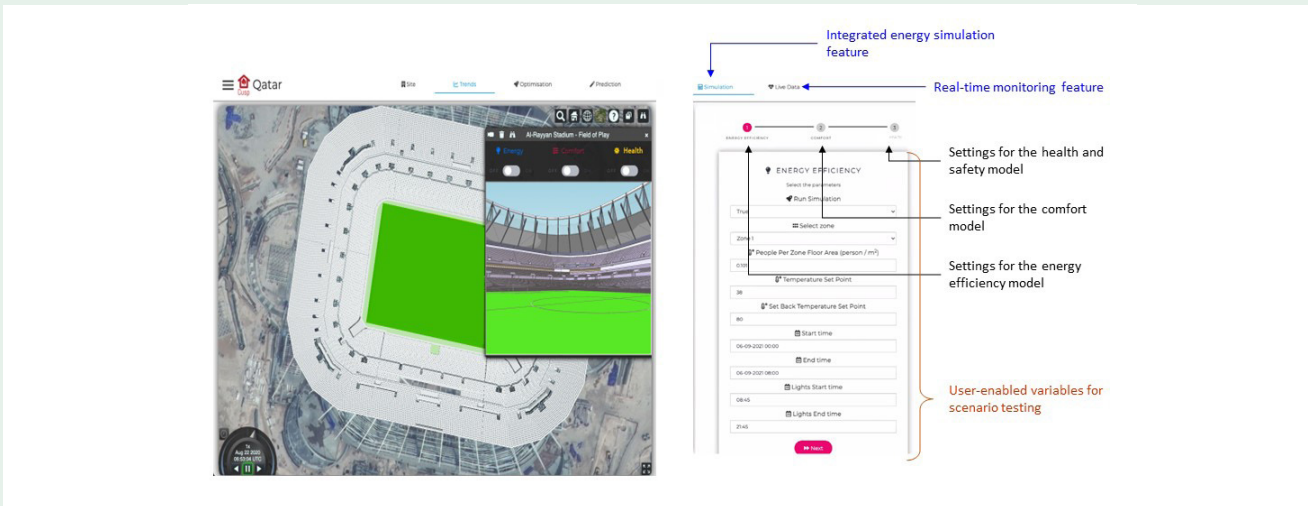

Figure 1: The CUSP model on the web server [SPORTE.3Q project website].

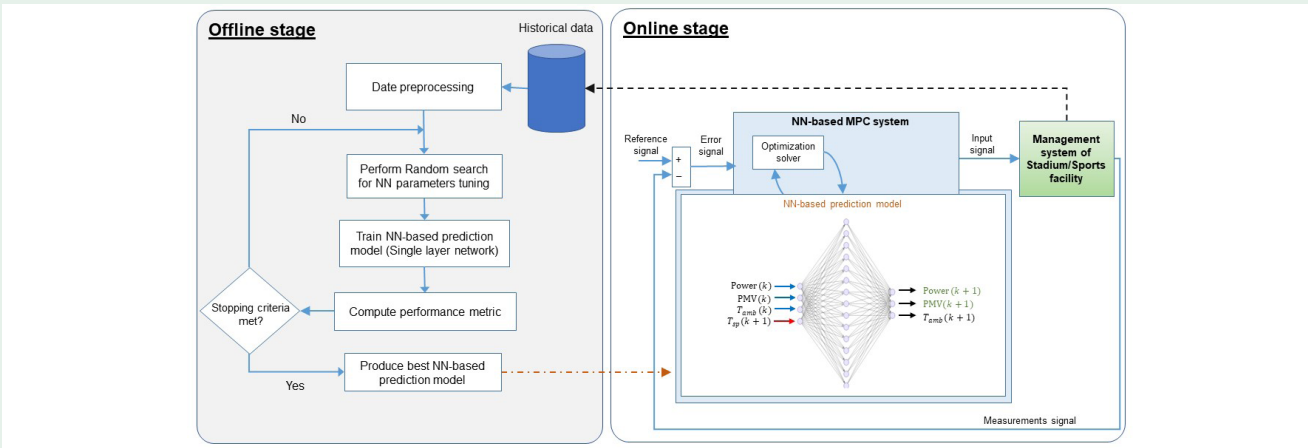

Figure 2: The CUSP model with three integrated models for efficiency, comfort, and health & safety.