TRANSLATING RESEARCH & INNOVATION IN THE BUILT ENVIRONMENT

Building and Construction Authority

CONTENTS

FOREWORD

Hugh Lim
Chief Executive Officer
Building and Construction Authority

The world today is very different from what it was a decade ago. In a short span of time, many more promising technologies and digital innovations offer to change the way businesses operate. Firms have to be agile and innovative if they want to lead change rather than be disrupted by it.

The Construction Industry Transformation Map (ITM) was jointly developed with industry to transform the Built Environment into an advanced and integrated sector with leading firms adopting cutting-edge technologies, especially in the key areas of digitalisation, productivity and automated technologies as well as green buildings.

To support the development of these technologies, BCA and the National Robotics R&D Programme Office (NR2PO) rolled out a Built Environment Robotics R&D Programme in November 2018 that supports research, development, demonstration and deployment of robotics for the Built Environment sector. The Cities of Tomorrow R&D Programme (CoT), a multi-agency effort led by the Ministry of National Development (MND), also supports partnerships between the research community and industry to co-develop solutions for a more productive, resilient, sustainable and digitally-integrated built environment. In addition, to bring about more seamless information flow across the construction value chain and enable firms to generate new growth models that leverage data analytics, BCA and IMDA launched a joint grant call for Construction Digital Platforms.

The Built Environment Accelerate to Market Programme (BEAMP) was launched in February this year with the objective of matching innovators and technology start-ups to meet the needs of BE firms and to build up a vibrant innovation eco-system for the sector. Following the strong response from industry and the innovation community to our first cycle launched in February, we will be rolling out the second cycle of BEAMP challenges in September this year. Our inaugural International Built Environment Week (3-6 Sep) will also feature a start-up zone and the Demo Day for the first wave of BEAMP challenge statements.

The government has been strongly encouraging innovation within the BE sector. The Building Innovations Panel (BIP) is one such platform that helps accelerate the development and implementation of feasible methods, processes, technologies or solutions for the BE sector. The government is also doing its part to lead demand in driving innovation and creating value for firms. Recently, with funding support from Enterprise Singapore (ESG), we awarded R&I projects to small-and medium-sized enterprises (SMEs) to develop drone systems for the inspection of building façades.

I hope this publication, which showcases some of the exemplary building projects and technologies, will provide insights to research and innovation activities in the BE sector and spur your own innovation journey to transform the way we Build Singapore.

RESEARCH & INNOVATION APPROACH

Today, Singapore is regarded as a liveable and sustainable city, driven by innovation, good governance and long-term planning. To continue this success in the decades ahead, Singapore has to overcome many key challenges. These include increasing constraints on resources such as space, manpower and energy, ageing infrastructures and the adverse impacts of climate change. We also need to remain competitive in an increasingly circular economy.

There is thus a need to accelerate the harnessing of new technologies and innovative solutions to solve real-world problems in these arenas. This will require a change in our approach to research and innovation; there will have to be a greater level of co-innovation and collaboration amongst public and private sectors, clients, research community, solutions providers and other stakeholders at various stages.

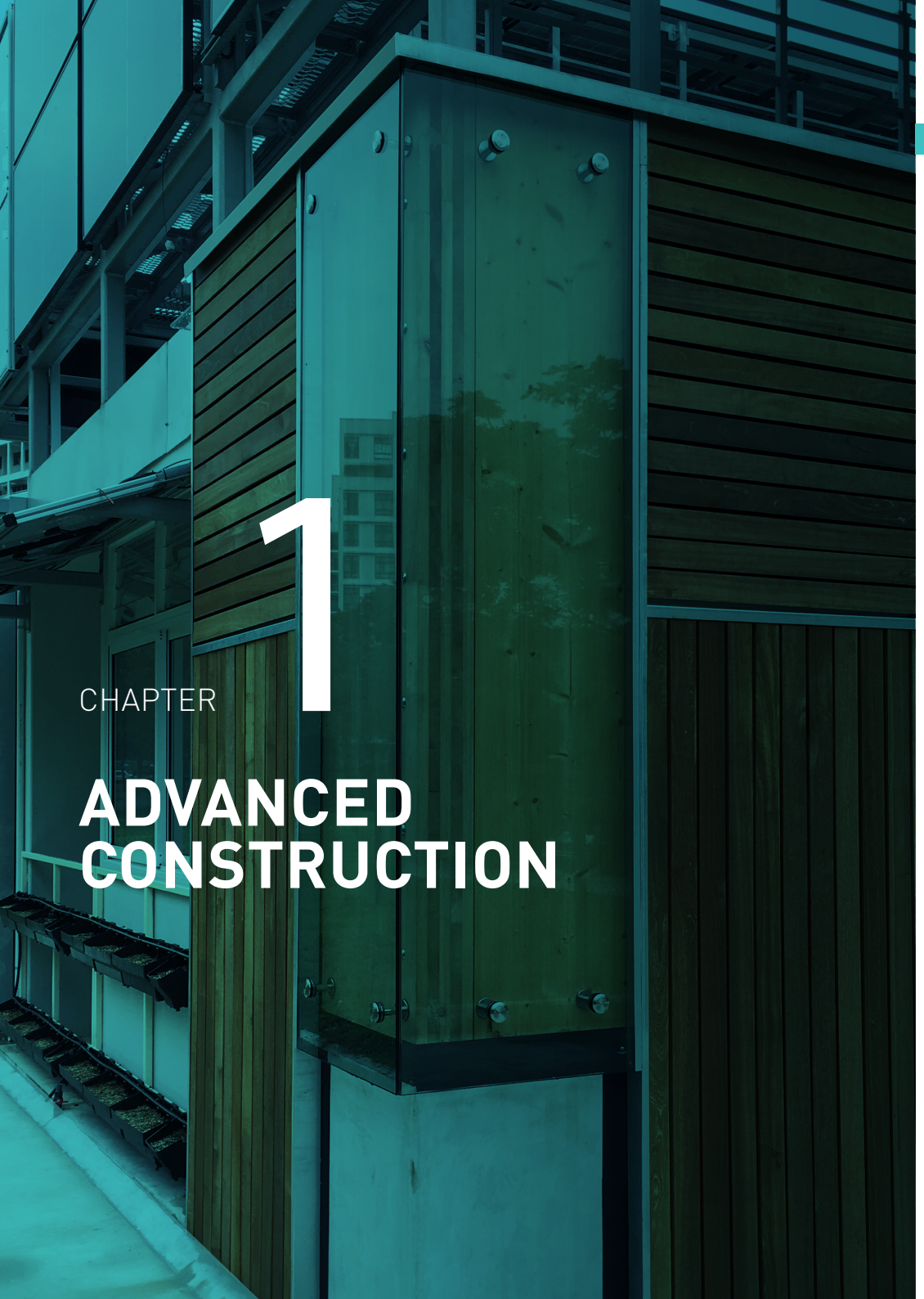
At the roadmap development stage, several rounds of consultation with various stakeholders are conducted to understand current issues and identify areas to focus on for future research. Further focus group discussions are also held to formulate challenge statements for R&D.

At the R&D stage, academic researchers are encouraged to collaborate with industry partners in developing solutions. Projects that require testing and performance validation can make use of facilities such as the BCA SkyLab to test and verify their prototypes.

Industry partners can also identify and offer suitable sites for test-bedding of developed solutions in real-world conditions. For example, in 2018, BCA supported a range of emerging green building technologies, piloted at the Keppel Bay Tower through BCA-Keppel Land Joint Challenge Call.

Innovators that can offer more ready solutions to address industry-clients' challenges but require support to further develop and market their products can tap on funding programmes such as 2-Stage Innovation Grant (iGrant) and Built Environment Accelerate-to-Market (BEAMP) to bring their products to commercialisation.

This publication includes many projects that have adopted this closer collaboration and co-innovation approach.



CHAPTER 1

ADVANCED CONSTRUCTION

BUILT ENVIRONMENT ROBOTICS TECHNOLOGIES

OVERVIEW OF BUILT ENVIRONMENT ROBOTICS R&D PROGRAMME

This multi-agency effort, led by the Building and Construction Authority (BCA) together with the National Robotics Programme (NRP), recognises the opportunities that robotics can offer in improving efficiency, safety and quality of work processes, reducing manpower, and creating new higher value-adding jobs in the BE sector.

FOCUS AREAS

The programme focuses on 3 key areas, each addressing a different stage in the construction value chain:

a. Manufacturing
This research area explores advancing the degree of automation in DfMA facilities and ICPHs as well as expanding their capabilities to meet future needs.

Examples of possible R&D projects include mobile robots that can carry out finishing works faster and more accurately in areas such as tiling, painting and installation of architectural components within Prefabricated Bathroom Unit (PBU) and Prefabricated Prefinished Volumetric Construction (PPVC) modules.

b. Assembly
This research area explores solutions to improve on-site productivity through automation and robotics. It also intends to future-proof the industry against evolving on-site demands as the industry shifts towards greater adoption of DfMA methodologies.

Examples of possible R&D projects include exploring robots which can quickly and accurately transport materials as well as assemble prefabricated components on-site. Other areas to be explored include automation of labour intensive site monitoring and investigation tasks that are critical for large-scale infrastructure projects. There is potential to integrate robotics into assembly techniques and methods for DfMA projects for structural, finishing, and mechanical and electrical systems for different building types.

c. Smart and Sustainable Assets
This research area looks into developing smart solutions for facilities operation and management. In addition, it seeks to address problems that come with an ever-increasing number of older buildings. This will include civil engineering works.

BUILT ENVIRONMENT ROBOTICS TECHNOLOGIES

QUICABOT B20 – ADVANCED INSPECTION ROBOT FOR CONSTRUCTION INDUSTRY

In the construction industry, building inspections and quality control are vital to delivering a quality product to meet both statutory requirements and customer expectations. This project develops new sensing and analytical technologies to digitise CONQUAS-9 (Construction Quality Assessment System) standard and automate inspection and assessment. Transforma's inspection robot inspects facilities using advanced instruments and the latest robotics technology.

In a typical CONQUAS Internal Finish Assessment, a team of two Quality Assessors (QA) is deployed onsite. Our robot halves the number of QAs needed while increasing inspection speed and minimising the manual effort for such repetitive tasks. The inspection robot can inspect the floor, internal walls and ceiling, while the human QA inspects the more challenging areas such as doors, windows, and cabinetry. Inspection data gathered by the robot is objective and digital, providing unbiased data and feedback for all stakeholders such as policy makers, developers, designers, builders, contractors, sub-contractors and unit owners.

The lightweight version of the inspection robot, called Quicabot B20, was unveiled at BuildTech Asia 2018 and showcased at the Singapore International Robot Exhibition (SIRE) 2018. Quicabot B20 has been tested at a few project sites, including condominiums and industrial buildings, for inspecting surface finishing, surface alignment and evenness, tile lippage, crack and damage as well as hollowness.

The robot is equipped with inspection tools and is capable to self-manoeuver and overcome obstacles around the target inspection area. It is able to withstand harsh conditions such as dusty environments, certain rough terrain, direct sun and drizzles at construction sites. The inspection data can be stored, transferred or analysed in the field or off-site. Quicabot B20 is also supported with T-Cloud, a cloud-based robot-and-task management system capable of storing and processing the inspection data over a wireless network in real-time.

POTENTIAL APPLICATIONS

Transforma Robotics has started running pilot-test programmes for the robot to continue validating commercial and technological aspects of Quicabot B20. The plan is to deploy the robot beyond industrial, commercial, and residential spaces, to the built-environment in general, including pre-fabricated works, public works, rail tunnels, and underground environment.

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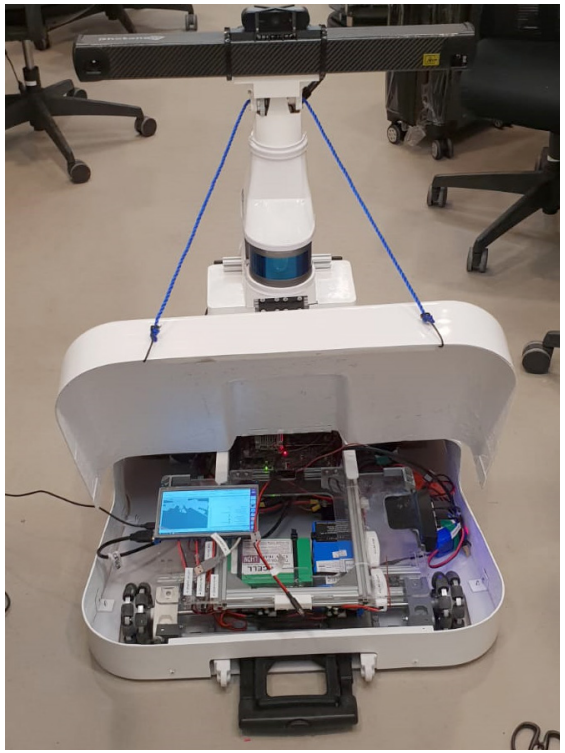
TRANSFORMA

BUILT ENVIRONMENT ROBOTICS TECHNOLOGIES

INSPECTION ROBOT TO ADVANCE CONSTRUCTION INDUSTRY



This project aims to develop an autonomous self-navigating robot, which can be used for inspection of buildings. Equipped with state-of-the-art technologies including computer vision and sensor fusion, coupled with high resolution camera for inspection, the robot can also read information from Building Information Modelling (BIM).

It is trained with existing data sets of inspection sites and can perform inspections and subsequently inform users of any defects found. The types of inspections include surface finishing, surface alignment, cracks and damage, assessment of neatness and consistent width of tilting joints/ pointing, as well as overall cleanliness of the space.

POTENTIAL APPLICATIONS

In addition to ensuring site inspection assessments can be done more objectively and consistently, this project will save time and reduce the manpower needed for effective site inspections.

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MOVEL AI
VRcollab
XJERA LABS videos to insights

ADVANCED CONSTRUCTION MATERIALS

INNOVATIVE MASS TIMBER CONSTRUCTION SYSTEMS FOR HIGH-DENSITY URBAN ENVIRONMENT IN THE TROPICS

While Singapore kicked off one of the first Mass Engineered Timber (MET) constructions in Asia in 2013, most projects at the time imported the MET from Europe due to its Eurocode compliance.

However, in the tropics, trees grow faster. The year-round sunlight here enables local plantation species to grow up to four times faster than those in a temperate climate. With relatively weak mechanical properties on their own, they can be suitable for construction use if developed into MET.

This study aims to encourage regional foresters to plant more fast-growing species suitable for MET, which ultimately promote symbiosis between sustainable forestry and urbanism in the region.

Based on growing speed, mechanical properties and productive volume, the following fast-growing species were short-listed as prospective materials suitable for MET: jabon merah (Anthocephalus macrophyllus), sengon (Falcataria moluccana), acacia hybrid (Acacia mangium x A. auriculiformis), and laminated bamboo lumber (LBL, Dendrocalamus asper).

Among the combination of six layups and two adhesives tested, sengon and jabon with 1C-PUR adhesive demonstrated reasonable lamination properties for MET. However, a critical factor is to control harvesting cycles of plantation timber: the current 5–7 year cutting cycles of sengon and jabon are slightly too early to achieve the requirements of the C24 strength class. By corresponding to Eurocode Timber Structures – CLT (BS EN CLT 16351:2015) and related standards, 3-Layer CLT strength test was conducted in NUS and this was followed up by 5-Layer CLT strength test in Switzerland.

The tropical MET prototypes in various architectonics configurations were tested at the NUS Tropical Technology Laboratory (T2 Lab) to monitor the effects of relative humidity, moisture content and surface temperatures, in comparison with European MET made of spruce.

POTENTIAL APPLICATIONS

Successful development of tropical MET that can fully comply with Eurocode requirements will have high potential to be used in the construction sector in Singapore and across Southeast Asia.

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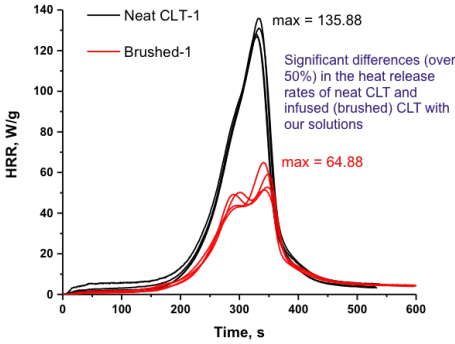
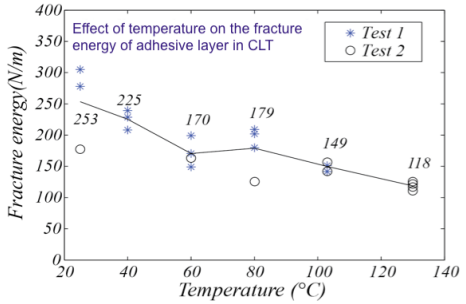
ADVANCED CONSTRUCTION MATERIALS

UNDERSTANDING FIRE RESISTANCE AND TERMITE PROTECTION OF SOFTWOOD BASED ON CROSS LAMINATED TIMBER IN TROPICAL CONDITIONS





This project aims to develop a knowledge base on the use of softwood Mass Engineered Timber (MET) in Singapore construction technologies. More precisely, it aims to understand factors like fire resistance, mechano-sorptive damage and termite resistance on Cross Laminated Timber (CLT) in tropical conditions.

Charring provides an insulating layer that protects the material beneath against fire. However, the strength of the adhesive bond between CLT layers decreases as temperature increases, with shear strength decreasing more significantly in perpendicular grains compared to parallel grains. Hence, charring rate is not an ideal way to analyse fire resistance time of CLT.

This research adopted a novel methodology where flame-retardant solutions were applied either by brushing or dipping. The solutions react in-situ in timber and form insoluble compounds that are resistant to leaching. The fire performance of these MET samples, when tested according to EN13823 (EN13501-1), showed a rating of 'C'-s1-d0, suggesting an unrestricted usage according to European regulations.

Mechano-sorptive creep and moisture-induced cracking were also shown to be key issues in a tropical country like Singapore, while termite resistance of treated samples showed promise compared to untreated samples (tested under controlled but accelerated conditions). Field tests are currently underway to correlate with the laboratory termite-resistance data.

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INTEGRATED DIGITAL DELIVERY

HARMONISING DIGITAL TECHNOLOGIES IN INTEGRATED DIGITAL DELIVERY

One of the three key strategies under the construction industry transformation map is Integrated Digital Delivery (IDD). Aimed at digitalising and integrating the built environment value chain from design to fabrication and construction, IDD also underpins better asset delivery & management so that project stakeholders can achieve objectives such as better design performance, shorter target construction period, safer construction site, or better quality deliverables.

Research & Innovation (R&I) in IDD focuses at how individual digital technologies that can work together to derive greater value collectively. For example, how Building Information Modelling (BIM), video analytics, Internet of Things (IoT) sensors, and mobile devices could act in unison to monitor and ensure construction site safety. R&I in IDD also aims to pave the way for more innovative ways to solve problems faced by the industry by leveraging digital data and a more streamlined workflow.

POTENTIAL APPLICATION

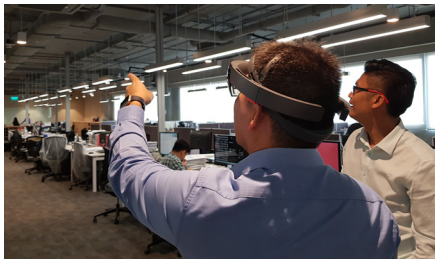
As part of the R&I journey, we encourage the involvement of key demand drivers, end users and technology providers to work together to jointly develop, test and deploy innovative solutions in actual projects. Overtime, we can build up a strong applied R&I culture within the industry and potentially open up new business opportunities for the ops-tech ecosystem.

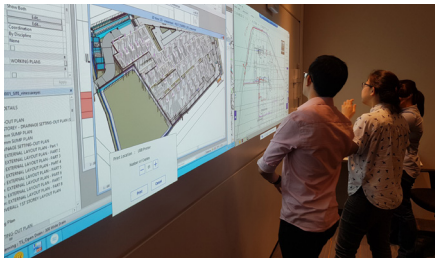
INTEGRATED DIGITAL DELIVERY

INTEGRATING DIGITAL DELIVERY - THE TIONG SENG WAY

Tiong Seng clinched the Singapore Quality Award in 2012, and has further distinguished itself with its Singapore Innovation Class and People Developer certifications. In 2019, Tiong Seng became the first builder to be awarded the highest accolade - BCA Built Leadership Award (Platinum Star) for its sustained excellent performance.

Design for Manufacturing and Assembly (DfMA) mindset is institutionalised in Tiong Seng's operations. This is evident through the company's prefabrication capabilities developed over time – being the first in Singapore to embrace precast automation, leading to the creation of its proprietary LitheTM line of Prefabricated Bathroom Units (PBUs) and Prefabricated Prefinished Volumetric Construction (PPVC) technology. Tiong Seng is also known for being digitally advanced.





Tiong Seng collaborates with NatSteel to re-define re-bars ordering workflow. Within the Building Information Modelling (BIM) platform, Tiong Seng's site team now order re-bars by simple clicks of buttons. Bar Bending Schedules (BBS) of selected components are auto-generated, and orders sent to NatSteel seamlessly. To prevent multiple ordering, components (re-bars ordered) are "locked" and reflected in a different colour in the model. This initiative won the Singapore International Chamber of Commerce (SICC) 2018 "Most Scalable Collaboration" Award.

Tiong Seng has also made construction progress updating more productive. It developed a new workflow utilising BIM technology to auto-generate drawings that have QR codes displayed by the side of every building component. A scan of the QR codes on the drawing with mobile device is all that is required to record work completed. Corresponding components in the BIM model change colour to reflect progress. This new system provides a common platform for all parties to agree unanimously on the progress computation since calculation is done scientifically by computer.

These innovations improve quality and consistency while streamlining processes to enhance productivity. Labour efficiency has since increased by more than 30%, and project management has also improved.

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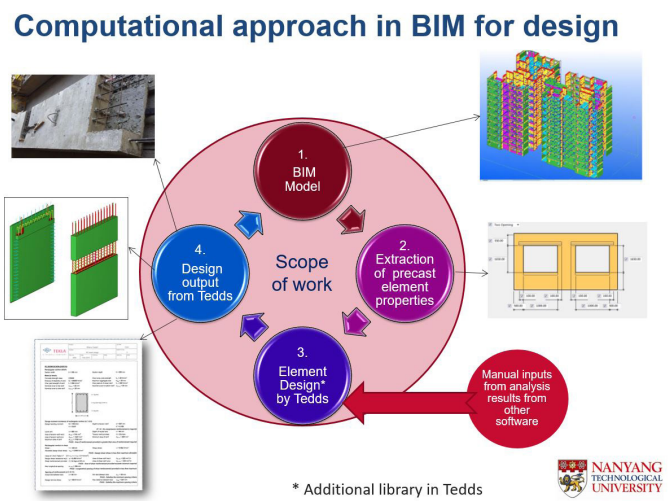
INTEGRATED DIGITAL DELIVERY

EUROCODE-COMPLIANT INNOVATIVE AND PURPOSE-BUILT SOLUTION FOR PRECAST ELEMENT DESIGN

The primary objective of this research is to develop a solution to equip engineers with an effective tool to perform EUROCODE-compliant precast element design holistically and quickly. The solution will empower engineers to easily automate repetitive structural design computations and cope with changes encountered in building projects.



Physical parameters of the precast elements can be populated directly from Building Information Modelling (BIM) models and engineers will be empowered to define further on design parameters such as material strength, loadings, construction loads and short/long term factors in accordance with the code of practice. Engineers will be able to deliver precast design accurately and quickly in a professional format that is acceptable for electronic submission in the Construction and Real Estate Network (CORENET). Users are also able to appropriately customise the level of details of output.

POTENTIAL APPLICATIONS

The developed BIM model interoperable precast elements include:

- Pre-stressed Planks
- Non-Prestressed Planks
- Precast Columns, Walls, Beams and Staircase
- T-beams
- Precast Facades (With Opening) and
- Precast Parapets

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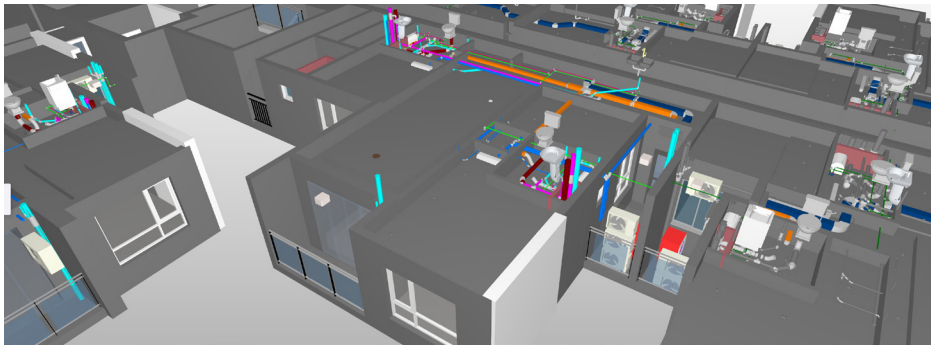
INTEGRATED DIGITAL DELIVERY

CLOUD-BASED BIM MODEL SERVER

In the construction industry, effective coordination between multi-disciplinary project teams is very challenging. This project aims to facilitate better collaboration with the development of a Building Information Modelling (BIM)-based collaboration platform called Model Server. The platform allows for centralised storage, management and sharing of BIM models among the multi-disciplinary users, using a non-proprietary open-exchange format. The platform used in this project is Trimble Connect.

POTENTIAL APPLICATIONS

Model Server can generate an up-to-date Key Performance Indicators (KPI) dashboard for various project activities related to Request for Information (RFI) such as design clarifications, addition and omission of scope, alternative design proposal and design changes. Coupled with Radio-frequency Identification (RFID) technology, Model Server makes it possible for collaborative parties to have quick, accurate and automated construction status updates with 3D visualisation.



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INTEGRATED DIGITAL DELIVERY

HUBBLE MAPS

The Integrated Digital Delivery (IDD) roadmap is dependent on the implementation of Building Information Modelling (BIM) to integrate data, processes, and stakeholders along the value chain. However, there is currently a BIM-to-Field gap at construction sites where stakeholders are still using 2-dimensional (2D) floor plans instead of BIM in their operations. This results in significant data slippages and lack of data continuity from design, to build, to facilities management.

Hubble Maps is a precise indoor tracking technology that integrates users' real-world position to the BIM position, thus allowing users to know exactly where they are in the BIM.

POTENTIAL APPLICATIONS

Hubble Maps can track users' eye coordinate and head movement and allow them to know exactly what BIM element they are looking at in the real world. In doing so, Hubble Maps will bridge the BIM-to-Field gap and allow all stakeholders to interact with one common BIM across the entire value chain.

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INTEGRATED DIGITAL DELIVERY

RISK ASSESSMENT WITH ARTIFICIAL INTELLIGENCE CAPABILITY

As safety is a major concern for construction projects, risk assessment is a top priority before any work is allowed to begin. Permit-to-work systems are a requirement but they mainly require manual paperwork. Even when digitised, they do not account for a multitude of factors around the job site that can greatly impact the outcome of any assessed risk. Hence, this project aspires to enhance the permit-to-work systems that meet the requirements with the use of Industry 4.0 technologies like video analytics, IoT sensors and artificial intelligence.

POTENTIAL APPLICATIONS

The system will allow stakeholders to continuously monitor all types of work and to assist safety personnel in enforcing Workplace Safety and Health (WSH) practices. Through the timely alerts, breaches in environmental or safety parameters such as excessive noise or the removal of helmets during work, supervisors can be prompted to act quickly before dire consequences occur. The use of smart tags to track people and assets will also serve to improve existing risk controls . With plans for further enhancements through the use of artificial intelligence via Google's Tensorflow 2.0, the project aims to develop useful machine learning models in risk assessment for the construction industry.

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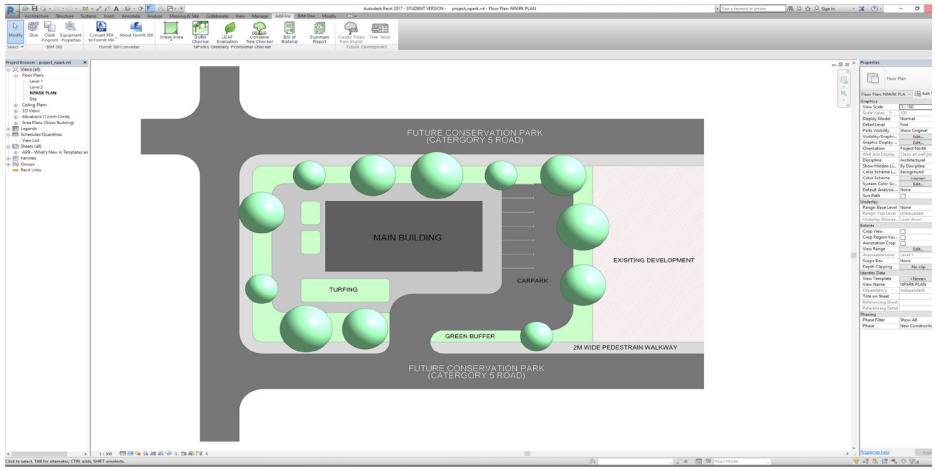
INTEGRATED DIGITAL DELIVERY

AUTOMATED CHECKERS FOR LANDSCAPE BIM SUBMISSIONS



This project aims to develop Building Information Modelling (BIM) auto-checker plugins based on NParks regulatory requirements as well as uncover the necessary object parameters to be included in order for these checkers to work. For example, vegetation objects need to have a Leaf Area Index (LAI) parameter in order the Green Plot Ratio (GnPR) to be calculated.

Knowledge derived from this project will be another springboard for the adoption of BIM in the landscaping industry with the streamlining of BIM delivery to checking processes.

POTENTIAL APPLICATIONS

Research outcomes can improve construction productivity in the following ways:

- Automated checkers allow consultants to rapidly assess their developmental plans against statutory requirements
- Pre-established BIM landscape object libraries reduce redundancy in creating and handling model information
- Leaner and more streamlined BIM Model delivery process reduces man-hours
- Improves professionalism among the landscape practitioners
- Productivity improvements for agencies who track vegetation statistics in developments such as URA, HDB, BCA and JTC

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BIMLife

NATIONAL PARKS
LET'S MAKE SINGAPORE OUR GARDEN

CHAPTER 2

RESILIENT INFRASTRUCTURE

FAÇADE INSPECTION SYSTEMS

DRONE INSPECTION SYSTEM FOR BUILDING FACADE

Figure 1: Inspection of using drone at BCAA

The inspection of building façades is typically a long, tedious and costly process that requires the inspector to work at height using a gondola or mobile elevating work platform (MEWP). These issues are further aggravated by increasing building heights and complexities of façade elements used in modern building. With an ageing building stock, inspection of building façades is becoming more important than ever.

Drone technology has been maturing rapidly over the years in tandem with advancements in sensors technology, mapping techniques, computing power and artificial intelligence. It is a matter of time before drones are used for the purpose of building façade inspection. This project aims to develop a fully digital inspection system centered upon drone technology. Its scope covers designing a software to manage and organise data, develop an artificial intelligent (AI) engine to analyse and identify defects autonomously, and creating a seamless inspection workflow. This novel inspection solution would surmount the physical challenges associated with high-rise building and complicated façade design, to enable inspection at a faster, safer and more cost-effective way.

POTENTIAL APPLICATIONS

High-resolution visual and infrared thermal images captured from the drone-mounted camera can be quickly analysed using A.I. engine to detect defects autonomously. A programme will be developed to manage these images, reconstruct the building 3D model, assess and flag out the defects, generate inspection report, and facilitate repair management. All of these processes are to be seamlessly performed on a single integrated platform.

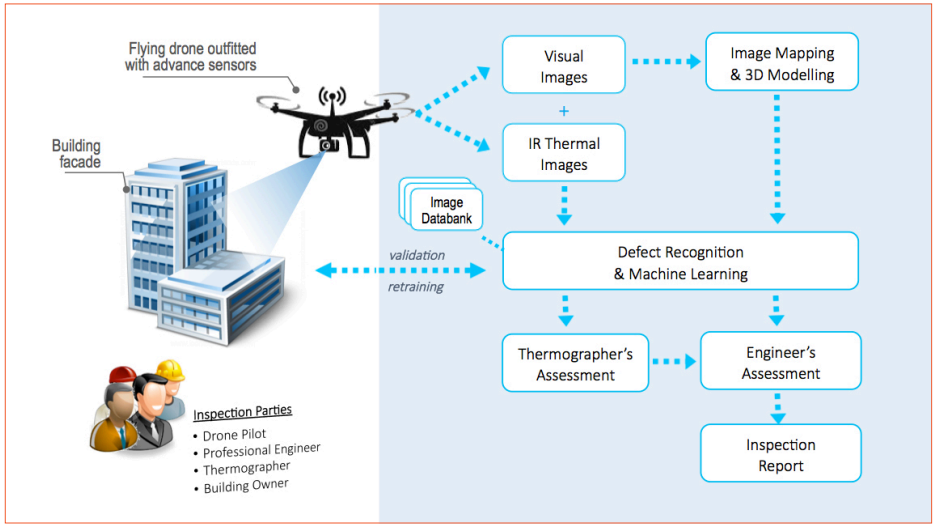
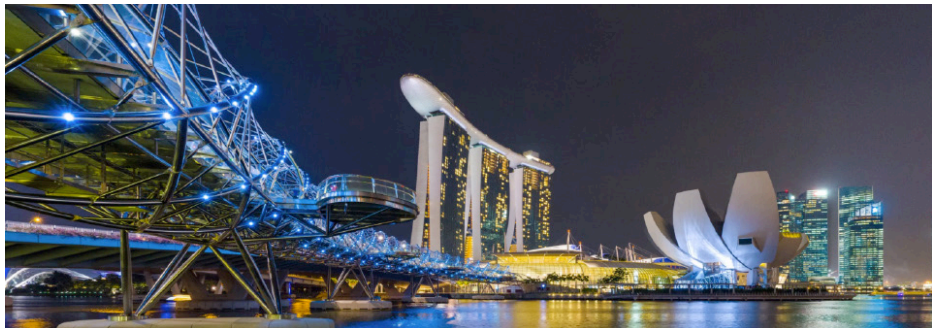


Figure 2: Drone Inspection Workflow

MAINTAINABLE DESIGN

MAINTAINABLE DESIGN APPRAISAL SYSTEM



Design for Maintainability

Design for Maintainability (DfM) is the practice of integrating operations and maintenance experience into project planning and design to achieve effectiveness, safety, and economy of maintenance tasks throughout the life of a facility. Design-related maintenance concerns can generally be categorised into three areas; "Access space", "design & detailing" and "choice of materials".

Challenges for FM Practitioners

Facility Management (FM) personnel of a newly handed over building may experience difficulties in carrying out maintenance activities efficiently and cost-effectively. That is because, traditionally, maintenance operations and requirements are only considered when the building is handed over to FM service providers. For example, a building Facility Manager takes over a building only to realise that his equipment room is not big enough to perform regular maintenance optimally, potentially leading additional demand for manpower, time, and financial resources. Inconvenience to building occupants or disruption to businesses as well as safety risks to maintenance workers are added challenges.

Maintainable Design Appraisal System

To help developers and designers better consider DfM into their projects, BCA is collaborating with a multi-disciplinary team led by Surbana Jurong [Principal Investigator (PI)] and the Singapore University of Technology and Design (SUTD), Nanyang Technological University (NTU), and the Energy Research Institute at NTU (ERIAN) as Co- Principal Investigators to develop a Maintainable Design Appraisal System (MiDAS). MiDAS assesses a building design's degree of maintainability through the lens of labour efficiency and cost-effectiveness of downstream maintenance. MiDAS is applicable to high-density residential as well as non-residential building typologies.

How MiDAS Works

MiDAS systematically maps buildings' systems and sub-systems with their respective Key Maintenance Items (KMIs) – i.e. cost and labour intensive maintenance items – and which are influenceable by design. It then presents a set of design strategies and solutions to address the KMIs, with a view on overall lifecycle.

The design solutions are referenced to current industry best practices. Notwithstanding, MiDAS gives designers / developers the flexibility to adopt alternative and innovative solutions to meet the desired intent of the KMI.

Where feasible, MiDAS adopts a Life Cycle Costing approach to validate the design solutions by presenting a view on the differential initial cost premium – depending on the adopted solutions – and the potential labour and cost savings over the project's life span. *(Please see Figure 1 for an illustration).*

A MiDAS score is then derived based on the set of design solutions adopted. The final score gives designers and developers an estimate of the potential labour and cost savings downstream.

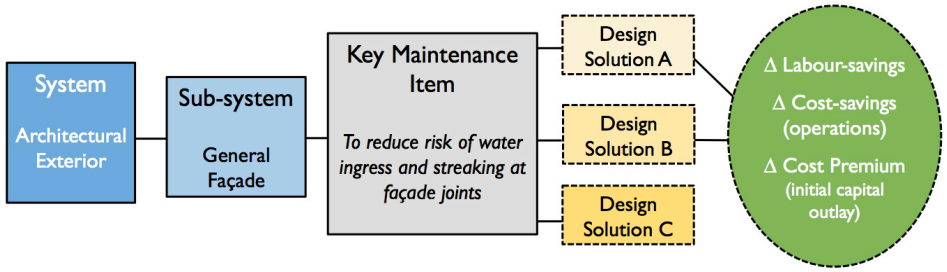


Figure 1: Illustration of MiDAS tool

Coverage

The scoring framework covers the key disciplines – architectural (exterior and interior), mechanical, electrical, and landscape – and also comprises an innovation section to promote adoption of technologies. Below is the brief summary of the system and sub-systems covered in the MiDAS framework.

GENERAL REQUIREMENTS	*I.e. Integrated design approach, Adoption of BIM tools, LCC, performance based contract etc.*
ARCHITECTURAL EXTERIOR	*I.e. Façade, Tile and stone cladding, metal cladding and glazing systems, Eternal walkways, paint, roof, railing, façade features and balustrade etc.*
ARCHITECTURAL INTERIORS	*I.e. Floor, wall/partition, ceiling, wet room and storage, basement, loading bay/service areas etc.*
MECHANICAL AND ELECTRICAL	*I.e. Chiller Plant, Air distribution, Domestic water and Sanitary system, BMS, Lighting and Power, ELV, Lifts, Solar PV and Lighting protection systems etc.*
LANDSCAPE	*I.e. Soft scape, Hardscape, Vertical Greenery and Roof & Sky Terraces*
SMART AND INNOVATION	*I.e. Smart Solutions.Innovative Technologies*

Figure 2: Summary of systems and sub-systems covered in MiDAS framework

Benefits

As a first-of-its-kind design appraisal tool, MiDAS

I. Fosters greater collaboration among designers, developers, and FM practitioners to deliver better and more maintainable designs;
II. Promotes holistic sustainability by considering not only the environmental aspects but also economic and social good through greater cost savings and reduced reliance on manual labour;
III. Enables designers and developers, through the MiDAS score, to make more informed design decisions upfront and take a life cycle view of the development, i.e. considering not only initial capital expenditure but also operating expenses; and
IV. Enhances the reliability and operational productivity by integrating smart FM tools and Internet of Things (IoT) based technologies.

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CHAPTER 3

GREEN BUILDINGS

ENERGY EFFICIENT TECHNOLOGIES

BRIDGING THE GAP BETWEEN AIR-CONDITIONING AND ARTIFICIAL INTELLIGENCE

Throughout Asia, air-conditioning remains the most controversial topic in the built environment. On one hand, it has allowed countries like Singapore and India to transform from hot and humid rural economies into the world's most dynamic and vibrant cityscapes. On the other hand, it's massive energy requirements has led to many people asking "How can we address the two greatest megatrends of our generation – Urbanisation and Climate Change?"

The main problem is that, similar to other systems with multiple components working together, the energy consumption of an air-con system is dependent on a large number of independent variables (e.g. flow, temperature and pressure). To deliver an energy efficient system, engineers must constantly analyse data and adjust set points of the independent variables to accommodate changes in operating conditions.

Furthermore, the complex relationships between these variables are too much for humans to understand. Thus, many air-con systems (even those with brand new equipment and the latest technology) are not optimised and waste huge amounts of energy.

To address this, Kaer looked for inspiration from the world of artificial intelligence and machine learning to achieve better system performance for tenants and energy efficiencies for landlords.

ENERGY EFFICIENT TECHNOLOGIES

Phase 1: Collaboration

Kaer needed to bridge the gap between air-con experts and AI experts to marry the two disciplines required to develop the world's first AI software to drive efficient operations and a better customer experience. To achieve this, we collaborated with experts from ADSC who provided the fundamentals and background in big data management and neural network algorithms.

Phase 2: Prototyping

After learning from ADSC, Kaer was able to develop the first prototype of the software (known as brIQs) and deployed a beta test across 15 assets in Kaer's regional "air-conditioning as a service" portfolio. After many months of testing and fine tuning, Kaer successfully rolled out a cloud-based, highly dependable and automated data-driven energy management system to tackle challenges in chiller plant design, control, diagnostics and optimisation.

Phase 3: Product Development

Kaer is currently partnering with the Racks Central data centre to develop an end-to-end, fully autonomous self-optimising control system that prioritises user requirements and IEQ along with building load reduction and system efficiency. The projected outcome is best-in-class IEQ conditions and a reduced Power Usage Effectiveness (PUE) of more than 40%.

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ENERGY EFFICIENT TECHNOLOGIES

ON-LINE SMART AIR-BALANCING SYSTEM FOR NET ZERO ENERGY BUILDINGS

Air balancing is a technology that allows air flow to be distributed according to the design of the ducting system. An accurate amount of air supply contributes to better indoor air quality and thermal comfort, as well as higher occupant productivity and performance in the office. It also reduces energy consumption of buildings, prolongs life expectancy of Heating, Ventilation and Air-Conditioning (HVAC) systems and lowers duct noise.

This project aims to develop a novel low-cost and high-performance 'On-line Smart Air Balancing System' (OSABS), which will contribute towards the net zero energy buildings.

Fig.1 The application of the smart air balancing system.

Fig. 2 The tested smart air balancing system.

Potential Application

Unlike the commonly used Variable Air Volume (VAV) system that relies on manual air balancing techniques, the OSABS can be balanced automatically on-line. It solves the problem of over-ventilation by providing accurate air supply, contributing to energy savings of about 50% compared to existing HVAC systems. The OSABS can be easily installed in an existing HVAC system by upgrading its control system.

The OSABS can also significantly reduce labour and shutdown maintenance costs.

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NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

AIR T&D

ENERGY EFFICIENT TECHNOLOGIES

NEW GENERATION ACMV SYSTEMS – TOTAL ENERGY EFFICIENCY SOLUTIONS

The research focuses on developing new technologies related to Air-Conditioning and Mechanical Ventilation (ACMV) systems to provide satisfactory Indoor Environmental Quality (IEQ) with high energy efficiency.

To verify the applicability and performance of the developed ACMV technologies, a laboratory in NTU was renovated and incorporated with these state-of-the-art technologies for demonstration and conducting real-time testing and commissioning.

The ACMV system consists of:
- Air Handling Unit (AHU),
- Energy Recovery Ventilator (ERV),
- Liquid Desiccant Air-Conditioning system (LDDS),
- Variable Air Volume box (VAV box),
- Active Thermosiphon Beam and Passive Thermosiphon Beam (ATB and PTB)

The system is configured to operate under four different modes (AHU+VAV mode, ERV+PTB mode, LDDS+ATB mode, AHU+PTB mode). Each mode is tested for its energy consumption and indoor air quality to find the optimum configuration. The mechanical design of the developed ATB and PTB terminal unit is further optimised with innovative nozzle arrangement, cooling coil placement and air chamber configuration.

In addition, to optimise the supply air flow rate and maintain indoor CO_2 level, Intelligent Air Balancing System (IABS) and Smart Air Damper (SAD) technologies are applied in the air distribution system.

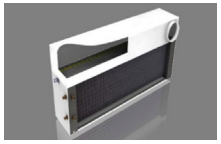
Indoor temperature, humidity and CO_2 level are controlled using a self-developed building management system called BSTAR and real-time data is recorded in the data base.

Potential Applications

Implemented in some of the tutorial rooms and a conference room at NTU, this innovative ACMV system has potential to become the standard air-conditioning system in modern buildings.

The novel working principle behind the new system is that it enables flexible control of indoor room temperature, humidity and CO_2 level. Furthermore, the air flow characteristics of the system improves indoor thermal comfort.

Based on experimental results, ERV+PTB mode is the optimum configuration that can achieve around 50% reduction in energy consumption compared to conventional VAV systems.



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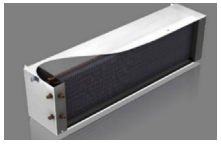

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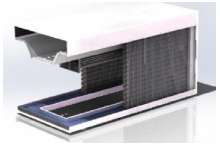

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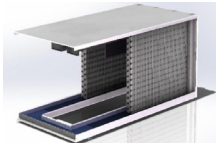

(PTB-C)

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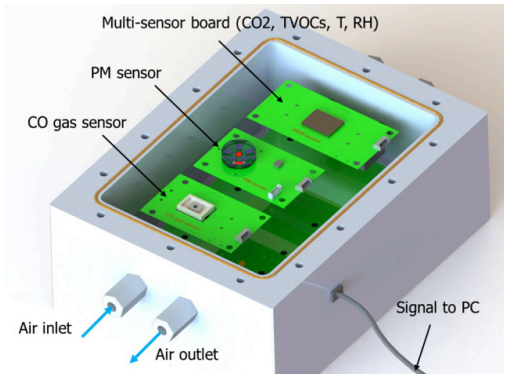
ENERGY EFFICIENT TECHNOLOGIES

REAL-TIME MONITORING AND CHARACTERISATION OF PARTICLE COUNT AND INDOOR ENVIRONMENTAL QUALITY WITH INTEGRATED LOW-COST SENSORS

A team comprising researchers from A*STAR's National Metrology Centre (NMC), A*STAR's Institute of Microelectronics (IME) and National University of Singapore (NUS) developed novel gas sensors using advanced micro-electromechanical and photonic technologies for reliable, accurate and fast monitoring of indoor environmental quality. A dynamic gas mixing and characterisation system was also developed to test the sensors, which is required for validating the performance of the sensors. The test ensures that the sensors are suitable and reliable for measuring indoor environmental quality parameters such as carbon dioxide, carbon monoxide, total volatile organic compounds, particulate matters, temperature and humidity.

In large-scale applications such as Smart City, Intelligent and Green Buildings and Cyber-Physical Production Systems, a multitude of sensors are normally deployed. They are used to measure and collect huge amounts of data on parameters such as air pollutants, temperature, noise, vibration and air flow for the purposes of planning, design, equipment maintenance and other decision-makings. However, the trustworthiness of the big data set may be compromised due to malfunctions, drifts and inaccuracy of the sensors. To overcome this, the project team has also developed self-diagnostic and self-healing sensor technologies for real-time monitoring and calibration of networked sensors.



The prototype with novel low-cost sensors for IEQ monitoring and characterisation

On 21 Sep 2018, the technologies developed were showcased during the visit by SM Teo Chee Hean (then DPM) to Building and Construction Authority (BCA), the funding agency of the research project.

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ENERGY EFFICIENT TECHNOLOGIES

SPEEDING TECH-TO-MARKET WITH INDUSTRY PARTNERS

With stiff competition, industry is facing increasing pressure to innovate and accelerate time-to-market of services and products. Public-private partnerships offer a way to tackle these challenges.

Through collaboration with public research institutes or institutes of higher learning, industry players can reduce or manage R&D risks through pilot projects and test bed new and emerging technologies without heavy upfront investment. They can also gain knowledge and access to new research trends and novel experimental techniques. These partnerships facilitate the validation of R&D innovations, allowing companies to accelerate the commercialisation of new technologies for industry.

A leading consumer goods company and a large indoor air-quality consultancy firm are partnering with A*STAR's National Metrology Centre (NMC) in emerging technological areas of integrated photonic-based indoor environmental sensors, and multi-gas mixing and testing platform.

Design and development of:

- Integrated photonic-based indoor environmental sensors
- A multi-gas test platform for chip-level sensing components to device-level sensors
- A proof-of-concept Self-Diagnosis Self-Healing (SDSH) system, which can autonomously monitor and correct the drift in sensors, saving time and improving productivity

Future Prospects

The development of the SDSH proof-of-concept has attracted interest from more industry partners. Currently, Singapore Technologies Electronics Limited (STEE) is working with NMC on the demonstration of the SDSH system under a project funded by BCA. The benefits of the SDSH system are not limited to indoor air quality monitoring but can be applied to other industry areas as well.

STEE hopes to commercialise the developed technology upon the successful completion of this project.

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ENERGY EFFICIENT TECHNOLOGIES

REPLACEMENT OF COOLING TOWER BY COMPACT, WATER- AND ENERGY-SAVING SUPER HYDROPHOBIC MEMBRANE-BASED EVAPORATIVE COOLER

In the hot and humid climate of Singapore, air-conditioning is essential not just for human comfort; it is directly related to productivity that affects the economy of the entire country. Air-conditioning systems in typical commercial buildings account for 50 – 60% of total building energy consumption. Apart from energy, scarcity of water is another pressing environmental issue that will impact the livelihood of mankind.

In this project, a compact, water- and energy-saving super hydrophobic membrane based evaporative cooler (MEC) has been developed to replace cooling towers.

The new MEC system helps to save at least 50% of the water from evaporation. It achieves this by evaporating the water in a more controlled manner which can be partially condensed and reused. Compared to cooling towers, the MEC is able to achieve a larger temperature difference (ΔT). This ensures that the water entering the chiller system is at a lower temperature, hence reducing energy-consumption in the cooling process. Energy savings can also be achieved with less requirement for pumping. In addition to water and energy savings, the MEC can reduce carbon footprint by up to 80% compared to the conventional cooling tower.

The technology, proven in laboratory scale, was licensed to a local SME, RELIC Services. The evaluation license allows both parties to work together to develop a pilot scale 50RT / 180 kW MEC system and test its performance in real field conditions.

Prior to the pilot system, a 10RT / 36kW MEC prototype system was designed and built with the support from our industry partner to remove heat from the condenser unit of a variable refrigerant flow (VRF) air-conditioning system. A water loop was designed to carry the heat from the refrigerant to the MEC module that works like a cooling tower. The system has been installed outside a EWTCOI workshop at Ngee Ann Polytechnic and testing data was used to design the pilot system.

In this project, the concept of using membrane for cooling tower application has been proven and the technology has been developed from idea (Technology Readiness Level (TRL) -1) to a demonstration scale (TRL-6). However, during the demonstration scale study, the prototype module did not meet heat removal requirements. Further module design modifications were needed to at least triple the surface area per unit volume to achieve the desired heat removal. The project team will continue working with the industry partner to further optimise the MEC system for commercialisation.

Prototype of MEC system

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CHAPTER 4

TRANSLATION THROUGH TECHNOLOGY INTEGRATION

SAMWOH SMART HUB – FIRST POSITIVE ENERGY INDUSTRIAL BUILDING IN SINGAPORE

Samwoh Corporation is taking its 'green' journey' to another level with the construction of the first positive energy industrial building in Singapore. This 4-storey building known as Samwoh Smart Hub is an ambitious project which aims to surpass BCA's latest Green Mark Platinum Super Low Energy standards.

We are adopting numerous state-of-the-art technologies to bring down our energy consumption and at the same time, utilise the latest innovations in solar-panel systems to generate more than our required usage.

As a champion for sustainability in construction, our positive energy building will be constructed using various types of recycled construction materials such as recycled concrete aggregates (RCA), repurposed sedimentary rocks from the Jurong Rock Cavern, green cement, Manufactured sand (M-sand) and other innovative solutions.

Samwoh Smart Hub will be more than just a workplace for our employees but one that allows our employees to thrive in an open and lively environment. Spaces created are conducive for work, seeding of ideas and collaborations, relaxing reads or breaks with dedicated corners and thoughtfully designed cubicles, and staying active throughout the day with walkways lined in abundant greenery.

Our employees and guests can expect a high level of comfort and convenience from the intelligence embedded in the building. The company can reap the returns on investment in the advanced technologies deployed from the lower running cost.

We also hope that this development can be a fruitful learning ground for many built and energy professionals and when completed, be a showcase to inspire the drive towards greater sustainability among our BE community.

Front view of Samwoh Smart Hub

Rear view of Samwoh Smart Hub

To achieve the status of Positive Energy Building (PEB) in Samwoh Smart Hub, the design approach was to reduce energy consumption to its minimum and offset it with at least 110% on-site solar power. Samwoh Smart Hub is remarkably expecting energy savings of at least 50% from BCA Green Mark Criteria Version 2015.

Aerial view of Samwoh Smart Hub

The building façade has been optimised to reduce east and west sun exposure while drawing daylight through the entire length of north and south façade as well as courtyards despite the challenging deep floor plates.

Samwoh Smart Hub will be adopting a solar-driven direct current chiller and domestic water pumps. This DC chiller system is a technological breakthrough with one of the lowest power loss among many of the latest innovations in ACMV. It will be the first of its kind to be used in Singapore.

Samwoh Smart Hub is sited along the coastal waters of Singapore. Most of the outdoor equipment will be subjected to high corrosion risks. The Cooling Tower Open Circuit with electronically commutated technology addresses all these challenges with its robust corrosion-proof materials and innovative arrangement of the air/water interface for better heat exchange.

We are using a very special Direct Current Smart Fan Coil Units (Smart FCU) to eliminate the technical limitations with conventional FCU through the built-in air purging, fresh air supply and auto water balancing capabilities within the unit. These Smart FCUs are also able to provide cooling with elevated chilled water temperature to reduce overall energy consumption.

An artificial intelligence system built into the Energy Management System is developed through ZEB Technology's verified empirical data. The developed AI programming algorithms is expected to enhance building performance through smart automation controls and diagnosis features to further reduce energy wastages and optimise energy efficiency.

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SAMWOH
- INNOVATIVE INSIDE OUT

Innovation is rooted in the core values of Samwoh and it has been the major driver of growth for the organisation. More than a decade ago, we embarked on this journey with heavy investment in our R&D. Today, we continue to conduct researches that are practical and add value back to what we do.

Leveraging on our highly qualified researchers and leading-edge testing facilities, Samwoh has successfully developed several first-of-its-kind sustainable products for the industry with acceptance by the authorities. This initiative provides users with a competitive edge in terms of better technical expertise on the products and first-mover advantage over competitors.

Apart from product development, we also invest in innovative technologies that bring intrinsic changes to our operations. We are motivated to streamline our work processes and groom a smart workforce that yields high productivity gains in a safe manner.

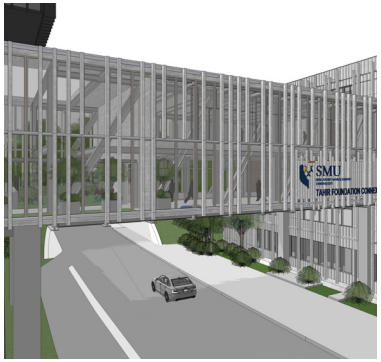
At Samwoh, we are an ardent advocate of continual innovation and believe that it is never just top-down. We promote ownership by empowering our employees to adopt innovative solutions in addressing challenges faced. By inculcating an innovative culture within our organisation, we create a complementary and integrated ecosystem while providing good quality jobs for our staff.

Illustration of Samwoh Innovation Centre

TAHIR
FOUNDATION CONNEXION

Tahir Foundation Connexion (TFC) is envisaged to be the first large-scale Mass Engineered Timber (MET) development in the city centre, as well as the first on-site Net Zero Energy Building (NZEB) with its energy demands entirely generated by the photovoltaic system located within the same building. The TFC building also boasts many green features and technologies to facilitate the attainment of Green Mark Platinum and WELL building standards.

In line with the Building and Construction Authority's (BCA) drive towards Design for Manufacturing and Assembly (DfMA) technologies, the TFC project will adopt structural steel and MET for construction to expedite its timeline. Mechanical, Electrical and Plumbing (MEP) modular spines will be implemented to reduce installation time for MEP services. The Passive Displacement Cooling (PDC) system is being implemented to significantly reduce the energy consumption for air-conditioning. Predictive and responsive smart building control solutions will further contribute to energy savings by turning off unoccupied areas.



Overall, these technologies can contribute to 500MWh of energy savings yearly.

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DEVELOPMENT AND TESTING OF AN AUTOMATED COMMISSION TO OPERATE (C2O) PLATFORM FOR SMART, GREEN BUILDINGS

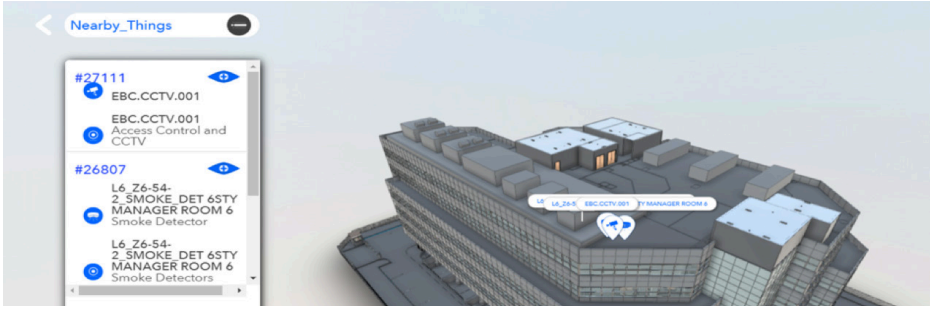
Smart Building and Green Building technologies enable the better management of building performance and energy optimisation using smart, integrated and automated operations and maintenance strategies. Unfortunately, the high cost and complexity of both the implementation and operations of Smart Buildings hinder their adoption.

This project demonstrates how cost and complexity of implementing and operating Smart Buildings can be significantly reduced using Eutech's Commission to Operate (C2O) cloud platform. The C2O platform digitises and integrates systems and processes from design to engineering, commissioning and handover. At handover, C2O delivers a fully integrated physical Smart Building and, also, its Digital Twin.

By integrating the building's Building Information Model (BIM) with other metadata (e.g. from building systems and IoT devices) the Digital Twin provides a working, digital replica of the building's physical assets, spaces systems and processes. As such, C2O provides a unique foundation for enabling smart (predictive) operations and maintenance and delivering digital tenant services.

APPLICATIONS

The complete C2O platform has been deployed at two key commercial projects in Singapore — Paya Lebar Quarter, a 1.3 million square feet smart precinct, and Certis Central a 130,000 square feet commercial building.



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TECHNOLOGIES TESTED AT THE BCA SKYLAB

Test Bedding Research for Innovative Technologies in SkyLab

This project investigates the performance and operational characteristics of a set of green building technologies, namely LED and auto-dimming lighting, active chilled beam (ACB) air-conditioning, automated daylight redirecting shading and Electrochromic glazing (EC) with respect to conventional reference systems consisting of Low-e double-glazing unit (DGU), manual blinds, FCU system and T5 fluorescent lamps, under the tropical climate conditions of Singapore.

Experiments are conducted in the BCA SkyLab testing facility which allows side-by-side comparisons and investigation of orientation effects of these technologies. The study focuses on revealing the energy, visual and thermal comfort performances as well as dynamic responses to weather conditions of these technologies when deployed individually or in combinations.

Research Outcome

Results show that more benefits can be obtained by deploying a combination of the tested technologies in terms of annual energy savings as well as thermal and visual comfort, compared to deploying the technologies individually.

Major results are highlighted below:

1. The combined technologies showed about 35% energy savings in North orientation, 33% in East orientation, 28% in West orientation and 29% in South orientation.
2. Both the automated blinds system and the EC glazing can provide thermal and visual comfort with unobstructed view when compared to a typical building using a Low-e DGU and manual blinds system.
3. The ACB system can provide better thermal environment with its lower air discharge rate characteristics, when compared to the traditional FCU system. However, the energy savings and thermal comfort potentials of ACB deteriorates as room heat load increases to over 112 W/m^2.

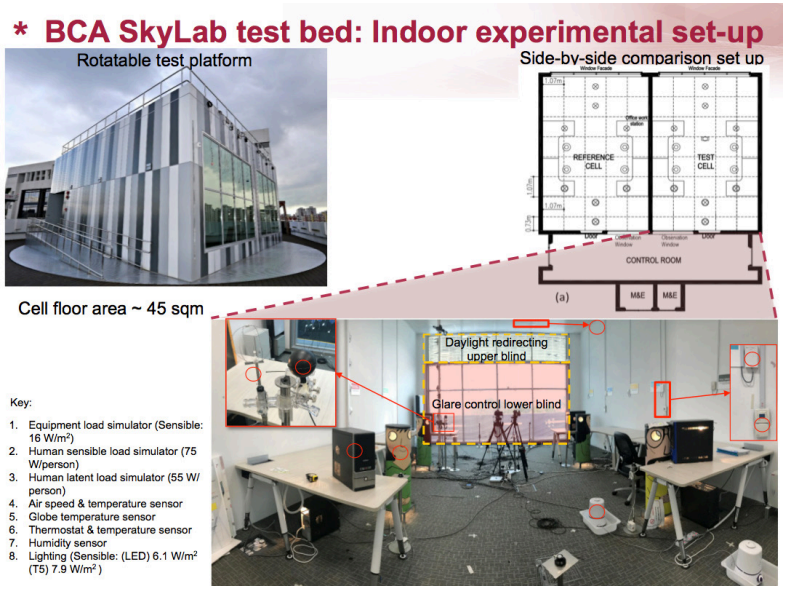

Figure 1: Indoor experimental set-up for Blinds and Lighting technology tests

Figure 2: Electrochromic glazing installed at BCA Skylab

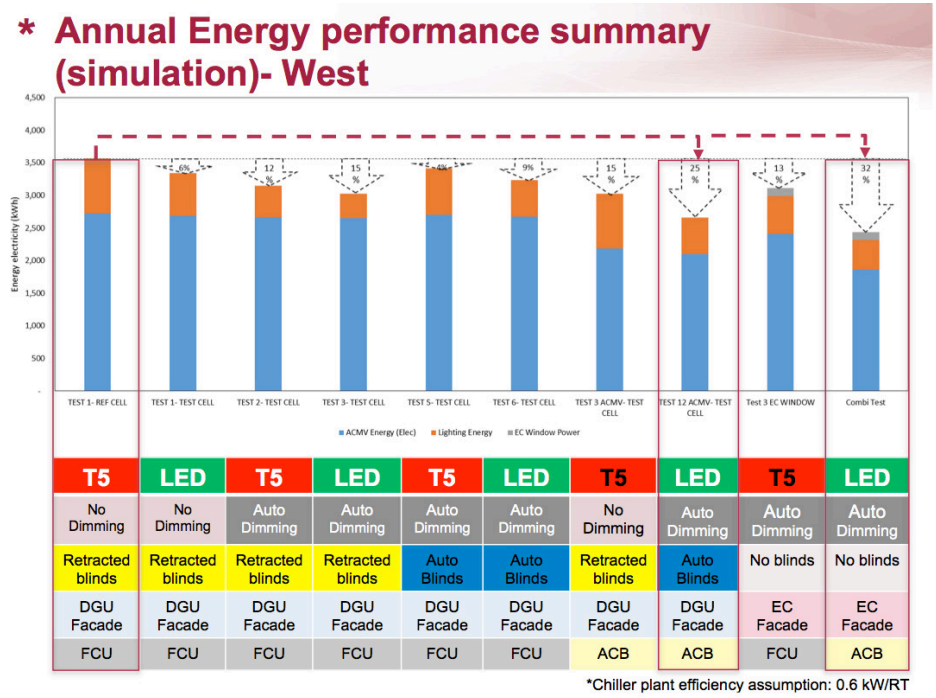

Figure 3: Annual Energy performance summary (simulation) for all combination technologies - West orientation

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BCA | NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Energy Research Institute @ NTU

Model-Predictive Control Testing in BCA's SkyLab

This project aims to develop an integrated building automation system that is based on a novel model predictive control (MPC) algorithm for real-time optimisation and control of different building systems, including ACMV, lighting and shading systems. A conventional building system could only control individually and usually reactive, but at the BCA SkyLab, a completed MPC system (including building mathematic model, human comfort models and MPC algorithm) was used to integrate multiple advanced building systems such as auto-dimming lighting, active chilled beam and electrochromic glazing. Side-by-side comparative experimental studies of MPC for integrated control of multiple building systems was conducted to explore the control performance in terms of energy efficiency and human comfort.

Research Outcome

On laboratory testing, the MPC system saves up to 22% building electricity consumption compared to conventional BAC system. Improvement of human comfort is also achieved. the MPC algorithm was also implemented in a lecture theatre with 240 seating capacity at NTU and around 20% of energy saving is observed.

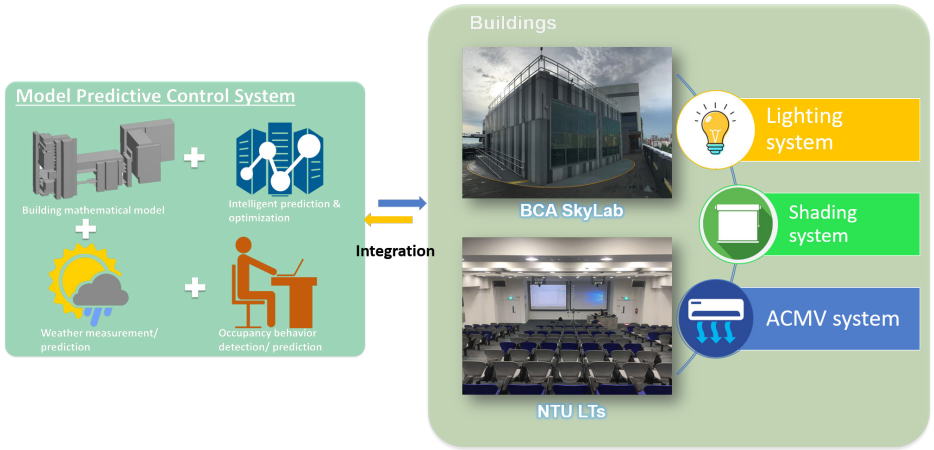

Figure 1. Schematic of MPC system and integration with buildings

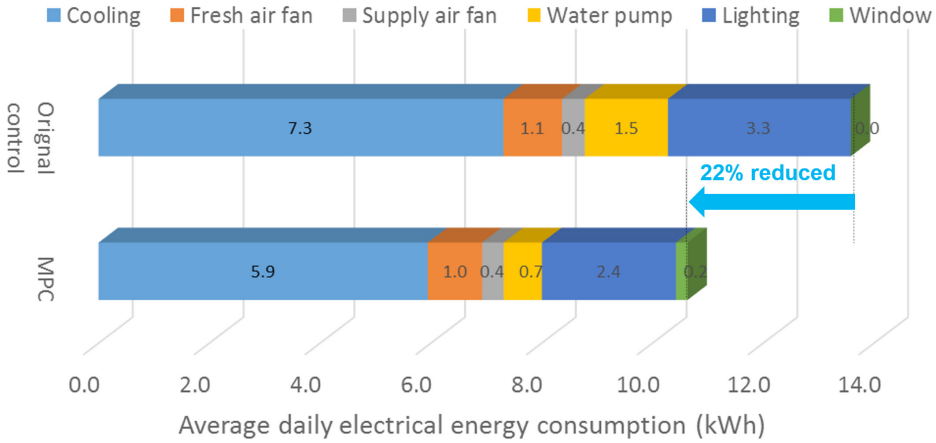

Figure 2. Energy performance of developed MPC system as compared to conventional BMS

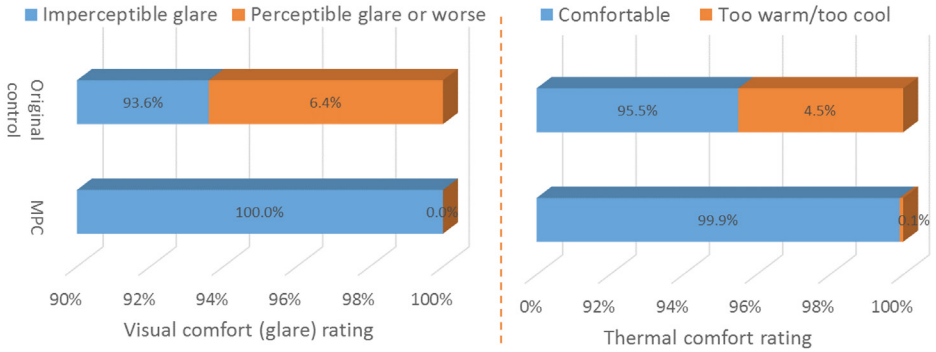

Figure 3. Thermal and visual comfort of developed MPC system as compared to conventional BMS

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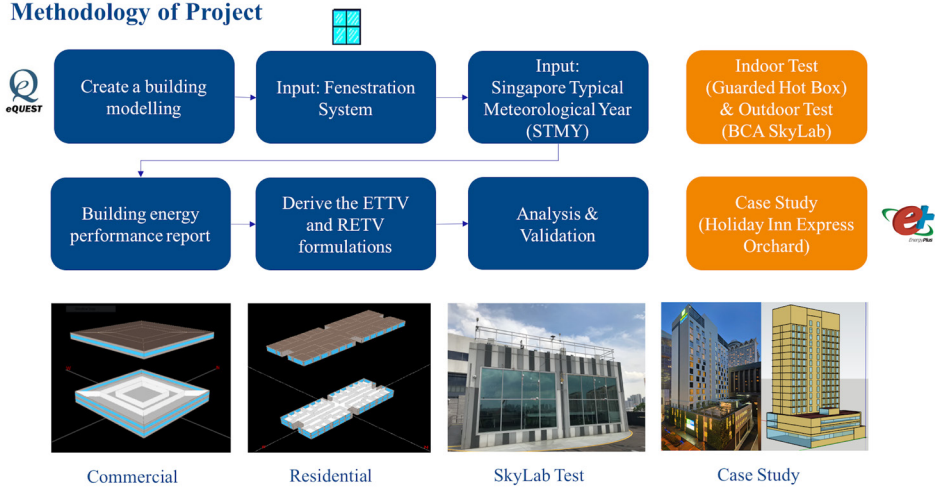
Energy-Efficient Facades for Thermal Comfort Environment

Buildings are energy intensive, accounting for a third of the total energy consumption in Singapore. The Envelope Thermal Transfer Value (ETTV) and the Residential Envelope Transmittance Value (RETV) are among the key pillars of our building energy conservation efforts.

This project aims to review and enhance the ETTV and RETV formulations, motivated by advancement in fenestration technology and practice, climate-warming effects necessitating the compilation of a new annual weather file for modelling and simulation, and the need for enhanced calculation methodology that facilitates application of materials and systems offering improved envelope thermal performance. The enhanced ETTV and RETV formulations offer opportunities for and motivate the adoption of "green" and energy efficient technologies towards achieving sustainable building energy performance.

Methodology of Project



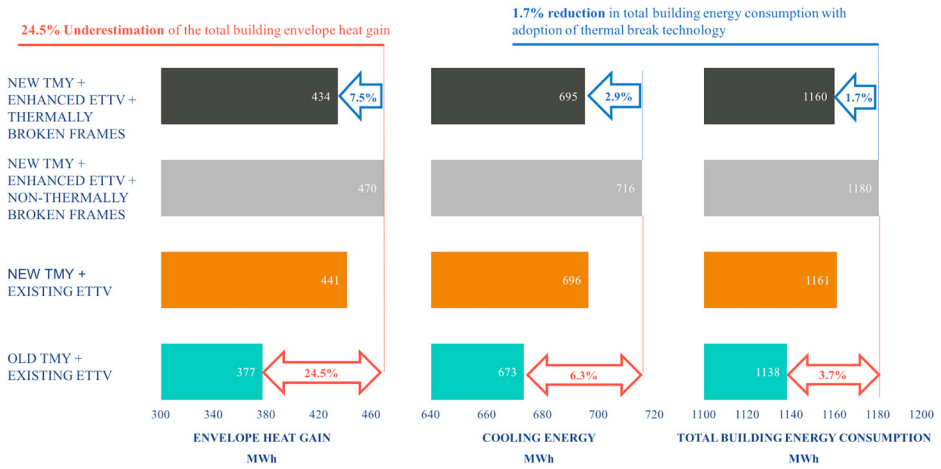
Research Outcomes

Our research managed to derive a fresh Singapore weather file, STMY, for energy modelling. We also derived enhanced formulations of the ETTV and RETV by simulations, which are then validated by guarded hot box test and Skylab test results. Case studies were conducted to validate the results and test the energy saving potentials of the enhanced formulations.

The following are our key research findings:

1. Climate warming in urban areas causes increased heat gain of the envelope by about 11% to 17%.
2. Existing ETTV and RETV formulations show an underestimation of the true envelope heat gain, in certain cases, by up to 78%.
3 ETTV/RETV and cooling energy consumption are highly correlated.
4. Incorporating thermal break systems can result in a substantial reduction in the ETTV (based on the newly formulated enhanced equation) of between 7.5% to 36.0%; translating to a reduction of a cooling energy consumption of between 1.5% and 18.0%.

Case Study Results



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TECHNOFORM

SUPER LOW ENERGY BUILDING SMART HUB

To support its Super Low Energy (SLE) programme, BCA is rolling out the Super Low Energy Building (SLEB) Smart Hub as an online resource centre for comprehensive knowledge services to help building owners, developers and consultants in sourcing and evaluating green building technologies.

A key initiative of the Green Building Innovation Cluster, funded by the National Research Foundation, the Smart Hub presents data and information on the latest green building technologies and Green Mark projects in Singapore. It also translates data into actionable insights by applying the latest big data and artificial intelligence techniques for data analytics.

As shown in Figure 1, the Smart Hub serves as a data-driven platform to promote stakeholder collaboration in developing and adopting Green Building Technologies.

Figure 1 Stakeholders and Resources

Key features (See Figure 2) of SLEB Smart Hub include:

1. Smart Advisor (shown in Figure 3) – provides expert recommendations for building owners, developers and consultants on what green building technologies may work best in their projects to achieve the SLE target; also provides "what-if" simulations on the project costs and energy savings;
2. Technology Directory – provides insightful information about green building technologies and solutions;
3. Project Directory – provides data and information on research projects and demonstration projects;
4. Building Energy Performance Dashboard – provides statistical analyses of building energy-efficiency and the adoption status of green building technologies;
5. Air-conditioning System Efficiency Portal – monitors the energy-efficiency of connected air-conditioning systems;
6. Data Dictionary – standardises the definitions for data terms and data fields commonly used in the green building sector.

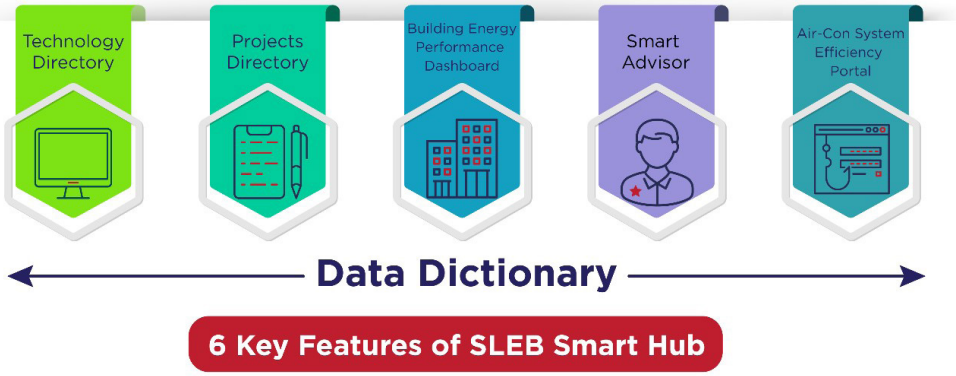

Figure 2 Key features

Figure 3 Smart Advisor

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SURBANA JURONG'S DIGITAL EDGE - LEVERAGING RESEARCH AND INNOVATION FOR GROWTH

In the four short years since its formation in 2015, Surbana Jurong has morphed from a Singapore-focused company into a global urban, infrastructure and management services consultancy group with 16,000 employees across 40 countries. In the same period, revenue jumped six-fold from $270 million to $1.6 billion. To better manage rising business complexities, the company embarked on its digital journey in 2016 with the aim of improving productivity, attracting talents and building capabilities.

At the onset, the group opted for a people-centric approach, focusing on generating ideas and solutions which would help its clients realise their vision and solve challenges. These solutions should also bring about measurable return on investments and quantifiable benefits to clients.

An Innovation Programme Office was set up in the same year to drive research and innovation initiatives. The team's priority then was to create an environment of innovation by motivating people to embrace and initiate new ideas. In 2017, the Digital Management Office was established to accelerate the development and deployment of digital tools such as End-to-End Building Information Modelling (BIM), Augmented Reality/Virtual Reality (AR/VR), drone capabilities, among others. This effort was aimed at spearheading the adoption of the Integrated Digital Delivery process as well as to support the Singapore Industry Transformation Map for the Construction industry. Notably, Surbana Jurong is a frontrunner in the development of digital facilities management using BIM technology.

Recognising the importance of foreseeing further disruptions and taking the lead in creating a pipeline of solutions for the future, in July 2018, Surbana Jurong and Nanyang Technological University (NTU) launched the SJ-NTU Corporate Lab. The mission was to develop innovative and next generation solutions in digitalisation, sustainability, and future of the industry, and to translate research into practical solutions relevant to real-life challenges. In addition, outcomes of such research, development and innovations would be shared with industry players, including overseas groups who visit Surbana Jurong to learn about our innovation journey.

Mr Wong Heang Fine, Group CEO of Surbana Jurong commented, "Innovation is core to Surbana Jurong's continued growth. Staying at the forefront of technological advancements allows us to address the impending challenges in the built environment. As we continue to expand into more geographical markets and deepen our capabilities, innovation also further sharpens our competitive advantage amidst the evolving global landscape."

Floating Ponds, an innovative vertical farming concept developed by Surbana Jurong in collaboration with Apollo Aquaculture Group

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CHAPTER 5

UNDERGROUND CONSTRUCTION

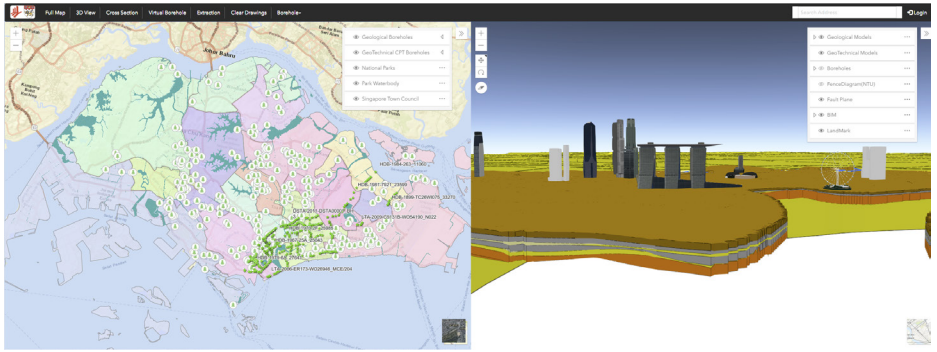
WEB-BASED 3D GEO-DATA MODELLING AND MANAGEMENT SYSTEM (GEM2S)

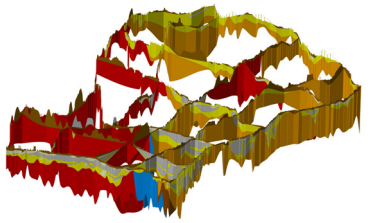
This project aims to establish a web-based 3D Geo-data Modelling and Management System (GeM2S) that will lead to cost savings and increased productivity for future infrastructure or underground construction projects in Singapore.

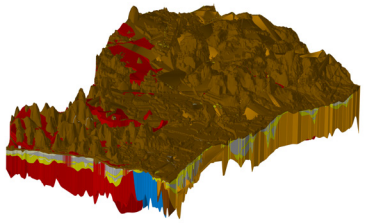
A large amount of geological borehole data and geotechnical testing data has been obtained over the years from various types of projects. GeM2S can turn these data into a valuable resource to guide future underground developments in Singapore, saving developers a considerable amount of money and time.

POTENTIAL APPLICATIONS

This system will enable users to utilise both geological and geotechnical data to enhance the design reliability of underground construction projects. It enables users to visualise underground geological conditions, especially at the potential geological hazards (e.g. faults, thrust, etc.) area to reduce ground conditions uncertainties. The system can also provide a better guide for site investigation works at new development projects.







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CHAPTER 6

FUNDING SCHEMES

BUILDSG TRANSFORMATION FUND (BTF)

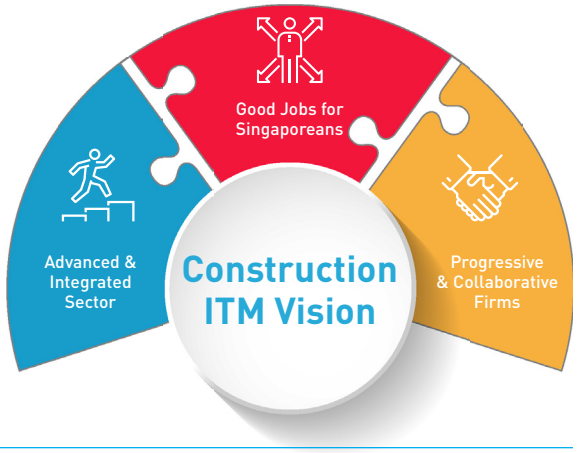
BuildSG Transformation Fund

Supporting Built Environment Transformation Journey

ABOUT BTF

The BuildSG Transformation Fund (BTF) helps built environment firms and individuals embark on their transformation journeys to step up and build essential capabilities for future growth. BTF has various incentive schemes supporting the value chain, from startups to businesses at different stages of growth, to students and professionals. It allows firms to leverage on technology and innovation, and upgrade their manpower to create higher value jobs with relevant skillsets to meet their transformation needs as laid out in the Construction Industry Transformation Map (ITM).

BTF supports our ITM vision to develop an advanced and integrated Built Environment sector with widespread adoption of cutting-edge technologies, led by progressive and collaborative firms well-poised to capture business opportunities, and supported by a skilled and competent workforce offering good jobs for Singaporean. The BTF is managed by BCA's BuildSG office.



BuildSG TRANSFORMATION FUND

TECHNOLOGY AND INNOVATION

Leverage on technology to develop firms' capability and competitive advantage

Research & Development

- **Cities of Tomorrow R&D Programme (CoT)** supports technology development through R&D to address key challenges in the BE sector
- **Green Buildings Innovation Cluster (GBIC)** supports research, development and demonstration of energy efficient technologies and solutions
- **Built Environment Robotics R&D Programme** supports research, development and deployment of innovative robotics solutions

Innovation & Capability Building

- **Productivity Innovation Project (PIP)** for firms to build up their capability in DfMA technologies, IDD and improve processes for higher site productivity
- **2-Stage Innovation Grant (iGrant)** for industry in conducting fast track, proof-of-concept innovation projects for subsequent quick deployment
- **Offsite Construction Special Scheme (OCSS)** a voluntary manpower incentive scheme that encourages the shift towards DfMA and more off-site work
- **Investment Allowance Scheme (IAS)** supports the mechanization efforts of firms through providing tax incentives for capital investments on productive construction equipment
- **Building Retrofit Energy Efficiency Financing (BREEF) Scheme** for building owners to obtain financing from participating financial institutions to offset upfront costs for energy efficient retrofits of existing buildings and repay the loans through energy savings reaped

JOB & SKILLS

Support individuals in their skills training so that they remain relevant with the transformation needs of the industry

- **iBuildSG Scholarship and Sponsorship** for students and in-service personnel pursuing BE-related courses
- **iBuildSG Workforce Training and Upgrading** for firms' upgrading of workers' skills via co-funding of selected skills assessment and training courses
- **SkillsFuture Study Awards** for Singaporeans in the development and deepening of specialist skills

ACCELERATE TO MARKET

Build a vibrant innovation eco-system

Built Environment Accelerate to Market Programme (BEAMP) supports the fast-tracked development and commercialization of innovative solutions

FOR MORE INFORMATION

https://tinyurl.com/bsgtf2019

BuildSG TRANSFORMATION FUND

GOV-PACT

About Gov-PACT

As part of efforts to develop industries and enterprises, Enterprise Singapore will provide assistance to companies to collaborate and undertake innovative projects initiated by government agencies. Under Gov-PACT, the Government will work with the companies to develop and testbed innovative solutions yet to exist in the market.

The opportunity to supply solutions to Government will help companies to build up their innovation capabilities and at the same time, add on to their track records with Government as their reference customer as they scale up locally or export their solutions overseas.

How It Works

Participating Government Agencies
- generate lead demand by identifying problem statements that could be addressed by innovative solutions
- seek partners through calls-for-proposals.

Participating companies
- engage in different stages from product development to pilot trials with the support of the lead demand Agency

Outcome
- if expectations are met, Agencies will procure the final solution from the participating company.

CONTACT DETAILS
Government Agencies with challenge statements that likely require innovative solutions can contact Enterprise Singapore.

Companies may find open innovation calls under Gov-PACT at https://gov-pact.ipi-singapore.org/.

Email: gov-pact@ipi-singapore.org
Institution/Company: Enterprise Singapore

ENTERPRISE DEVELOPMENT GRANT (EDG)

About EDG

Today and into the future, companies that thrive are the ones that have strong business foundations and strategies, adopt technology and innovative processes, and grow their overseas presence.

EDG helps Singapore companies grow and transform. This grant supports projects that help companies upgrade their business, innovate or venture overseas, under three pillars:

1. **Core Capabilities**
   Projects help businesses prepare for growth and transformation by strengthening their business foundations beyond basic functions such as sales and accounting.

2. **Innovation and Productivity**
   Projects support companies that explore new areas of growth, or look for ways to enhance efficiency. For example, reviewing and redesigning workflow and processes, and tapping into automation and technologies to make routine tasks more efficient.

3. **Market Access**
   Projects support Singapore companies that are willing and ready to venture overseas or expand into overseas markets.

Funding Support

Up to 70% of qualifying project costs
Includes third party consultancy fees, software and equipment, and incremental internal manpower cost

Eligibility Criteria

- Registered and operating in Singapore
- Minimum of 30% local shareholding
- Financially viable to start and complete the project

Applications will be assessed by Enterprise Singapore based on project scope, project outcomes and competency of service provider.

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ACKNOWLEDGEMENTS

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Green Building Technology, BCA

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Design for Maintainability Department, BCA

Geological and Underground Projects Department, BCA

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ISBN 978-981-11-3668-9