

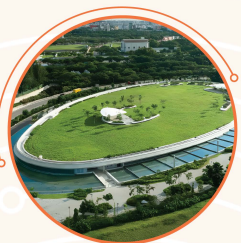
# RESOURCE RESILIENCE

Maximising resource efficiency is necessary to overcome global resource constraints, besides ensuring a safe and secure supply of critical resources.

## Keppel Marina East Desalination Plant

Singapore's fourth desalination plant, the Keppel Marina East Desalination Plant is designed innovatively to treat both seawater and freshwater. The plant began operations in June 2020 and it is the country's first large-scale, dual-mode desalination plant, capable of producing 137,000 m<sup>3</sup> of potable water daily.

Desalinated water is weather-resilient and boosts Singapore's water resilience. During dry weather, the plant will produce desalinated water. When there is abundant rainfall, it switches to treating water from a nearby reservoir, which uses less energy. The plant also has an open green rooftop for community recreation, as its treatment facilities are contained underground.



Funded by PUB

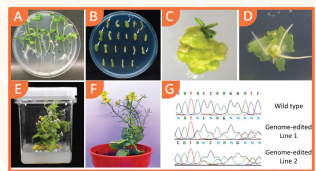
## Genetic Improvement Of Indoor Farming Crops

National University of Singapore and Temasek Life Science Laboratory explores advanced breeding strategies, including genomic selection of complex traits and precise gene editing using the CRISPR-Cas9 technology, to create novel leafy vegetable varieties with desired traits tailored for controlled environments in order to maximize the productivity and quality of urban agriculture.

Genetic improvements in crops plays a pivotal role in enhancing the resilience of agriculture by developing varieties that can withstand wide range of challenges such as climate change, pest and disease outbreak.

This would boost Singapore's resilience in upstream seed inputs for local vegetable production and potentially build interdependence with regional food producing countries through the supply of superior seed germplasm.

Establishing the gene-editing system for Choy Sum



- 1 choysum seedlings grown on MS medium
- 2 calli formation after Agrobacterium-mediated transformation
- 3 generated shoot from a callus;
- 4 root induction;
- 5 a putative transgenic plant grown on MS medium
- 6 a transgenic plant grown on soil
- 7 two choysum plants with targeted genome-edited sites

A high-yielding and uniform-growing Choy Sum cultivar



Jade001 Original

Funded under Singapore Food Story R&D Programme 1.0 - Theme 1 Sustainable Urban Food Production

## Boosting Aquaculture Growth With Functional Fish Feeds

Nanyang Technological University is developing functional feeds supplemented with a selected probiotic and an immunomodulatory nutrient.



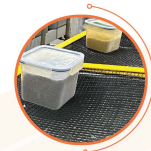
Combinational usage of probiotics with nutrients was observed to have synergistic effects against pathogens in vitro. From fish growth trial, groups fed with functional feeds showed an increase in body weight.

Functional feeds with encapsulated nutrients are promising for enhancing aquaculture productivity by improving growth rates and survivability of the farmed fish, thereby contributing to Singapore's food security and resilience.



Pelletizing of fish feeds

Funded under Singapore Food Story R&D Programme 1.0 - Theme 1 Sustainable Urban Food Production



Fish trial



Growth rate studies of Asian seabass

## Identification Of Unknown Foodborne Hazards In Novel Foods

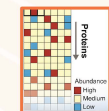
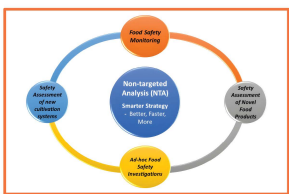


Singapore Food Agency has developed the smart Non-Targeted Analysis (NTA) strategy which integrates multiple functions, including expandable High-Resolution Tandem Mass Spectrometry (HR-MS) databases, automated data processing and predictive modeling, leading to higher throughput, efficiency and accuracy in NTA of various food samples.

Implemented in synergy with conventional targeted monitoring, this NTA strategy has been applied for rapid screening of unknown chemical foodborne contaminants with many advantages, e.g., improved efficiency and accuracy, wider coverage scope, early alert for potential food safety risks, etc.

This project also allows Singapore to establish the testing capabilities for food safety assessment to support local fast-growing innovation efforts, thereby enhancing food security and resilience in Singapore.

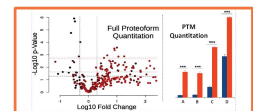
Expanding NTA capabilities for proteomic analysis - Establishment of a non-targeted proteomic platform to support food safety assessment of alternative protein-based novel food products, with the enhancement of the validated smart NTA data processing tools to improve areas, e.g.,



Biomarker Identification & Proteome Profiling



Post-Translational Modification (PTM)



Quantitative Proteomic Characterisation

Funded under Singapore Food Story R&D Programme 1.0 - Theme 3 Food Safety Science & Innovation

# BUILDING SYSTEMS

As our infrastructure ages, the need for more intensive and regular inspection and maintenance becomes important. Through the development of capabilities in predictive maintenance, remote inspection and monitoring, we seek to build smarter building systems to enhance the performance and reliability of the inspection and maintainability services.

## Holistic Management of HDB Flats against Spalling Concrete

As buildings continue to age, spalling concrete will become more prevalent for older flats. These buildings are built using concrete of a lower grade e.g. Grade 20, which is more porous. HDB together with BCA, Nanyang Technological University (NTU) and Kajima Technical Research Institute (KaTRI) have developed robust methods to repair and prevent recurrence of spalling concrete.

### Sealing Paint Method

For Densely Formed Cracks



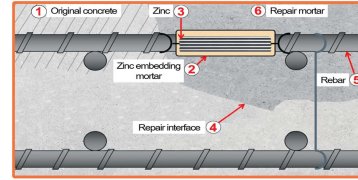
#### Newly Developed Sealing Paint

- Conventional paint makes use of spherical pigments
- Newly developed paint has customized pigments to retard corrosion by increasing the pathway of carbon dioxide, oxygen and moisture into concrete



### Sacrificial Anode Method

Severe Spalling With Corroded Steel Bars



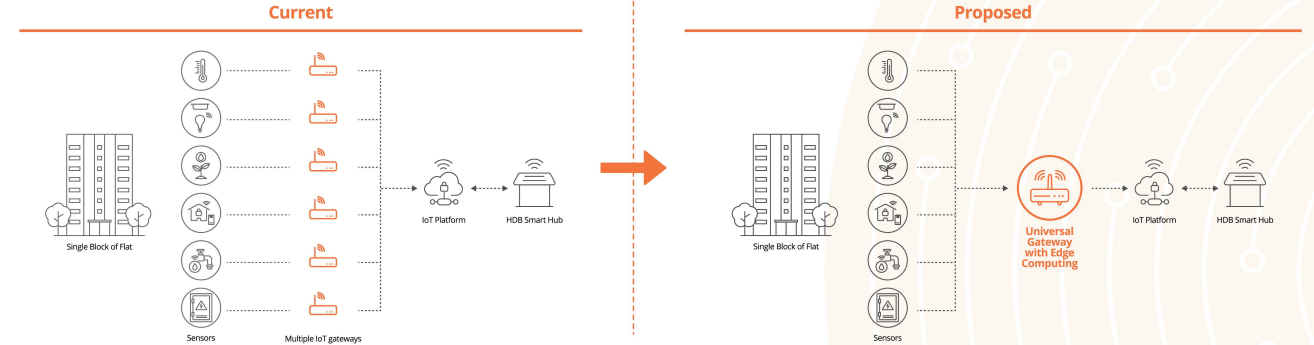
#### Adoption Of Sacrificial Anode

- Prevent macro-cell corrosion due to Ring Anode effect\* after repair
- Ring Anode effect: Corrosion occurs in neighboring parts of concrete after repair
- Sacrificial anode (usually zinc) with lower electrochemical potential (more reactive) will be attached to the steel rebars. This way, zinc will corrode in place of the steel rebars
- Protects a larger area around the repaired location to prevent recurrence in other locations

## EstateSense: A Scalable Distributed Sensing System for Smart Estates

Sensors are deployed in HDB estates to manage estate services in the common areas. (e.g. Smart Lighting, Smart Pump)

Typically, sensors have individual gateways, industrial controllers and communication modules, resulting in duplicative costs for hardware and lack interoperability. This makes it cost-prohibitive to roll out and maintain sensors in a wider scale across all HDB towns.



This project aims to test-bed a universal gateway which enables various sensors and actuators to communicate and interoperate on the edge. It is envisaged to allocate and share computing resources to manage multiple sensors' use cases concurrently and securely, as well as enabling analytics to be carried out at the edge.

# RESILIENT BIODIVERSITY

Science and technology play a key role in informing and equipping Singapore's ongoing efforts to conserve our native biodiversity and ecosystems, and strengthen island-wide ecological connectivity, so as to conserve and extend our natural capital amidst the challenges of climate change and rapid urbanisation.

## Grow-a-Reef Garden

As part of wider efforts to conserve and enhance Singapore's marine biodiversity, the Grow-a-Reef Garden initiative by NParks, JTC Corporation and National University of Singapore (NUS) seeks to assess the efficacy of purpose-built artificial reef structures off Sisters' Islands Marine Park, following their earlier deployment in 2018 for biodiversity conservation and research test-bedding.

Findings from ongoing biodiversity monitoring efforts at these artificial reef structures have indicated a high rate of coral translocation success, as well as successful coral natural regrowth.

The project also examines the connectivity of fish populations in Singapore's waters by performing fish community surveys around the artificial reefs.



Researchers conducting a coral survey on the artificial reef structures off Sisters' Islands Marine Park. (Photo credit: Nicholas Chew)



Fish start to colonise the base of the artificial structures. School of small brown-striped red snapper (*Lutjanus vitta*).



Due to the abundance of sunlight, Sargassum seaweed begin to colonise the tops of the artificial structure, forming dense thickets.

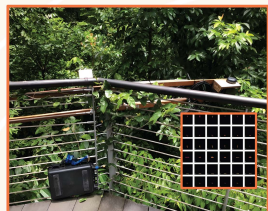


The understorey of the middle levels provide a good hiding place for some bigger fish, like this starry pufferfish (*Arothron stellatus*).



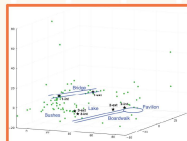
## Passive Acoustics Monitoring

This pilot study by NParks and National University of Singapore (NUS) prototyped the use of acoustic technologies for biodiversity monitoring and urban bird surveys, by developing a portable acoustics monitoring setup coupled with software algorithms to identify bird calls. Algorithms developed from the study were able to identify specific bird calls to the species-level in an urban soundscape, and to classify unidentifiable sounds into clusters based on their spectrograms, for easier subsequent verification by experts. The prototype system was also able to determine the location of bird calls. A separate algorithm was also developed to estimate bird roost sizes.

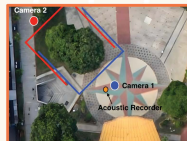


Main: Set up of pilot study at Singapore Botanic Gardens. Bottom-right: The algorithm classifies various natural sounds in the landscape based on the properties of their spectrograms.

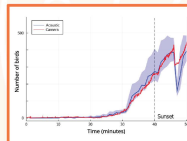
Collectively, these outcomes will augment existing survey methodologies to better understand our biodiversity and wildlife populations, so as to further inform ongoing biodiversity conservation and wildlife management measures.



3D representation from the Keppel Discovery Wetlands in Singapore Botanic Gardens showing triangulation of location source of bird calls using multiple recorders.



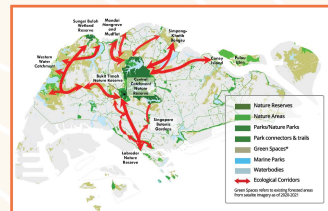
Video camera footage was used to validate bird roost size estimates provided by the acoustic recordings. The coloured lines represent virtual fences for each camera.



Bird roost size estimates from the acoustic recordings modelled over time, compared against the video footage estimates. The comparison showed that acoustic roost size estimates are a close proxy of video roost size estimates, hence validating the acoustic method.

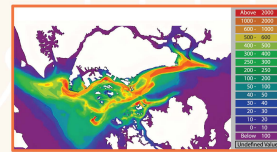


## Ecological Profiling Exercise



Map showing terrestrial ecological connectivity identified through NParks' Ecological Profiling Exercise

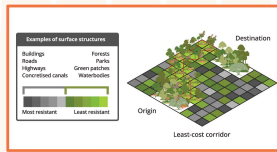
ecological corridors between core habitats by establishing plans for Nature Park Networks and Nature Corridors in Singapore's land use plans. By adopting a holistic and science based approach, the EPE empowers planners to include ecological considerations upfront in the land-use planning process, to better balance development with nature conservation. Findings from the EPE will also help Singapore extend its natural capital beyond the nature reserves, bringing nature closer to people and strengthening the ecological resilience of our City in Nature.



Agent-based spatial modelling for coastal and marine habitats simulates the movement of large numbers of individual organisms to understand their dispersal patterns, such as coral larvae dispersal following a mass spawning event. (Map shows predicted cumulative densities of coral larvae within Singapore's coastal waters following a mass coral spawning event in 2013.)

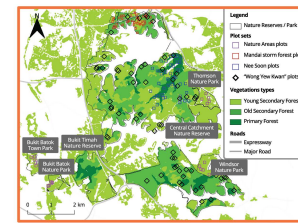


The Ecological Profiling Exercise (EPE) led by NParks aims to develop a comprehensive picture of Singapore's island-wide ecosystem and ecological connectivity, by using a combination of least-resistance pathway and agent-based modelling tools to understand the role of specific sites in providing refugia and ecological connectivity for native biodiversity. Completed in 2022 in tandem with the Urban Redevelopment Authority's Long Term Plan Review, the EPE allowed the identification and safeguarding of key



Least-resistance pathway modelling for terrestrial habitats identifies the surface structures (e.g. roads, forests, buildings) between core habitats and assigns a numerical value to each structure, with a lower value indicating greater conduciveness for an animal to cross. The least-resistance movement pathway is then established based on the route comprising pixels of the lowest value.

## Long-Term Forest Ecological Monitoring in Singapore



Map of the permanent forest plots included in the Long-Term Forest Ecological Monitoring plot network.

To advance ongoing and upcoming research efforts in tropical forest ecology, NParks' Long-Term Forest Ecological Monitoring project will establish and maintain a network of permanent research plots in Singapore's forests by re-surveying historical plots and carrying out additional studies involving wildlife surveys, tree phenology monitoring and litter trapping. Outcomes from these studies will contribute towards resilience of Singapore's native forests by improving our understanding of the long-term dynamics of our forest ecosystems and tree populations.

The research infrastructure and data provided by the plot network will also be used to facilitate further collaborative efforts between NParks and key research partners, such as to study carbon sequestration by forests.



Equipment used during a typical survey in the permanent forest plots, including measuring tapes, camera, binoculars, GPS device, and sheets for recording data.



Measuring the diameter of trees to track their growth over time in the permanent forest plots.



# BUILDING SYSTEMS

As our infrastructure ages, the need for more intensive and regular inspection and maintenance becomes important. Through the development of capabilities in predictive maintenance, remote inspection and monitoring, we seek to build smarter building systems to enhance the performance and reliability of the inspection and maintainability services.

## Integrated Robotic-BIM Inspection System

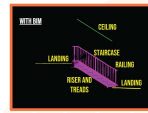


Quadruped Robots (Boston Dynamics) undergoing scanning mission

Traditional non-compliance inspection processes are time-consuming, labor-intensive, and prone to human errors. The main objective of this project is to develop a robotic inspection system that integrates with Building Information Modeling (BIM) technology to automate the inspection process during the building handover phase. The solution was developed by NUS and industry partner Surbana Jurong.

At the heart of the system are artificial intelligence algorithms that analyses the collected point clouds to identify non-compliances accurately and efficiently.

The system integration with BIM technology allows automatic tagging of non-compliances detected to the corresponding elements in the BIM model, creating a comprehensive repository of identified issues, which can be easily retrieved and followed up accordingly by the relevant stakeholders.



Integrating AI methods for non-compliant detection and measurement



Enhancing non-compliant reporting with BIM in the Cloud-based Inspection System



## 360 Reality Capture Solution for Site Inspections

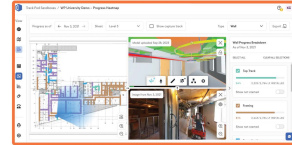
JTC conducted several field trials at JTC construction sites from 2021 to 2022 to evaluate the value proposition of 360 Reality Capture Solutions (360RCS). The trials focused on the 360RCS' ability to improve general inspection productivity, site documentation, information relay, and collaboration among construction project stakeholders.

The 360° camera use its 360° field of view to capture and stitch multiple perspectives into a single panorama. The result is an image that can be planned both horizontally and vertically, allowing viewers to have an immersive and detailed view of the space. Additionally, the solution captures images with automatic time and location tagging, which saves substantial amount of time in data organising and retrieval.

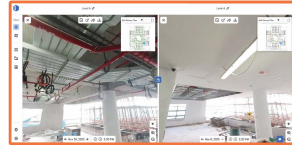
JTC concluded that the 360RCS is reliable and has useful features for remote inspections and remote tracking of site progress that has resulted in manhours savings from streamlining tedious daily tasks on site.



Customisable Dashboard for Tracking & Reporting



Timeline Feature - Progress Tracking @ Site



Funded by MOF RF under B&I CentEx

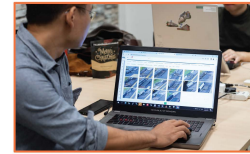
## Automated Estate Inspection

From 2021, JTC together with Public agencies (LTA and PUB), have worked with solution providers Startup, Vebits AI to develop a virtual estate/road inspection solution. This reduces the manpower required for inspections, and makes it safer for inspectors.

The developed solution uses smartphones as a data-capture and transmission device. When mounted on the dashboard of road vehicles during a drive, it picks up footage of its surroundings. This footage is then transmitted to servers, where the trained AI models accurately identify defects.



Phone is mounted on vehicle dashboard and photographs are captured while driving. (Photo credits: JTC)



Inspector reviews photos of AI-detected defects analysed from the earlier drive. (Photo credits: JTC)

After their ride, inspectors can then review and verify the defects, before having an approval report instantaneously generated for rectification works.

In Nov 2022, JTC deployed the solution at one-north successfully and validated the solution's workability within an actual operations. The solution was further demonstrated by JTC and Vebits to more than 50 public officers since, and are currently in advanced stages of discussion to adopt the solution in the respective agencies' use cases.

### Benefits of using solution

- Process reduced from 2 days to 1 hour
- No of Inspector reduced from 2 + 1
- More flexibility in period for inspection
- More accurate in capturing defects
- Safer inspection

Funded by MOF RF under B&I CentEx

## Virtual Temporary Occupation Permit (TOP) Inspection

Every development in Singapore requires a permit before residents can move in. When the building works are completed, the applicant and the qualified person applies to the Commissioner of Building Control for a Certificate of Statutory Completion (CSC) or a Temporary Occupation Permit (TOP). As part of the TOP/CSC process, a physical site inspection by BCA is normally required.

Experienced in digitalising construction processes, JTC has initiated Singapore's first virtual TOP process, whereby a virtual TOP will replace the need of a physical presence at site. The virtual TOP inspection was made possible using existing technologies like 360° camera and LiDAR scanners. Together with BCA, JTC conducted two pilot projects at the JTC Logistic Hub, and Semicon Space factory. Following the projects, JTC and BCA were able to develop an effective virtual inspection process. These examples serve as useful case studies that could encourage the industry to adopt virtual inspections in the future.

### Re-creating the virtual environment using LiDAR scans and 360 photos

With advancements in reality-capture technology, accurate and reliable 3D data can now be produced. By using point cloud data and integrating it with 360° photo capture, detailed inspections can be conducted on construction works. This facilitates the checking and tracking of work progress.

### Virtual TOP sessions held at JTC Summit Office

A virtual TOP session for JTC Logistics Hub and JTC semiconSpace was led by the Digital Built Environment team at JTC. Conducting this session provided an alternate setting for TOP inspection, reducing the manpower and time required in the inspection process.



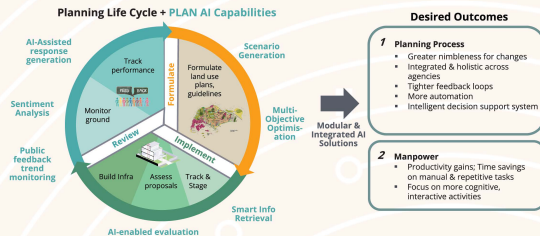
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# SMART PLANNING

Advancements in disruptive technologies like Artificial Intelligence (AI) are prompting a fundamental re-think of our conventional mode of operation, and can help develop more efficient ways of planning our urban systems.

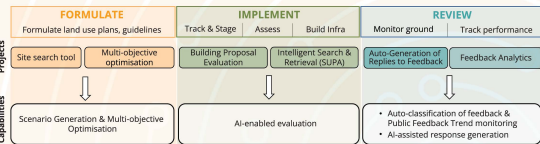
## PLAN AI

URA will harness Artificial Intelligence (AI) to transform Singapore's urban planning system and processes for better outcomes.



- Desired Outcomes**
- Planning Process**
    - Greater nimbleness for changes
    - Integrated & holistic across agencies
    - Tighter feedback loops
    - More automation
    - Intelligent decision support system
  - Manpower**
    - Productivity gains: Time savings on manual & repetitive tasks
    - Focus on more cognitive, interactive activities

PLAN AI projects are a series of modular capabilities that will progressively be researched, prototyped, test-bedded and deployed. Each component forms part of a wider, end-to-end ecosystem of solutions that will help unlock the transformative potential of AI in planning, towards an integral 'Smart Planning Assistant' toolkit.



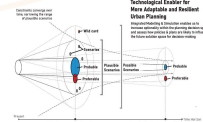
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Check out the TV for more →

## R&I Sectoral Thinkpiece

### Section 1: Transformation of Urban Planning and the Development of New Technological Capabilities in Response to Complex Challenges Facing Singapore

Planning in Singapore involve a range of mechanisms to balance competing land needs whilst keeping our city liveable. Yet, urban planning has become more challenging in an increasingly uncertain and complex operating environment.



In the latest Long-Term Plan review, we adopted a less deterministic approach to assess planning strategies and navigate future uncertainties. This shift reduces the emphasis on deterministic parameters and enables us to operate with greater flexibility and optionality.

### Section 2: Dealing with Increasing Complexity and Uncertainty in Urban Planning

Urban planning optimises land use for sustainable and equitable growth, addressing current demands and anticipating future needs, inherently embodying multi-objective optimisation (MOO) principles.

While Modelling & Simulation (M&S) technologies offer insights to inform land use planning today, M&S capabilities can be deepened and expanded to a wider range of urban planning practice:

- Long-Term Strategic Planning: M&S can quantify planning interdependencies and assess their dynamics over time, evaluating their impact on development potential
- Mid-Term Master Planning: M&S can expand the planning decision space by studying diverse land use scenarios and surface issues early
- Near-Term Implementation, Monitoring and Feedback: M&S can simulate potential built environment outcomes in the absence of actual data, shortening the planning feedback cycle

### Section 3: Quantum Leap in M&S Capabilities for Urban Planning & Design

Advancing our M&S capabilities will radically transform MOON in urban planning, enabling us to:

- Define baseline performance and codify constraint criteria
- Formulate scenarios, assess their alignment with land availability (both spatially and temporally) and establish pathways to desired futures
- Quantify and evaluate the impact of planning policies on overall development potential and planning vision

### Section 4: The MOON-Shot



The MOON-shot ahead of us is to synergise these models as a system-of-systems framework that would allow planners to see further, sense-make faster and act decisively in the face of uncertainty.



### Invitation to Rally

Collaborate with us as we grow local R&D expertise in M&S for urban planning, guide the translation of research prototypes into usable applications and grow Singapore's presence as a thought leader through international engagements.

Supported by URA and Urban Planning & Design Technology Centre of Excellence (URBEX)

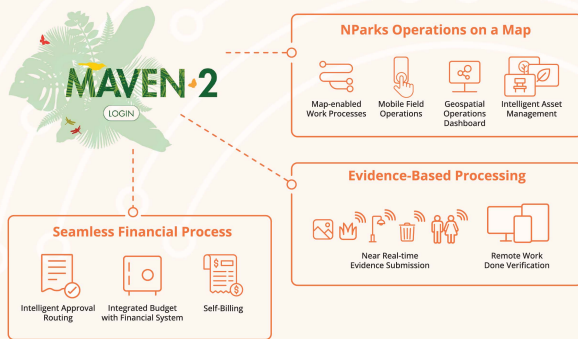
# URBAN GREENERY

As Singapore transforms into a City in Nature, the development and deployment of enhanced technologies and tools will increase the operational effectiveness and productivity of the landscape sector, while strengthening the overall resilience of our urban greenery.

## MAVEN 2

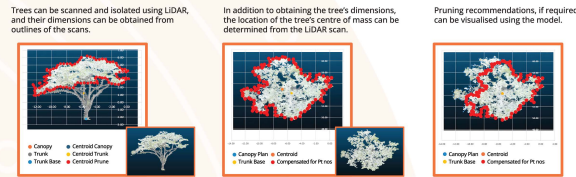
NParks' new MAVEN 2 system is a centralised geospatial platform to support NParks' operations such as greenery management, where information from various digital tools, such as the Grass Height Sensor and the Contractor Fleet Management System, will be interfaced onto a dashboard, enabling a seamless end-to-end work process for NParks and its contractors.

With the implementation of MAVEN 2, work processes will be automated and streamlined into one platform, to enhance NParks' overall park and tree management operations. Contractors will be able to update operational data of works completed under their purview and receive issued work orders via their mobile devices. Routine paperwork processes such as invoicing and billing will also be streamlined and automated. In addition, officers will be able to get real-time updates on various park amenities, so that they can better manage resources to optimise the efficiency of park facilities management.



## Tree Structural Model+ (TSM+)

Urban trees are "living structures". As such, the Tree Structural Model+ (TSM+) provides NParks' arborists with an additional tool to perform field assessments of the structural stability of individual urban trees. The model incorporates various inputs such as tree geometries, greenwood properties, pruning measures, internal defects and rooting depths, in order to derive estimated wind speeds that can cause tree failure. TSM+ is under constant development, and recent research outcomes on tree tilt sensing, canopy streamlining and tree anchorage strengths have also been incorporated to improve model fidelity. In addition, scheduled mobile LIDAR scans of urban trees along our streetscapes now provide more accurate and repeatable acquisitions of individual tree geometries, as extracted via NParks' Remote Tree Management System (RTMS), which further improve the accuracy of tree structural stability assessments by TSM+.



The use of TSM+ has been integrated into NParks' Remote Tree Management System, that can be used by field officers for remote assessment of tree structural stability.



Ultimately, the use of TSM+ allows NParks to enhance its management of Singapore's growing urban tree population, by providing rapid quantitative assessments to inform NParks' arborists and contractors on appropriate tree management measures, such as tree pruning and removals. Future research in the areas of new technologies for tree defect detection, better wind load estimations, and soil moisture effects on tree stability, will also enable further improvements to the input parameters and model fidelity of TSM+.

## GeoBarrier System



GBS - sustainable retaining structure



Mechanised compacting of geotextile bags



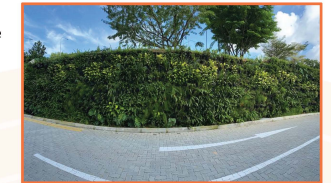
Testbed for Advanced Moisture Sensing Technology

HDB has also partnered a local industry player Hocklim Engineering to improve the productivity of filling and compacting the geotextile bags used in GBS, through mechanisation.

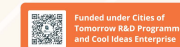
HDB is developing an innovative slope stability and plant health monitoring system using Advanced Moisture Sensing Technology (AMST). AMST together with the enhanced GBS will provide an ecosphere of safe vegetative slopes that significantly minimizes the risk of rainfall-induced slope failure.

HDB collaborated with Nanyang Technological University (NTU) to develop the GeoBarrier System (GBS). GBS is an innovative slope enhancement system with capability to retain high slope strength, support wide variety of plants and significantly lower carbon footprint as compared to conventional concrete retaining walls.

Using unsaturated soil mechanics principles, the GBS prevents rainwater from infiltrating the soil beneath, reducing the likelihood of rainfall-induced slope failures.



The enhanced GeoBarrier System has been implemented at the Bidadari Woodleigh, resulting in a decrease in the number of GBS workers required on site from 12 to 5, as well as a reduction in the construction time of GBS from 6 months to 3 months.



# SMART CONSTRUCTION

While we have begun to incorporate automation and digitalisation capabilities to improve maintenance operations, advancements in disruptive technologies like, Augmented Reality / Virtual Reality (AR/VR) and robotics / drones are prompting a fundamental re-think of our conventional mode of operation. The Built Environment looks towards leveraging on these technologies to create smarter building and construction systems.

## Automated Lane Closure and Re-Opening System (ALCROS)



ALCROS integrated vehicle

The ALCROS concept enables workflow to be completed from the safety of the vehicle deck, without the need for the worker to step foot onto the road surface. On top of improving safety, the manpower required for the operation can be reduced to as much as 80% compared to the current manual process.

The objective of the project is to automate the lane closing and opening procedure, which involves the deployment and retrieval of traffic signages and traffic cones, in a way that has not been demonstrated anywhere else in the world yet.



Signage deployment sequence

Traffic cone deployment sequence

The solution was developed by ITE College Central – Technology Development Centre (ITE-TDC) in collaboration with Gim Tian Civil Engineering Pte Ltd.

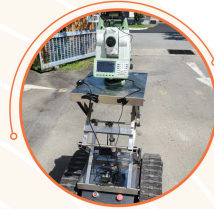
The versatile setup of ALCROS means:

- Modifications to the robot end effector and tool changer can be converted
- For other tasks to be accomplished after the completion of lane closure duties
- The outdoor construction sector may stand to benefit from automation and robotics



Funded under the Built Environment Robotics R&D Programme

## Tracked Robotics Surveyor



Tracked Robotics Surveyor being trialed on site  
Image credit: Geomatics

Tracked Robotic Surveyor (TRS) was developed by Geomatics (S) Pte Ltd to conduct measurements of building movement or ground settlement using optical prisms. The objective of TRS is to reduce the reliance on manpower needed for site monitoring works. By having semi-automation to the processes of surveying works, we can achieve manpower reduction on-site and off-site, up to 65%. The TRS enables movement from one location to another swiftly, and reduce the time needed for the setting up on the system in the next location. Surveyed data can be directly uploaded onto the server and presented on online portal or reports generated without human intervention. These automation helps to increase the productivity of the team.



Image credit: Geomatics



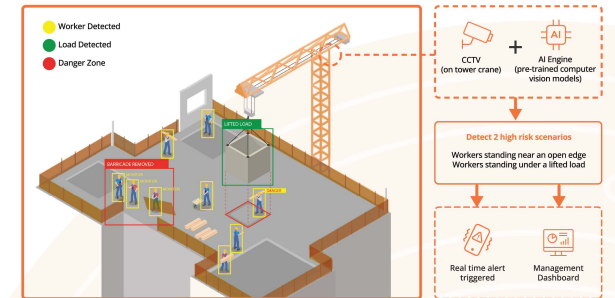
Funded under the Built Environment Robotics R&D Programme

## Video Analytics for Construction Site Safety

HDB collaborated with National University of Singapore (NUS) and AI Singapore (AISG) to develop a system to achieve continuous and real-time monitoring of hazards through live CCTV footage by integrating video analytics and AI technology.

To augment manual supervision, tower cranes at HDB construction sites are installed with CCTV to record construction activities. By utilizing footages from these cameras, the AI model was able to detect 2 high risk scenarios: workers standing near an open edge, and workers standing under a lifted load.

Upon detection of these high-risk scenarios, violations will be flagged and notifications are sent in real time via mobile messaging to site supervisors on the ground for the appropriate rectification. The research data and models developed in the project will broaden the application of video analytics in the field of construction management and supervision for HDB worksites and the construction industry as a whole. With the success of this R&D project, HDB is now introducing it to all new BTO construction projects.



Funded by AI Singapore and HDB

# ALTERNATIVE BUILDING MATERIALS

Innovative advanced materials high-strength and light-weight properties could enhance the durability and performance of infrastructure and improve the ease of construction. Beyond productivity, it is also important to strengthen our supply chain resilience by locally developing sustainable, cost-effective, and durable alternative materials.

## Substitution of Natural Sand with Granite Fines in Concrete Production



Granite Fines

Natural sand is conventionally being used as fine aggregates to produce concrete. With concerns regarding the impact to environment caused by sand dredging, alternative materials are now being sought for sustainable concrete production.

To ensure environmental sustainability and supply resilience, we can reduce our reliance on natural sand by finding suitable substitutes. Hence, a study was commissioned to affirm the suitability of using 100% granite fines<sup>(1)</sup> in concrete production.

<sup>(1)</sup> Granite fines is a by-product from crushing/mining granite which may be used for various purposes such as floor finishes or vanity tops.

The results of the study show that concrete produced using granite fines instead of natural sand can achieve the desired performance in terms of workability, strength and durability. A joint circular was issued by BCA, HDB, LTA and JTC in Dec 2022 to inform the industry on the study results and that the Institution of Engineers, Singapore (IES) and Association of Consulting Engineers Singapore (ACES) are supportive of using granite fines to replace natural sand in concrete production.



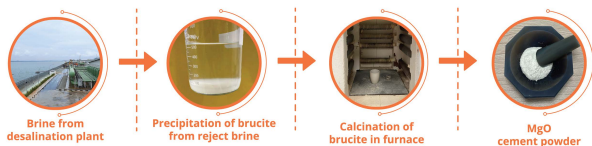
Natural Sand

Concrete Production



## Development of MgO Cement using Waste Discharged from Desalination Plants

Led by HDB and NTU, this project aims to develop a commercially viable MgO cement which is comparable in cost and performance with Ordinary Portland Cement (OPC). This would be achieved by developing a sustainable cement binder using reject brine, the by-product from local desalination plants. Compared to OPC, the developed MgO cement has lower carbon footprint, possesses high sequestration capability and recyclability without compromising structural performance.



Trial casting using MgO cement e.g. pavement blocks

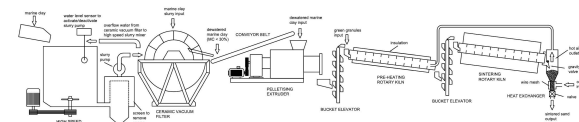


## Clay Sintering



To upcycle the soft clay collected from construction industry, HDB had collaborated with NUS, together with industry partners, Geotests (S) Pte Ltd and NeWall Tech Pte Ltd, to create a 'sand-like' material.

A prototype of the optimized sintering process was developed (patent pending).



Tests conducted successfully concluded that the sintered clay has geotechnical properties similar to sand.

Consolidated Drained Triaxial Test  
Friction angle 39°  
(Similar to dense sand)



Constant Head Permeability Test  
K = 1x10<sup>-9</sup> m/s  
(Similar to coarse sand)



2500x image of sintered material  
Weak kaolinite converted to strong metakaolinite (pictured)



Long term indissolubility test  
After 5 years, low turbidity & no mass change





# ALTERNATIVE BUILDING MATERIALS

## Using Waste Glass to Make Sustainable and Durable Concrete



Project Competition Prize from American Concrete Institute (Singapore Chapter)

Funded by MOF RF under B&I CentEx

Cement has been widely used for the production of concrete in the construction industry. However, the production of cement is an energy intensive activity that contributes significantly to global carbon dioxide emissions.

To address this issue, JTC worked with NUS (through JTC Innovation Challenge) to conduct a R&D project to utilise locally generated waste glass to partially replace cement in the concrete production. The project aims to reduce the embodied carbon and production cost of concrete as well as promote circularity by upcycling waste into construction materials.

For 20% cement replacement by waste glass powder, the new material can achieve:

1. Material strength comparable to normal concrete with enhanced durability;
2. Potential to achieve 14-37% of embodied carbon savings;
3. Potential to achieve 4-6% cost savings

In this project, the team demonstrated that waste glass powder is a suitable supplementary cementitious material (SCMs) for making sustainable and durable concrete. The team is now exploring potential onsite applications to bring this material one step closer to industrial adoption.

Semakau Landfill is expected to be filled by 2035. There is an urgency to explore alternatives to divert waste from landfill, while contributing to options for building materials.

## MSW Slag as a Fine Aggregate Replacement in Concrete



MSW Slag collected at the Tuas South Waste-to-Energy Research Plant.

JTC and the Nanyang Environment & Water Research Institute (NEWRI), with the support of NEA and JFE Engineering (Japan), conducted scientific research on the use of Municipal Solid Waste slag (MSW slag) as a replacement for fine aggregates in concrete. The MSW slag was sourced locally from the Waste-to-Energy Research Facility located at Tuas South and the material was produced through JFE Engineering's patented high temperature slagging gasification technology.

The high-temperature slagging gasification process, which aims to reduce the amount of ash produced by typical mass burn incinerators, generates MSW slag as its main by-product. Unlike ash from traditional incineration, MSW slag is a vitrified material with a glass-like texture that is chemically inert. This unique property makes it a promising candidate for use as a replacement for aggregates in construction.

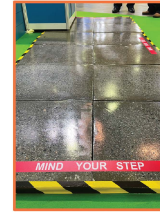
The research concluded in early 2023 with successful outcomes. JTC and NEWRI had developed a novel concrete design with 100% replacement of natural sand with MSW slag as the fine aggregates. This concrete design was later used to construct a 45 meter concrete footpath at one of JTC's infrastructure site at the Tuas Western Coast.



Funded by MOF RF under B&I CentEx

## Sustainable Transformation of Incineration Bottom Ash into Green Aggregate

Republic Polytechnic has developed a cost effective and scalable encapsulation technology to treat incineration bottom ash (IBA) for potential use in concrete applications. The scalability of the technology was strongly backed by EnGro, a ready-mix concrete supplier. Upon successful development, this technology may be considered, along with other commercially available IBA treatment technologies, for the future NEWSand Facility.



Concrete footpath constructed with treated IBA

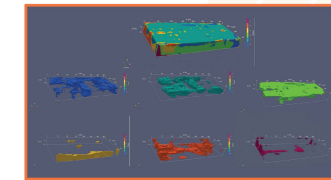


Visit by Min Grace Fu at the CSO 2022 event



## Breaking The Ground at Semakau Landfill: Technological Solutions for Site Investigation and Material Reuse

Preliminary results of stratification of landfilled materials based on geophysical survey data at Cell 11



The stratification will be further validated against borehole data. The deposit pockets with distinctive geophysical features (as shown in different colours) will be further correlated to various combination of waste materials and other properties to inform the study on the technical feasibility of excavation and treatment.

The project by Nanyang Technological University aims to conduct detailed site investigations and characterise the mixed materials (MM) within Semakau Landfill Phase 1. Technical feasibility of extracting the MM and the processing and treatment approaches involving REMEX, NatSteel Chemicals and JFE as collaborators to use the recovered materials as aggregates replacement will be studied (e.g. construction, land reclamation).



# ALTERNATIVE BUILDING MATERIALS

## Feasibility Study on Asphalt Pavement Containing Recycled Plastic

LTA and NEA had collaborated with Samwoh Innovation Centre (SWIC) and Singapore Polytechnic (SP) to conduct a field trial using asphalt containing recycled plastic waste along Jalan Buroh (East Bound).

Better technical performance (e.g. higher strength) than conventional asphalt was observed and could potentially enhance durability. Environmental impact was found to be comparable with conventional asphalt.



Asphalt containing recycled plastic waste along Jalan Buroh (East Bound)



Storm water sampling device tied to the drain grating



Cross section of asphalt with recycled plastic



Funded by LTA and NEA



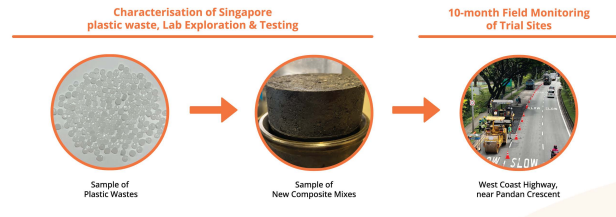
Project information

In the year 2022, only 6% out of approximately 1 million tonnes of plastic waste were recycled. Typically, plastic waste could be mechanically processed into pellets/flakes or chemically/biologically transformed into monomers. Beyond these recycling methods, plastic waste could be used as alternative materials in building and infrastructure applications.

## Plastic Roads: Developing Composite Pavements Using Plastic Waste

Developing a new bituminous-plastic composite materials for roads with the focus of reducing plastic wastes in Singapore and encouraging resource circularity where plastics and roads can eventually find useful new economic value at the end of their infrastructure asset lives.

This project studies and develops a new bituminous-plastic composite pavement that can be standardised, monitored for performance, and implemented on Singapore roads in a cost-effective manner, ensuring reduction of plastic pollution whilst having cleaner and quieter roads.



Funded by LTA

## Recycled Waste Plastic as a Fine Aggregate Replacement

Singapore generated 982,000 tonnes of plastic waste in 2021, with only 6% being recycled. The rest was incinerated – contributing directly to carbon emissions, and the remaining ash was disposed of at Semakau Landfill. Singapore's construction industry also relies on the imports of natural aggregates such as river sand and granite gravel.



To overcome the challenges of managing plastic waste and sourcing for alternative natural aggregates for construction, JTC, NEA and Temasek Polytechnic developed a new method to recycle plastic waste into valuable construction materials. The new plastic-concrete mix formulation replaces up to 20% of natural sand with plastic waste and was applied to construct precast concrete kerbs and drain channels in one of JTC's infrastructure projects at Tuas Link. This R&D project was funded by JTC.



Project Prototypes of Precast Drain Channels and Kerbs

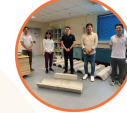


Funded by JTC

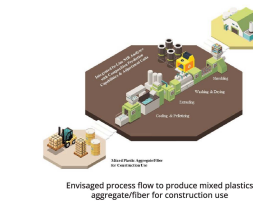
Plastic-Concrete Drain Prototypes Installation on Site



Project Team Photo at Temasek Polytechnic Laboratory



## An Integrated System to Produce Recycled Mixed Plastic Ingredients and Composites for Infrastructural Applications



Envisaged process flow to produce mixed plastics aggregate/fiber for construction use

Temasek Polytechnic (TP) has developed various formulations of mixed plastic incorporating LDPE, HDPE, PP, PS, PET for use in building and infrastructural applications. Near Infra-Red (NIR) technology was customised to detect the composition of mixed plastics, enabling the consistency of formulations needed for various applications. The mixed plastics aggregates are undergoing trials in concrete footpath at TP, while mixed plastic polymer modified asphalt is being tested in asphalt road pavement at Samwoh Smart Hub.



Mixed plastic feedstock processed into grinded forms for concrete footpath & asphalt road pavement



Construction of concrete footpath sections for environmental field monitoring at Temasek Polytechnic



Collection of groundwater samples for water quality analysis

Funded under Closing the Waste Loop

Project information