RESEARCH & INNOVATION STRATEGY FOR MODELLING & SIMULATION TECHNOLOGIES IN URBAN PLANNING AND DESIGN

Lim Xiao Wei, Alvin Chua, Ching Tuan Yee, Julian Cheng

URBEX (Urban Planning & Design Technology Centre of Excellence) aims to build up strategic and critical Science, Technology and Engineering capabilities to advance urban planning and design for Singapore. We drive innovation, encourage experimentation and sharing of lessons learnt, in collaboration with partner organisations.

The URBEX working paper series serves as a platform to share insights from ongoing efforts and studies with the wider urban planning community. The overall intent is to rally communities of interest around strategic and emerging subject areas of relevance to urban planning & design technology.

Correspondence concerning this article should be addressed to: urbex@ura.gov.sg

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

Singapore is a global city and vibrant economic hub in Southeast Asia. Over the years, Singapore has developed effective mechanisms to balance allocation of land resources to meet competing needs and to keep our city liveable. Yet, urban planning has become more challenging due to increasingly complex constraints[1]. A small low-lying island with limited land resources, with one of the world's highest population densities and an open economy, Singapore is subject to many global challenges including rising sea levels, urban heat, and shifting population demographics. It must also adapt to a VUCA[2] world to overcome its vulnerabilities.

In Singapore, as with many other cities around the world, urban planning involves the complexity of allocating land for housing, recreation, commerce and industry, as well as other public facilities and infrastructure. As a land-scarce nation state with limited resources, urban planning plays a significant role to ensure efficient and effective use of land. To create liveable urban environments, urban planners carefully optimise development potential to support sustainable and equitable growth that fulfils today's needs, while providing options for future generations. As the demand for land continues to intensify, it will be increasingly challenging to do so.

---

[1] Ho, Peter. 2019. "Governance in Complexity: A Singapore Perspective". Delivered at the Conference of Complex Systems 2019, September 30, 2019.

[2] VUCA (*Volatile, Uncertain, Complex & Ambiguous):* Originally used in the military context to describe the challenges faced in certain operational environments, the term has been widely adopted in various fields including business, economics, and urban planning, to characterize the nature of today's complex and rapidly changing world.

Section 2: Dealing with Complexity and Uncertainty in Urban Planning

2.1 Modelling & Simulation for Urban Planning & Design

The ability to understand our urban systems, as well as the interactions between urban systems, is critical for the delivery of good planning outcomes. Today, Modelling & Simulation (M&S) technologies are utilised by infrastructure & environment agencies to understand urban dynamics and inform the formulation of plans. M&S gives urban planners the capability to:

- Formulate, understand, and evaluate 'what-if' scenarios, build confidence, tweak parameters and assumptions before embarking on testing, experimentation, and evaluation of solutions.
- Test a range of scenarios to determine the best combination of outcomes versus trade-offs to achieve end-goals in a low-cost environment.

The capacity to do so in an integrated manner is potentially transformative and will help us nimbly adjust to ever-shifting conditions and opportunities. The following examples are illustrative applications of integrated M&S at different scales of planning:

Scale of Planning	Scope for M&S	Illustrative Applications
Long-Term, Macro Scale Strategic Planning	• To quantify the interdependencies of driving forces at play in land use planning. • To assess the dynamics of driving forces over time and evaluate their positive and negative impacts in relation to desired planning outcomes.	• To simulate how changes to land use influence the distribution of commercial and recreational activities, as well as travel demand. • To simulate how changes in physical constraints affect island-wide development potential, e.g., lifting of height restrictions from redevelopment of Paya Lebar Air Base (PLAB).
Mid-Term, Local-to-District Scale Master Planning	• To identify a subset of optimal solutions and surface the trade-offs between them.	• To simulate how siting and sizing of social & community facilities at different locations impact population access to opportunities and services. • To simulate the potential land saving accrued by co-location of synergistic facilities. • To simulate the potential impacts of development scenarios on local traffic and environment.
Near-Term Implementation, Monitoring and Feedback	• To simulate potential issues that may emerge from development application proposals.	• To predict the possible changes that a development may undergo (e.g., change-of-use) throughout its lifespan and simulate the impact of the changes on the environment.

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

3.1 M&S Technology for Multi-Objective Optimisation

Urban planning today involves a considerable degree of ingenuity to effectively address our complex challenges and seek a balance between desired outcomes and trade-offs that arise from development. Urban planners must navigate a wide range of inter-dependent factors to optimise for multiple objectives. The build-up of integrated M&S capabilities can provide fresh and usable insights for Multi Objective Optimisation (MOOn) in urban planning and design. M&S technologies can help us to:

- **Represent or measure** baseline performance (e.g., optimise land yield) and codify physical constraint criteria (e.g., height, nuisance buffers).
- **Formulate scenarios and assess trajectories/goodness-of-fit** against land availability, both spatially (physical built environment constraints) and temporally (lease, rejuvenation, potential for adaptive reuse) to establish pathways between the present and desired futures.
- **Size the effect of planning policies** on overall development potential (land elasticity/optionality) against desired policy outcomes.

3.2 The MOOn-Shot

A consolidated multi-domain M&S thrust, or "MOOn-Shot", will be a key enabler for the next bound of integrated land use planning and urban design for Singapore. To realise this, we must:

- Understand the interconnected urban issues and systems at play, and how their convergence manifests in physical and temporal space.
- Incorporate optionality in urban planning. To do so, we must evolve from the traditional notion of using M&S for optimisation within distinct domains (e.g., energy, mobility, environment) and shift our focus towards integrated M&S to identify a Pareto front – a range of optimal options – across multiple domains.
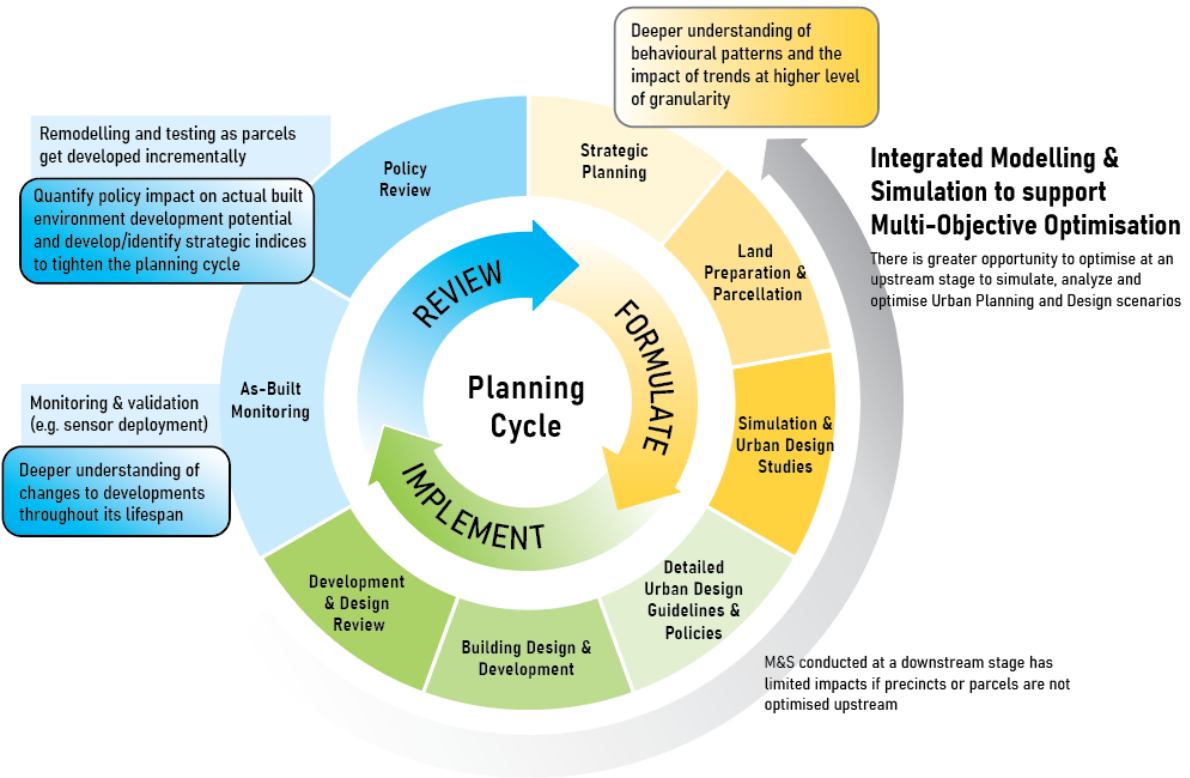
Figure 1: Envisioned outcome of an integrated M&S practice within the Plan Formulation-Implement-Review Cycle.

Examples of broad capability deltas for M&S and their alignment to planning priorities are as follows:

Capability Deltas and Illustrative Examples	Alignment to Planning Priorities
Deeper understanding of behavioural patterns and the impact of trends at higher levels of granularity e.g., Understand how socio-economic factors influence home and firm location preferences.	• To build more inclusive, close-knit and future-ready towns • To design more attractive job nodes • To meet the needs of a rapidly aging and increasingly diverse population
Deeper understanding of the changes to developments throughout their lifespan e.g., Anticipate the lifecycle of a development based on past projects of similar typology.	• Maximise alignment of planning intention with the implemented built environment, to assist in redevelopment strategies for brownfield sites to meet new needs, and/or intensifying to further optimise land
Quantify planning and policy impacts on the built environment and develop & identify strategic indices to monitor within the planning cycle.	• To review development strategies, positioning and pace of development for areas undergoing growth or rejuvenation • Enhance planning, coordination, implementation of national

e.g., Calculate the delta in development potential through the removal or reduction of physical buffers (e.g., Health & Safety Buffers), understanding and quantifying trade-offs.	infrastructure in relation to planning and development strategies.

Section 4: Strategies to Realise the MOOn-Shot

To realise the MOOn-Shot, URA as the URBEX will partner with agencies to build up integrated M&S capabilities. This will be achieved through a strategy comprising initiatives to cohere investments into research and innovation, development of enabling technologies and platform to facilitate collaboration and policies to build up the S&T competencies of the urban planning community.

4.1 Key shifts for Research & Innovation

Initiative 1: Consolidate and improve our existing M&S capabilities as strategic digital assets.

Value proposition:

- Achieve common appreciation of desired planning outcomes, constraints, operating environment, and M&S approach.
- Synergise M&S across whole-of-government (WoG), where models are built for interoperability with the intention to interface with other models.
- Maximise value of existing M&S capabilities from a WoG lens, especially for those areas where agencies possess deep capabilities.

Initiative 2: Build a dynamic knowledge base of planning data encompassing past and current *(e.g., development application history such as land subdivision, redevelopment, and change-of-use)* as well as future scenarios, to inform upstream plan formulation and policy development.

Value proposition:

- Establish data foundations for M&S of future land use and development scenarios.
- Anticipate likely development lifecycles and typologies through planning simulations informed by historical development data.

Initiative 3: Bring integrated 2D-3D technologies upstream as a development potential feasibility quantification tool.

Value proposition:

- Achieve a more holistic assessment of development potential with quantified constraints and feasibility for development potential*.*
- Map pathways to desired land use scenarios and quantify trade-offs between scenarios.

- Develop methodologies and pipelines to exploit 2D-3D data and facilitate integrated and iterative M&S.

Initiative 4: Identify and drive research into new topics of strategic relevance to urban planning, to broaden our understanding of the interactions between urban systems.

Value proposition:

- Understand how the built environment shapes health and well-being.
- Deepen knowledge of population preferences and social trends.
- Develop methodologies to inform and interact across multiple relevant domains, such as carbon accounting, environmental, traffic etc, for integrated impact assessments.

4.2 Development of Enabling Technologies & Platform

Initiative 5: Create the framework and protocols to shape and grow an eco-system of M&S capabilities.

Value Proposition:

- Achieve a steady-state M&S capability across planning agencies, anchored with URBEX.
- Develop effective M&S applications that are well-integrated into URA and planning agencies' workflows and are tightly coupled with planning considerations and quantifying potential benefits and impacts.

Initiative 6: Mainstream access to M&S capabilities through a common data and computing environment for cross-organisational collaborations involving data analytics and M&S.

Value Proposition:

- Establish a protocol to federate data and models for integrated M&S.
- Reduce engineering resources required to create and deploy research prototypes.
- Create and maximise synergies for integrated M&S across urban systems by allowing practising urban planners and designers to interact directly with M&S models. This will:
  - Decrease reaction time between understanding M&S results and policy/plan implementation and refinement.
  - Increase adoption of M&S by reducing complexity of M&S workflows (e.g., data preparation and interfacing with compute environment)

4.3 Deepening Science & Tech Competencies through People Development

Initiative 7: Foster build-up of cross-domain expertise among specialist M&S teams, and with practising urban planners and designers.

Value Proposition:

- Achieve more consistent coupling of M&S capabilities with urban planning and design practice.

- Grow a community of specialists with inter-disciplinary experience and common vocabulary to carry out integrated M&S.
- Create pathways between agencies, academia, and industry to build M&S talent pool.

Section 5: Data and Platform for Integrated M&S

In line with Initiatives 5 and 6, enabling technologies will be built on existing platforms and there is an on-going effort to enable broader access and use of data and models within government. These are:

Planning Sectoral Data Hub (PSDH)

URA as URBEX has formulated a sectoral data strategy to help cohere data requirements and standards across the entire urban planning and design sector. In the coming years, URA will develop a PSDH to establish processes to fuse core datasets as well as build sustainable data pipelines. This effort will standardise the creation of high-quality metrics to inform urban planning and design. This will include key datasets required to facilitate advanced and accurate M&S workflows. The PSDH will work in tandem with the proposed Urban Solutions & Sustainability (USS) Data Sharing System to allow researchers access to the same datasets, where possible, to conduct more accurate and relevant research on our city.

ePlannerX

ePlanner is an existing 2D-3D GIS web platform used by more than 1600 officers across 40 government agencies. It provides officers quick access and intuitive visualisation of more than 200 planning datasets, as well as data analytics tools for planning and urban design. E.g., buffer analysis, network routing analysis, etc.

Since the introduction of ePlanner in 2013, URA has continually improved the platform and recently enhanced it to also support 2D-3D urban design workflows. Architects and planners can now quickly view 3D urban models and its parameters (e.g., Gross Plot Ratio, building height, dimensions), conduct 3D analytics such as line of sight and sun shade, run simple 3D site simulations, and collaboratively edit urban form massing scenarios.

URA has also formulated a roadmap to further extend the ePlanner platform to enable the creation of integrated M&S workflows through a common M&S technology stack. This would allow ePlanner's community of urban planners and designers to directly leverage on M&S solvers such as environmental modelling (e.g., wind, solar and noise), traffic modelling, etc., within a common data preparation and visualisation environment to holistically evaluate planning and development scenarios more accurately. The common M&S technology stack is envisioned to be modular, allowing systems, solvers, and compute environments (e.g., cloud-based high performance or even quantum compute) to interface via Application Programming Interfaces (APIs). This would have to be developed in close collaboration with the research community as well as technology partners, to define and implement standards, protocols as well as interfacing requirements for Singapore's integrated M&S landscape.

There are also plans to extend ePlanner to a wider community through an internet-facing and multi-tenanted platform – ePlannerX. When ready, ePlannerX could allow researchers and other partners to exchange data, access and develop solutions on the same platform, reducing downstream development and technology integration effort to deploy M&S solvers

into production for practitioners. We envisage that ePlannerX and the proposed M&S technology stack would provide a synergistic end-to-end integrated M&S platform where researchers can efficiently direct their research and development to address real-world problems and challenges issued by planning agencies, develop, and publish their models/solvers for trial/use by the end-users (e.g., agencies' planners, policy analysts and decision-makers) in an intuitive ePlanner / ePlannerX environment.

Section 6: Call to Collaborate

The build-up of integrated M&S capabilities is an inter-disciplinary effort that involves agencies and the research eco-system. We seek opportunities to engage thought leaders and invite proposals to collaborate on the development and translation of M&S technologies for urban planning.

Join us in shaping the future of urban planning and design technology for a more sustainable and resilient Singapore!