Future Cities Laboratory

FCL

Singapore-ETH Centre SEC
Future Cities Laboratory
We are witnessing the transition to a predominantly urban world, providing opportunities of economic growth, wealth creation, technological and cultural innovation and social inclusion. As a consequence, at the global level, all future population growth will be in towns and cities. The global economy is already an urban economy, in which around 80 per cent of global GDP is generated in cities and towns. However, the dominant urbanisation patterns expanding all over the world are still highly fossil-fuel dependent with high impact on global warming and climate change. And the rapid urbanisation is linked with the urbanisation of poverty, growing slums, and environmental degradation. However, cities also represent the best hopes and preconditions to abolish poverty, and they are declared a possible solution to mitigate or even stop the impact of global climate change. Obviously the key challenge in a predominantly urban world lies in learning to explore and to exploit the positive potentials of urbanisation to find answers to equity, sustainability and resilience.

Better cities need better information. Big Data can offer powerful ways to understand urban patterns and dynamics and is becoming a growing source for evidence-based design and urban management. In this vision the ‘smart city’ could be seen as an integrated system of ICT solutions, allowing feedback loops between Big Data and the design and urban management to tackle inefficiency and to optimise the functioning of the city. However, we should not forget, we have to reinvent the city, to open up new trajectories to sustainability and equity. So we need smart citizens and bottom-up approaches leveraging the sociability of cities. How can we combine and reconcile the interactive possibilities of sensing technologies and the power of Big Data with the creativity of the smart citizens and the idea of the city as a public realm?

The Future Cities Laboratory offers a unique venue for transdisciplinary research dedicated to sustainable approaches to an urbanising world with high diversity of urbanisation patterns. The transnational cooperation opens the possibility to confront knowledge based on different urban contexts—especially in Europe and Asia—and to stimulate mutual learning in research and design. Regarding the very different dynamics of urbanisation processes on the global scale it seems likely, the urban future does not lie in Europe or North America. Rather, the future may lie in the rapidly growing cities and city-regions of Asia and Africa with their new urban growth patterns. In these regions we are facing the rise of ‘urban archipelagos’ with diffuse boundaries between the ‘urban’ and the ‘rural’, combined with highly diversified livelihood strategies. Studying these urban-rural linkages has to be placed high on the agenda. Not only to face environmental issues—such as degradation of land, water and forest resources—but also to understand the complex patterns of migration processes and to promote food security. With the in-migration—especially of rural poor—food security becomes a pressing challenge in many cities. Additionally, urban food security will in many regions be affected by the ongoing climate change.

The Future Cities Laboratory has already shown that it opens up the possibility to overcome the realm of isolated academic research by bridging the gaps between general scientific knowledge, context-specific information, design strategies, and societal on-the-ground-actions. The main challenge is to organise a common transdisciplinary research, communication, and cooperation process which will offer context specific solutions for the design and coproduction of a post-fossil, sustainable and equitable urban future.

Dieter Laepple
Member of Scientific Advisory Committee
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Foreword
Our Vision
The guiding vision of the Future Cities Laboratory is to shape sustainable future cities: through science, by design, in place.

Through Science
To achieve sustainability, science is essential. Science provides the basis for understanding how cities develop and interact with the environment at different scales. Cities are composed of physical stocks, resource flows, social institutions and cultural catalysts whose interactions generate a quantifiable ‘metabolism’. The scientific focus of our research is to quantify such metabolisms, and understand how they might be best structured for the benefit of sustainable cities.

By Design
A sustainable city must also be liveable. To achieve liveability, design is essential. Design is a collaborative process that combines analytical techniques, imaginative strategies and transdisciplinary knowledge to generate new ideas and bring them to fruition. Design skills bring, often conflicting, technical, economic, social and cultural demands (such as environmental sustainability, profit, comfort, convenience, identity, security, satisfaction and desire) into innovative and harmonious relationships.

In Place
Science and design are effective only if they serve places and the lives that are lived in them. Places result from common processes (growth and decline; competition and co-operation; ebb and flow of capital, people, goods and ideas; climate change) and differentiating factors (geography, culture, language, history). Our research addresses diverse lived places, from compact cities with high-density populations to extended cities with a mosaic of urban and rural land-uses.
Background

The Future Cities Laboratory (FCL) was established by ETH-Zurich and Singapore’s National Research Foundation (NRF), and operates under the auspices of the Singapore-ETH Centre (SEC) for Global Environmental Sustainability.

The SEC was established in Singapore in 2010 as a joint initiative between ETH Zurich and Singapore’s National Research Foundation (NRF), as part of the NRF’s CREATE campus. The centre frames two research programmes: the Future Cities Laboratory (FCL) and the Future Resilient Systems (FRS). The SEC aims to strengthen the capacity of Singapore and Switzerland to research, understand and actively respond to the challenges of global environmental sustainability.

The first phase of FCL ran from 2010–2015. The second phase began in 2015 and will be completed in 2020. FCL’s academic partners include École Polytechnique Fédérale de Lausanne (EPFL), the Nanyang Technological University (NTU), the National University of Singapore (NUS), and the Singapore University of Technology and Design (SUTD).

Rationale

Urbanisation: a global phenomenon with regional significance and local consequences.

The rationale for FCL emerges from the challenges of urbanisation and its consequences for Singapore, the ASEAN+ region and the globe. This rationale can be elucidated with three sets of indicative figures:

Demographics

Population growth is now primarily an urban phenomenon concentrating in the developing world to 2050 (world population +2.3 billion; Urban population +2.6 billion; Urban population in Asia +1.4 billion; Africa +0.9 billion). The proportion of the world population aged 60 and over will have shifted from 12% to 32% between 1950 and 2050.

Urban Footprint

As urban populations are growing household sizes are declining, thereby increasing the number of households at 2.3 times the rate of population growth. Most cities grew physically between 4.6 and 7.2% annually in ASEAN+ region (1990–2000); twice the rate of population growth in the region.

Ecological Footprint

Cities occupy 2% of the earth’s surface but contribute to up to 70% of the total greenhouse gas emissions. CO₂ emissions (metric tons per capita) increased in ASEAN+ region between 1980 and 2010: Indonesia 0.7–1.8; Thailand 0.8–4.4; Vietnam 0.3–1.8; India 0.5–1.7; China 1.5–6.2. The global energy consumption share for ASEAN+ grew from 24% in 1990 to 42% in 2013; for OECD countries it dropped from 52–38%.

The general challenges of urbanisation frame a set of inter-linked research rationales:
1 Planning challenges in Singapore for the coming 75 years. Singapore’s urban development poses challenges such as managing population density while improving resilience, environmental sustainability and qualitative aspects of everyday urban living.

2 Harnessing the power of information technology for responsive planning. Sustainable future cities need integrated planning that harnesses the full power of information technology appropriate to their large scale and complexity. This involves engaging diverse city-makers, including government, industry, academia, and civil society.

3 Formulating sustainable pathways to urbanisation for ASEAN+ and beyond. New ideas are urgently needed to guide the urbanisation of the ASEAN+ region, with its 1.4 billion urbanising population. In turn, the urbanisation of this region will have global impacts.

**Approach**

Transdisciplinary research linking science, design and place.

FCL is structured around three problem-oriented and transdisciplinary research 'scenarios' that link science, design and specific places.

The scenarios combine discipline-specific research in the following areas: architecture, planning and urban design, mobility and transportation planning, sociology and psychology, landscape and ecosystems, energy systems, materials and engineering, and information technology. The three scenarios are conceived as a complementary research groups that individually address situated and concrete challenges, and collectively advance the FCL vision. Each scenario brings disciplinary expertise to bear on complex urban questions, and helps to translate knowledge into action on the ground.

The scenarios are:

1. **High-density mixed-use cities.** Developing new integrated planning paradigms, research methodologies and implementation processes to support higher population densities, higher standards of environmental sustainability, and enhanced liveability.

2. **Responsive cities.** Harnessing the power of information technology to support an integrated, transdisciplinary planning approach that engages the large scale and complexity of future city systems.

3. **Archipelago cities.** Proposing viable pathways to sustainable urbanisation in the ASEAN+ region, to ameliorate the threat of uncontrolled urbanisation, and deliver resilient forms of development.

**Outcomes**

New knowledge, paradigms and action plans for sustainable future cities from the perspective of Asia.

The outcomes of FCL will be:

1. Knowledge of cities that integrates science and design
2. Understanding of diverse kinds of city and their interaction
3. Design scenarios for sustainable urban development
4. Curriculum development

Such outcomes will take the form of conference papers, journal articles, academic books and textbooks, exhibitions, PhD theses, design guidelines, planning support tools, and pilot projects.
High-Density Mixed-Use Cities
The High-Density Mixed-Use Cities scenario approaches this aim by combining analysis and design work on large-scale, mixed-use, master-planned urban projects with research in environmental science, civil engineering, psychology and behavioural science, transport planning, computational science, and cyber-physical systems.

This scenario evaluates key success factors for the design of high-density, mixed-use quarters through research on innovative environmental systems and technologies as tested through a set of international case studies, and in the context of a real-world strategic design proposal.

The design component of this scenario will not only inform the research and test its findings, but it will also support the development of new design tools and methods. Key features of the scenario—such as design, modelling, (big) data processing, new visualisation techniques, and the cross-fertilisation between different disciplines—will give it the character of a knowledge incubator. It will stimulate new forms of collaboration, new ways of designing, and new approaches towards implementing successful high-density, mixed-use cities. For the design-based scenario the Tanjong Pagar Waterfront will be transformed into a future oriented new quarter in Singapore.
The Grand Projet
Towards Adaptable and Liveable Urban Megaprojects

Exploring the characteristics and mechanisms of large urban projects as agents of development and redevelopment in contemporary cities.

The Grands Projets research aims to provide insights into the processes of conception, design, management, implementation an operation of comprehensively planned, mixed-use, large-scale urban projects in Asia and Europe. Over the past three decades these projects have increased in number and size in cities all over the world. Inserted in central urban areas, they have not only made significant contributions to the (re-) development of new urban districts, but they have also strongly influenced the planning and development of their cities and, in many cases, they have surfaced as a ‘symbol of global membership and a vital element of city branding’ (Christiaanse, Gasco, and Hanakata 2018).

To better understand the multiple implications and opportunities that Grands Projets have for the future of our cities, this project conducts research in and around eight case studies: Downtown Core in Singapore, HafenCity in Hamburg, Kings’ Cross in London, La Défense in Paris, Lujiazui in Shanghai, Marunouchi in Tokyo, West Kowloon in Hong Kong, and 22@ in Barcelona. The project analyses their qualitative and quantitative scope and complexity within their specific urban context. In a comparative perspective the research confronts key findings around specific themes of interest to the questions of adaptability and inclusiveness. In doing so, the research aims to identify and understand the implications that key Grands Projets have on their larger context and on the quality of their respective urban environments.

In the context of our research, ‘Grands Projets’ are understood as large-scale comprehensively conceived and carefully curated constitutions of power in specific, physical sites; they are based on a sometimes more, sometimes less articulate and cohesive objective for change that is realized under the oversight of a single directive body, independent of whether this body is represented by a single or by multiple entities. The study provides insights into the mechanisms of these projects and contributes to an emergent urban design approach which takes the complexity of long-term urban development projects and its various, disciplinarily contributions into consideration.

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16 High-Density Mixed-Use Cities

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Green spaces such as parks and gardens, and urban river networks, provide cities with a number of benefits which are known as ‘ecosystem services’. These ecosystem services include reducing flood risk, cooling urban areas, and providing spaces for recreation. Most research on urban ecosystem services has been conducted in temperate Europe and North America, but we know relatively little about how tropical urban areas can be designed to enhance ecosystem service provision. Tropical areas, particularly Southeast Asia, are rapidly becoming more urban, with cities growing larger and people living in higher densities. It is therefore important to better understand how rivers and green spaces can contribute to enhancing the sustainability of such cities.

The main aim of this project is to find ways of incorporating knowledge about tropical urban ecosystem services into design, both at a local scale and across larger city landscapes. We will quantify the role of individual plants and land use types in providing benefits at these different spatial scales, and in particular will focus on the role that vegetation plays in mitigating the urban heat island effect. Trees provide shade and can cool the air to provide a more comfortable thermal environment, and this effect can be measured for each individual tree. Infrared imagery and remote sensing can be used to measure the cooling effect of larger green spaces, and this cooling effect can be modelled across entire city landscapes.

In addition to quantifying ecosystem service provision in existing landscapes, experimental studies will provide a proof of concept for maximising service provision in future developments. Measurements of ecosystem service provision and the knowledge gained from such experiments will be used to develop models that link desired future designs to ecosystem service functioning. Such models will facilitate a 3D GIS-based collaborative platform to help design urban green spaces that provide desirable levels of ecosystem services.

Understanding how we can better design urban green spaces to provide ecosystem services to people

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Urban green spaces can take many forms; playing fields, street trees, parks and forest fragments all have a part to play in providing ecosystem services.

Tropical cities are mosaics of industrial, residential, and semi-natural land uses. The forest patches that remain in tropical cities provide habitats for biodiversity, capture water and can provide opportunities for recreation and education.

Multi-Scale Energy Systems (MuSES) for Low Carbon Cities

Leveraging synergies between urban development, urban design and energy systems for the efficient and sustainable supply of energy in cities.

The operation of buildings significantly contributes to global energy consumption and greenhouse gas emissions. Energy efficiency in buildings is a key action for climate change mitigation, especially if adopted at the urban scale, where financial instruments might facilitate a widespread integration of low-carbon technology. Current strategies to improve building energy efficiency and to utilise renewable energy sources (RES) are limited to the building scale. Therefore, they are isolated from developments, strategies and potentials that can be found in the wider urban context. Previous research at the Architecture and Building Systems Group at ETH Zurich has identified systemic synergies between energy systems, urban development and urban design practices that can support the mitigation of effects and adaptation to climate change in cities, while increasing occupant well-being. Conversely, a high uncertainty due to the longevity of planning processes and the constant change of cities is apparent.

Planning for human comfort, access to low-carbon technology, exploitation of systemic synergies, and control of uncertainty requires a multi-scale and holistic approach to energy systems design and integration. In awareness of this, Multi-Scale Energy Systems for Low Carbon Cities (MuSES) explores the interactions between urban and energy systems design from the building to the district scale. This is especially relevant in the Southeast Asian context, where urbanisation is rapid and highly dense, and mixed-use urban typologies are common. To address this, MuSES expands the Low-Exergy approach under research in the first phase of Future Cities Laboratory in three directions:

1. System. Expanding the systems approach for highly efficient building RES and HVAC technologies
2. Scale. Extending the scope of energy and climate systems from building to district scale
3. Synergy. Exploring interactions and synergies of multi-scale energy systems with urban development and design

A Singapore-based case study will be used to explore these three aspects, utilising novel spatial toolsets for energy modelling and analysis such as the City Energy Analyst Toolbox (CEA Toolbox). This research will uncover critical interdependencies, synergies and thresholds that influence the design of dense Asian cities and energy infrastructure as part of a joint and highly integrated process.

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Renewable energy integration in buildings and districts
Community energy network optimisation
Images: Jimeno Fonseca, Nguyen, Thuy-An, Schlueter, Arno, and Marechal, Francois, 2016
Contemporary architecture and urban design practice in Singapore and beyond is increasingly exploring the integration of green spaces in buildings, producing innovative building types for high-density urban environments that include public spaces, extensive sky terraces, sky bridges, vertical parks, roof gardens, and other ‘green’ components. Combinations of all these, often applied to mixes of residential, civic and commercial programmes, conjoin at times to produce ‘vertical cities’ in which the built sections become part of larger urban ecosystems such as parks, gardens and river networks. Density and sustainability here are not seen as contradictory, but rather as mutually dependent and synergistic.

*Dense and Green Building Typologies* explores these developments through a systematic study of the urban, architectural, environmental, social and economic benefits of such building types in high-density urban contexts. As such, the project contributes to the Future Cities Laboratory (FCL) High Density Mixed-Use Cities Scenario that develops new integrated planning approaches, research methodologies and implementation processes to support higher population densities, higher standards of environmental sustainability and enhanced liveability.

*Dense and Green Building Typologies* is organized in five work packages:

1. **Urban Design and Architecture Benefits.** Exploring design strategies that mitigate the negative effects of high density.
2. **Environmental Benefits.** Studying the performance of dense and green building types in terms of thermal comfort, heat gain, urban heat island effects, air quality and noise pollution.
3. **Social Benefits.** Investigating dense and green building types in terms of use and appropriation as well as psychological comfort.

Studying the urban, architectural, environmental, social and economic benefits of dense and green building typologies in high-density urban contexts.
4 Economic Benefits. Examining the role of dense and green building types in land value appreciation.

5 Design Strategies. Integrating all work packages to develop innovative approaches to future high-density urban planning, design and architecture.

The research team of Dense and Green Building Typologies is multidisciplinary and brings together expertise in urban planning and design, architecture, landscape architecture, building technology, social science, ecology and economy and works synergistically with others of FCL. It also actively contributes to the Lab’s Waterfront Tanjong Pagar project. Beyond FCL, the research team collaborates with Singapore Government agencies, developers and practitioners as well as academic institutions from around the world.

The research findings of Dense and Green Building Typologies have been presented at international conferences and symposia, published in journals and books including by Birkhäuser and Springer Nature and covered by various media including Neue Zürcher Zeitung. A book titled Dense and Green Cities: Architecture as Urban Ecosystem is slated for publication by Birkhäuser in 2019.

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The engaging mobility researcher tests a virtual reality head-set on the bicycle simulator.

Image: Tobias Wootton, 2018
Harnessing the power of information technology to support an integrated, transdisciplinary planning approach that engages the large scale and complexity of future city systems.

The governance of the responsive city encourages and enforces transparent and timely responses from the operational to the strategic level. This is made possible by taking advantage of new and abundant forms of data, new ways of exploiting former unfit data repositories, new sensing technologies, and new possibilities for interaction among people, communities and their physical environments. It builds on advances in citizen engagement, cyber-civil infrastructure and computing methods that focus on interpretation of sensor data, modelling uncertainty, probabilities and identifying unknown dependencies. But most importantly, it uses these technological advances to help citizens, communities and authorities understand the functioning of cities and the consequences of different planning options. By doing so, a responsive city is able to grow and adapt to changing needs and circumstances in ways that are environmentally sustainable and in the interests of all residents.

This scenario will systematically explore the practical potential of responsive cities. It will provide answers to questions regarding the impact on society, and it will offer design solutions towards building responsive future cities. This is done based on experiences with smart cities, harnessing the power of information technology to support an integrated transdisciplinary planning approach that engages the large scale and complexity of future city systems. The scenario brings together expertise in urban design and planning, computer science, engineering, behavioural science and transport planning, to analyse distinctive forms and quantities of data relevant to the flows and fabric of future cities. Insights from urban psychology open human-environment dimensions that are central to expand the responsive, interactive and participatory possibilities of information technology.
Big Data Informed Urban Design and Governance

With the rising complexity of modern cities, traditional urban planning, urban design and urban management methods reach their limits. Life in a city has become increasingly dynamic, whereas urban planning often relies on static and sectorial approaches, involving a very limited number of citizens and stakeholders in relevant decisions. At the same time, Big Data is becoming an exponentially growing source for evidence-based high-quality decisions by analysing existing or past situations. Big Data Informed Urban Design and Governance transcends the retrospective view by integrating advanced data analytics into the urban design and planning process. Our hypothesis is that this will directly improve the liveability and resilience of cities.

Big Data Informed Urban Design and Governance will develop a framework to support urban planning, urban design, and urban management with five work streams: urban governance, cognitive design computing, urban complexity, citizen design science and evidence informed urban design. We begin with data-mining for various types of geo-referenced data, such as socio-economic data of people, land use, infrastructure networks, mobility traces, emotional responses. Correlations detected through data-mining procedures are added to the urban model to describe the complex urban system in more detail. By investigating correlations between spatial configurations and behavioural phenomena, we look for contextual effects for their future usage and function that certain spatial configurations can have.

While information derived from Big Data will make urban planners and designers more informed and aware, it will also strengthen the role of design as an activity that sets goals beyond past evidence, in the future. Big Data Informed Urban Design and Governance will fundamentally improve the understanding and utilisation of urban data; it will support the formalisation of expert knowledge for the design and the decision-making processes. On the applied research level, it will integrate the methods developed by the team into an interactive planning support system, which, by visualising planning effects differently, provides a tool for designers, politicians, citizens, and other stakeholders. Big Data Informed Urban Design and Governance contributes to the scenario Responsive Cities and will interactively explore the design scenarios it creates with the High-Density Mixed-Use City and Archipelago Cities scenarios.

Informing urban design and governance through big data analytics, complexity science, cognitive design computing and citizen design science.

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Early detection of transforming neighbourhoods using Twitter data: low-rent areas with many affluent visitors (right panel, below grey squares) are prone to future rent increases.

Image: Steentoft, Poorthuis, Lee, Schlöpfer, 2018
Generation of parametric urban layouts for settlements in Cape Town, South Africa, Empower Shack Project. The generated layouts include street networks, blocks, plots, and placement of buildings for the rapid prototyping of urban settlements in Cape Town. Program developed by Peter Buš, ETH Zürich.

Visit Potential Model: Evidence-informed Urban Design and Planning Processes. The Visit Potential Model is a dynamic weighted graph model of the public space network, aiming at estimating the potential presence of people in public spaces over time (as shown in the right), and the effect of urban design qualities on this potential based on a Multi-Criteria Analysis framework (3D purple bar plots).

Image: Peter Buš, 2017 / Pieter Herthogs, 2017

Keong Saik Design Station: Citizen Design Science workshop at Urban Venture. Citizen Design Science is a participatory design approach that engages citizens in the planning process through online tools such as the Quick Urban Analysis Kit (qua-kit), developed by Artem Charkin, ETH Zürich, for the Future Cities Massive Open Online Course series.

Image: Johannes Mueller, 2017
Cyber Civil Infrastructure

The replacement of ageing infrastructure is not sustainable, not cost effective, not convenient, not safe, and sometimes not possible.

Worldwide, the need for strategic infrastructure requires an annual expenditure of more than US$3.7 trillion, or 5% of global GDP. Since the current supply is growing at only US$2.7 trillion each year, there is an infrastructure spending gap that is increasing by US$1 trillion per year. This gap can be reduced with more informed decisions related to ageing infrastructure. Civil infrastructure often has much reserve capacity since behaviour models at the design-stage, prior to construction, are necessarily conservative. More accurate estimates of real behaviour are needed once infrastructure is in service. Improved knowledge of current performance leads to better predictions of performance when weighing decisions such as extension, improvement, repair and replacement.

We use sensor measurement data combined with site-inspection results and engineering knowledge to improve behaviour models. Inspired by fundamental research in model-based diagnosis, we are developing sensor-data-interpretation methodologies for full-scale applications where complete knowledge of uncertainties is not available. Current strategies for interpreting data are weak. Such strategies do not adequately account for the typically high levels of systematic modelling uncertainty and when uncertainty information is not complete, interpretation—and most critically, predictions—may be biased.

The implementation of cyber civil infrastructure has the potential to ensure that massive investments are optimally managed, that infrastructure modifications are well engineered, and that future designs are improved. Building on experience of more than 15 years of civil-engineering research and development—including several full-scale applications in Europe, North America, Australia and India—this project focuses on the development of robust methodologies that use sensor data to improve decision making.

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Industrial Partner
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Levers to narrow the gap
1. Reduce demand
2. Build more new infrastructure
3. Extend, improve and repair existing infrastructure

Image: Adapted from World Economic Forum, Strategic Infrastructure, Technical Report, 2014
Engaging Mobility

Understanding, designing and evaluating active mobility solutions based on travel behaviour research and Big Data-informed transport simulation.

Walking and cycling are not only the most sustainable modes of transport, they are also the most sensitive to the quality of the built environment and climatic conditions. But due to car-oriented street design and modernist urban planning, the potential of active transport modes remains heavily underutilised in many cities. New solutions at the intersection of urban design and transport planning are required to retrofit existing urban landscapes and plan new developments that support active modes of transport.

The aim of this project is to understand, model and simulate future mobility solutions for dense urban areas. In order to understand what is needed to make walking and cycling viable modes of transport in tropical and dense cities, we apply a multi-method approach. We combine innovative survey approaches with virtual reality applications. This allows us to understand current challenges for walking and cycling in Singapore and test how to design new streetscapes, or retrofit existing ones, in order to impact travel choices.

New big data streams generated by public transport smart cards and mobile phones allow one to observe urban mobility at an unprecedented scale. But since this data lacks the level of detail that is required for predictive transport simulation models, the challenge is to enrich such data with behavioural information as obtained from conventional travel surveys and the new insights from the research on active mobility behaviour.

An existing MATSim Singapore model (developed in FCL phase 1) serves as the platform to test the viability of integrating big data stream for agent-based transport simulation and is instrumental to evaluate how different transport policies and urban design scenarios impact travel flows on the large scale. The evidence-based approach showcases how the potential of walking and cycling can be tapped to not only improve traffic conditions, but also increase the quality of life and well-being. Particular emphasis will be paid on developing solutions that surmount the challenges posed by the tropical weather conditions and existing urban fabric. Taking Singapore as a living lab, Engaging Mobility will showcase how to integrate various streams of data and forms of user feedback to facilitate a responsive and transformative planning paradigm.

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↑ Pedestrian crossing in Singapore’s Bugis Area
↑ Several million public transport smart card transactions are collected every day and document the flow of public transport users in Singapore
Image: Carla Teteris, 2014 / Pieter Fourie, 2014
Visualisation of the transport flows as modelled in MATSim Singapore. Simulation: FCL with data provided by LTA, URA, SLA, Singapore Statistics and others. Image: Engaging Mobility, 2016.
Understanding and modelling human wayfinding behaviour in complex, densely populated, and multi-level environments, using a combination of real-world and virtual reality experiments, spatial analysis, and simulation.

Wayfinding experiments, both in real-world and virtual-reality environments, are augmented by eye-tracking to provide precise data about the direction of volunteers’ gaze-patterns, which can indicate their intentions and choices. Simultaneously, physiological measures, such as skin conductance, are indicators of emotional responses to the environment. Spatial analysis methods, such as space syntax, are used to quantify network properties that can influence spatial decision-making. These are integrated in the development of ‘cognitive’ agent-based simulations that include the perceptual, cognitive and physical constraints of people.

Our methodology toolkit includes behavioural, physiological and simulation approaches. Pre-occupancy evaluations, based on virtual reality and agent-based simulation serve as a platform to anticipate wayfinding performance and user-experience for the assessment of different design options. At the local level, such spaces should lead to better traffic flow and patron satisfaction. At the global level, these spaces should integrate well with their surroundings and alleviate congestion elsewhere in the city. Using this evidence-based approach, the project aspires to produce scientifically grounded guidelines for the design of buildings and public spaces that are more responsive to the needs of both stakeholders and patrons.

Cognition Perception and Behaviour emphasises the interaction between cognitive scientists, architects and planners, through workshops, research collaborations and applied projects, with the primary aim of achieving a responsive design of urban environments.
Cognitive agent — signage perception model. A ‘cognitive agent’ responds adaptively to information available from signs embedded in the environment in order to navigate. The underlying computational framework is based on information theory, in order to quantify the uncertainty of wayfinding information in architectural spaces.

Real-world wayfinding experiment in progress. A participant has received instructions about a destination in the building, and the researcher follows at a close distance making records of behavioural observations.

Images: Rohit Kumar Dubey, 2017 / Panos Mavros, 2017

Image of pedestrian crowds inside a multilevel building, simulated in Virtual Reality. Participants were asked to complete wayfinding tasks, as part of a study investigating the effects of social density (crowding) on wayfinding.

Image: Li Mengshan, 2018
Proposing viable pathways to sustainable urbanisation in the ASEAN+ region, to ameliorate the threat of uncontrolled urbanisation, and deliver resilient forms of development.

Rapid urbanisation in ASEAN+ region—Southeast Asia, India and China—has generated quite novel and often unprecedented urban forms which feature hybrid, urban-rural patterns of settlement and new kinds of relationship between city and hinterland. These forms cannot be easily understood in terms of existing, usually western, urban models. In Europe and North America, which has been the empirical basis for many of existing urban models, urban growth has slowed, and many cities in those regions are even ‘shrinking’. We adopt the term ‘archipelago cities’ as a metaphor for the large and extended city-regions in Asia and for thinking urbanisation at the planetary scale. In this sense, we precisely invert Oswald Mathias Ungers’ use of the term ‘archipelago city’ in his proposal to manage the shrinking of post-war Berlin.

Understanding the patterns, forms and processes that emerge in the cities and hinterlands of Asia and beyond, is a necessary first step in rethinking the future scope and responsibility of urban planning and development. The research of the Archipelago Cities scenario focuses on better understanding this phenomenon from a transdisciplinary perspective that includes architecture, urban design, geography, material science, engineering, social sciences and the humanities.

This scenario aims to address the conceptual shortcomings of existing urban theory, and contribute to ameliorating the physical, social and environmental inadequacies of settlements in these rapidly urbanising regions. It aims to develop viable pathways to sustainable urbanisation in the ASEAN+ region, to ameliorate the threat of uncontrolled urbanisation, and deliver resilient forms of development. It does so through research on (terrestrial, aquatic and atmospheric) territories, hybrid urban-rural settlement patterns, alternative construction materials and processes, and cultural aspects of urbanisation, including the role of tourism and the leisure economy.
Today, urbanisation has become planetary. The boundaries of the urban have been exploded to encompass vast territories far beyond the limits of even the largest mega-city regions. Meanwhile, novel patterns of urbanisation are crystallising that challenge inherited conceptions of the urban as a bounded, universal settlement type. This project explores and analyses different examples of extended urbanisation.

The central aim of the project is a radical rethinking of inherited cartographies of the urban. The popular claim that we now live in an “urban age” because the world’s majority population lives in “cities” is a deeply misleading basis for understanding the contemporary “urban revolution” theorised by Henri Lefebvre. Cities are not isolated manifestations or universally replicated expressions of the urban condition, but are embedded within wider, territorially uneven and restlessly evolving processes of urbanisation at all spatial scales, encompassing both built and unbuilt spaces, across earth, water, sea and atmosphere.

This novel topic in urban research urgently needs further empirical as well as theoretical foundational work. In order to allow a better understanding of the basic mechanisms and dynamics of contemporary urbanisation, this project collects, analyses and compares selected examples of extended urbanisation in the Singapore region as well as in other parts of the world. The project will allow to develop a thorough understanding of this new field of urban research and the creation of a more nuanced analytical framework. It will result in a collection of innovative papers and a book with comparative essays that will form a foundational contribution to the emerging field of studies on extended urbanisation.

Additionally, a book publication on the hinterland of Singapore is projected for 2019. Through essays, maps, diagrams and photographs, this book will offer an alternative portrait of the city-state—not the accustomed view of Singapore as an island developed on the paradigm of a global city, but as a city whose present and future are tightly connected to its metropolitan region. The book will also serve as a source for redefining the notion of the hinterland at the start of the 21st century.

Territories of Extended Urbanisation

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This research is focused on the hybrid urban-rural regions emerging around many cities and towns in Monsoon Asia. Monsoon Asia supports close to 50 percent of the world’s population, and much of it is accommodated in urban-rural regions. As such they already represent one of the world’s dominant forms of settlement. Scholars have also suggested that they represent a distinctly Asian settlement type that is anomalous compared to cities elsewhere. How such settlements change in the future will have significant impact on the wider patterns of urbanisation at a regional and global scale. Despite this, we have little up-to-date information on the extent or characteristics of such settlements. Furthermore, it is unclear what planning approaches, urban design strategies, and material and technological interventions might effectively ameliorate the most damaging, and enhance the positive characteristics of urban-rural settlement types. Could it be that contemporary urban-rural regions of Asia contain the seeds for a distinctive urban-rural ‘urbanisation’? Could such hybrid regions offer insights into ameliorating the interconnected threats of urban population growth, deteriorating quality of urban environments, and declining productivity of agricultural regions? Furthermore, what might such insights offer to alternative approaches to urban design and planning elsewhere, and what might they have to offer to the emerging consensus around a global framework for sustainable urbanisation?

The research will:

1. Investigate the patterns (morphologies, infrastructures, land-uses), processes (economic, ecological, demographic) and practices (agency, culture, skills) of settlements in urban-rural regions of Monsoon Asia
2. Help understand the varying stable, transitional, vigorous or entropic dynamics that shape contemporary urban-rural settlements
3. Propose a range of knowledge strategies, design scenarios, and action plans for sustainable development pathways in Monsoon Asia.

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Investigating contemporary patterns, processes, and practices of urban-rural settlement in Monsoon Asia; understanding their dynamics; and proposing knowledge strategies, design scenarios, and action plans for sustainable development pathways.
Visualisation of urban-rural territories delineated by a range of criteria including population density and night light irradiance in Yangtze River Delta, China

Visualisation of urban-rural territories delineated by a range of criteria including population density and night light irradiance in West Bengal, India

Expandable house pilot in Batam, Indonesia

Images: ur-scape

Image: Dio Guna Putra
Alternative Construction Materials

As urban populations grow, so does the demand for materials and resources to support them. Where such resource demands were once satisfied by local and regional hinterlands, they are increasingly global in scale and reach. The Alternative Construction Materials project concentrates on material alternatives and their application in specific settings, taking into account the availability of materials, human resource capacities, and skills. The ‘alternative’ aspect of this focus emerges from an exploration of innovative and entrepreneurial thinking.

The research is structured in three sub-themes:

1. Mycelium-based composite materials. Mycelium, the structural part of fungi that forms its vegetative growth and mass, is a biological non-toxic material with high growth rate, which self-adheres to feedstock while utilising almost zero energy. Thus, mycelium-based composite materials are sustainable and attractive options for the replacement of building materials with the addition of reinforcements. The aim of this research is to characterize and improve the mechanical characteristic of mycelium-based composite materials grown on traditional sawdust substrate, as well as different agricultural waste. Preliminary results have provided deep insight into building with materials that can be effectively cultivated on construction site in addressing the environmental impact of human activities which is desperately needed.

Developing a radical paradigm shift from a mining-based mentality towards one grounded in cultivating, recycling, farming, and even growing future construction materials.
2 Advanced Fibre Composite Materials. This research aims to establish fibre composite materials as a future and alternative building material in developing territories of our planet. The research underway investigates the mechanical properties of natural fibres and how to control them in order to achieve desired characteristics for use as a construction material to replace steel and wood, and also to use it as a reinforcement system in concrete applications.

3 Constructing Waste. ‘The future city’ as Joachim Mitchell notes ‘makes no distinction between waste and supply’. Such metabolic thinking understands our built environment as an interim stage of material storage and includes the disassembly of buildings into the design processes as a precondition for a circular economy. The research aims to develop such new construction methods while activating abundant waste as building materials.

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The rapid growth of tourism and urban development puts the driving force of tourism—its content—under pressure. The development of significant and meaningful environments, themes, attractions, and itineraries is an important aspect of fulfilling the demand of tourism. This research project aims to provide more knowledge by studying—and developing—a particular case of heritage tourism in Southeast Asia.

We focus on the German explorer Franz Wilhelm Junghuhn (1809–1864). Junghuhn spent almost his entire life as a doctor and explorer in the service of the Dutch colonial authorities on the island of Java. His legacy in the realm of cartography, botany, geology and writing can only be compared to the role of Thomas Stamford Raffles, Alfred Russel Wallace or Alexander von Humboldt. In fact, he was often called the ‘Humboldt of Java’ but he remains in the shadow of his famous peers mainly because his writings were exclusively in Dutch and German. We use Junghuhn as an imaginary guide and as an exemplary figure in order to find out more about the relation between tourism, travel, research, and about the way sites have been transformed into sights and tourist attractions.

The project is aiming to link the present interest with the past. In view of accumulating artefacts, images, and narratives, the project consists of a series of expeditions from Singapore to Java, following the traces of Junghuhn. Each expedition consists of a group of international scholars from different fields, such as architecture, urbanism, art, volcanology, literary history, music, ethnography, and history. The scope is to understand connections between cultural heritage, landscape, political history, art, and society and to critically reflect the way architects, but also tourists in general, travel, perceive their environment, and represent their discoveries.

The project is conceived as an exemplary study which contributes to Singapore’s articulation and representation of its cultural heritage.
Franz Junghuhn: Gunung Guntur, Lithograph after a drawing by Franz Junghuhn
Image: Java Album, (Leipzig, Arnoldische Buchhandlung, 1856)
MycoTec, tree-shaped mycelium based composite structure supporting bamboo composite grids as part of the exhibition, Seoul Biennale 2017
Image: Carlina Teteris 2017
The first phase of FCL (2010–2015) produced a rich legacy of research. Some of that legacy takes the form of real-world applications that are ongoing. A number of the research teams working on these projects have secured funding through competitive proof-of-concept grants, and/or industry sources.

We showcase some of that research here as it represents an important part of the overall FCL phase 2 programme, and demonstrates our commitment to educate, mentor and support budding entrepreneurs to develop skills and know-how to bring advanced research to market. Research application, though mechanisms such as industry financing of potential spin-off technologies, licensing and royalty fees, is also an avenue for supplementary funding that may be reinvested into FCL research.

Channeling research from the first phase of FCL to real-world application projects through competitive grants and industry sources.

Research to Application

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- Cooling Singapore 90
A paradigm shift in the development of low-carbon high-rise buildings: integrating the design and construction of structural, mechanical, and electrical systems in order to lower material, space, and energy use in kind.

In new commercial buildings in Singapore and SEA region, air-conditioning and structural systems occupy up to $\frac{1}{3}$ of enclosed volumes, consuming valuable space that could otherwise be devoted to occupants. The ‘3for2’ concept is a design proposal for high-rise commercial buildings that virtually negates vertical space requirements for ceiling plenums and floor space requirements for air handling equipment. At the same time, it proposes to raise the comfort levels of occupants and increase overall building energy efficiency by a factor of two. In optimal conditions, the opportunity may arise to construct 3 floors in the conventional space of 2 without impacting occupant floor-to-ceiling heights, hence the name ‘3for2’.

Elements of the ‘3for2’ concept were implemented over 2014–2015 by FCL researchers under the ‘3for2 @ UWCSEA’ pilot project. Researchers oversaw the design, construction, and commissioning of a 550 sqm test case of the concept that would eventually become the administrative offices of United World College South East Asia (UWCSEA). The project demonstrated air-conditioning technologies that were previously rare to commercial buildings in the SEA region. Since 2016, pilot site has been a living laboratory for researchers to demonstrate their research. Smart building features such as (i) seamless building information management and visualization, (ii) Internet-of-Things (IoT) devices and networks, (iii) occupant-centric artificially intelligent controls, (iv) ultra-high efficiency cooling generation, and (v) virtual/augmented reality applications for fault detection.

Energy and comfort studies of the 3for2 office space have shown that the space consumes 40% lower energy in comparison to the top 10% of high-performance office buildings in Singapore, while achieving a high level of occupant satisfaction, especially in the thermal comfort and indoor air-quality parameters. Economic feasibility and market discovery studies, in collaboration with the University of St. Gallen and National University of Singapore Enterprise, has led to the development of an iterated version of the 3for2 concept and a scalable business model.

The project has brought together interested industry and government partners through the sponsorship of Siemens Building Technologies and Singapore Building Construction Authority, and academic collaborations with UC Berkeley and Princeton University.

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An architectural rendering of the 3for2 concept for a high-rise building in the tropics

Image: 2017
Advanced Fibre Composite Materials

Bamboo Composite Materials as an Alternative to Steel And Timber

Bamboo could revolutionise the construction sector as it is a locally available, extremely robust, yet affordable resource for the production of innovative fibre composite materials exactly in those territories of our planet where to expect the highest urbanisation rates: the tropical belt.

Steel-reinforced concrete is the most common building material in the world, and developing countries use close to 90 percent of the cement and 80 percent of the steel consumed by the global construction sector. However, very few developing countries have the ability or resources to produce their own steel or cement. But steel is not irreplaceable. There is a material alternative that grows around the globe: bamboo. Bamboo belongs to the botanical family of grasses and is one of nature’s most versatile products. In its ability to withstand tensile forces, bamboo is superior to timber and even to reinforcement steel.

Bamboo is also a highly renewable and eco-friendly material. It grows much faster than wood, is usually available in great quantities, is easy to obtain, and known for its unrivalled capacity to capture carbon. From an economic perspective, bamboo can strengthen local value chains, bring jobs and trade to producing countries, while lowering their dependency on international markets.

Despite its strengths, bamboo has a number of weaknesses as a construction material. Water absorption, swelling and shrinking behaviour, limited durability, and vulnerability to fungal attacks have limited most applications of bamboo so far. FCL researchers are working to activate bamboo’s potential by exploring new types of composite materials. Inspired by bamboo’s tensile strength, the Advanced Fiber Composite Laboratory is investigating the possibility of extracting its fibers in order to transform the grass into a manageable industrial building product, an alternative to steel and timber. Bamboo composites can be used for specific applications that best take advantage of the material’s tensile strength, such as reinforcement systems in concrete or beams for ceilings and roof structures.

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↑ Bamboo Composite reinforcement system
↑ Bamboo composite as reinforcement for structural glued laminated timber
Images: Carlina Teteris, 2017
Landscape Ecology
Designing and Modelling, a New, Environmentally Responsive Landscape Project along the Ciliwung River in Jakarta, Indonesia

Providing a sound project and vision that balances concerns over flooding, water quality, and ecology, with the realities of a rapidly growing Southeast Asian Megacity.

The Ciliwung River is the living symbol of a massive environmental crisis in Jakarta. Centuries of exploitation and, more recently, rapid and haphazard urbanisation, have left the Ciliwung valley with a heavily-polluted and instable river. Informal migrant settlements along the river have adapted to the chronic flooding conditions, but also rely on the river to compensate for a lack of potable water, sanitation, and commodity. The social and complexity of the present situation has thus far stymied any efforts at ecological remediation.

The research method combined environmental engineering with planning and landscape architecture and was strongly based on a combination of design conceptualisation, mathematical modelling and ecosystems services. Design research studios at NUS and the ETH generated rich output that contributed further to research and design simulations. The interdisciplinary team conducted research at three river scales to better focus on the hydrological and ecological dynamics. At the overall catchment scale, focus was on the hydrology of the watershed and the range of land use. At the river corridor scale, detailed mathematical models provided insight into how future changes in the river and adjacent lands could directly affect river dynamics. Landscape modelling was developed on selected sites to generate, test and analyse possible topographic and hydrographic changes to the river bathymetry and adjacent urban areas. At a local site scale, detailed investigations between urban, sub-urban, and rural sites provided potential for alternative landscape configurations and designs. Feedback from stakeholders (including residents, community organisations and resource managers) helped better define the quality and focus of possible designs. Through this process the team developed a transformative understanding of the river that is both culturally respectful and ecologically congruent with the situation at hand. Beyond this initial case study on the Ciliwung River, the project aims at defining sound ways to influence the course of rivers in similar demographic and socioeconomic contexts of Southeast Asia.

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84 85
Mobile Robotic Tiling
Bringing the Productivity of Robots to Construction

Applying robotic technology to building construction work to increase productivity, reliability, quality and safety.

There is a high potential to apply robotic processes in the construction industry as the productivity of construction work has remained low compared to other manufacturing industries. In particular, on-site work is still heavily dependent on manual labour. The situation in Singapore seems particularly suited for the adoption of robotic solutions for construction work and can act as a catalyst for widespread application. While the expected high population growth over the next decades demands a high degree of unbroken building activity, the country suffers from a shortage of skilled workers. Tiling is the predominant surface treatment in Singapore and the high-rise typology with repetitive floor plans is conducive to automation.

Robotic systems with intelligent control software offer the dexterity and flexibility needed for construction work and can thus be a feasible solution to increase productivity. Tiling is a well-defined subdomain of construction and a task with clear interfaces that can easily be singled out. It is a repetitive task and features no complex joinery. However, it is still executed in a slow manual process by a skilled worker. Challenging to an automated process, it imposes tolerances rarely found elsewhere on site and involves a precisely dosed viscous bonding material. Our proposed solution is a compact mobile manipulator that is able to work largely autonomously and in confined residential floor plans. The vision is a robotic co-worker that can safely work alongside humans and capitalize on their strengths, improving their work profile. It is to be integrated into the existing construction workflow, lowering the entry barrier for adopting new technologies in the building industry.

The goal of the project is to realise an automated tiling process which demonstrates the feasibility of applying a mobile robotic system for planning and executing on-site construction work. An essential benchmark for the system is its ability to compete against manually executed work in regards to quality, time and costs. The result will be evaluated against current construction work in Singapore.

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- Building Construction Authority (BCA)
The Reclaiming Backlanes Project focuses on two case studies of the city centre area in Singapore and makes a proposal that brings together energy technologies and common spaces. The team proposes design visions for backlanes that are not only up to 50 percent more energy efficient but also reprogramme the backlanes into viable common spaces. On the micro scale the project proposes a new type of neighbourhood scale cooling system, to not only reduce energy consumption but also to enhance the comfort in the backlanes. On the urban scale, the aim of the project is to enhance the overall connectivity of the respective neighbourhood. Furthermore, transforming the quality and usability of the backlanes results in more commercially attractive and visually pleasing backlanes.

The introduction of a neighbourhood-scale cooling system—either a district cooling system or a heat bus system—not only reduces energy consumption, but also frees facades from being completely covered in air-condition units and further enhances the thermal comfort in the backlanes. A technical refurbishment is taken as a trigger to improve overall neighbourhood connectivity and pedestrian walkability. Further increasing spatial qualities and usability of backlanes are likely to result in commercially attractive and visually pleasing spaces. While all aspects have value and justification on their own, only their combination can unlock the full potential hidden in these neglected urban spaces.

Additionally, the project emphasises means by which urban comfort is achieved and implications how these are achieved. Reclaiming Backlanes has the capacity to function as attractors that help to positively transform urban neighbourhoods.
Cooling Singapore

Due to global climate change, the daily mean temperatures in Singapore are projected to increase by 1.4°C to 4.6°C by the end of the century. This will have serious implications on socio-economic activities in tropical Singapore. More significant than the implications of global climate change can be the urban heat island effect. Even today the temperature difference between urban areas in Singapore and its rural surroundings can amount to as much as 7°C. With an increasing population, the impact of the urban heat island can be expected to rise even higher in the future.

The negative consequences of increasing temperatures, whether it be due to global climate change or urban heat islands, on society, economy and the environment will require affected cities to respond decisively by implementing policies that allow for greater control of the urban microclimate. Such a response requires a coordinated effort involving multiple public and private stakeholders.

The Cooling Singapore project aims to develop a roadmap for mitigating the urban heat island effect in Singapore in order to improve outdoor thermal comfort and liveability. To facilitate close interaction with relevant government agencies, a task force has been established. Furthermore, the project aims to identify knowledge and technology gaps to guide future research and development activities. Research carried out by Cooling Singapore includes definition and evaluation of suitable metrics to quantify the urban heat island and its impact on Singapore, evaluation of mitigation strategies in the context of selected case studies and developing guidelines and recommendations for retrofitting of existing and planning of new developments.

Cooling Singapore is the first multi-institutional project funded under the NRF Intra-CREATE Collaborative Grant scheme. The research is conducted by a multidisciplinary team led by SEC researchers in collaboration with colleagues from SMART (Singapore-MIT Alliance for Research and Technology), TUM CREATE (Technical University of Munich) and NUS (National University of Singapore).

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Collaboration Platforms
The research of FCL is supported by a set of important collaboration platforms. These include:

Value Lab Asia
The Value Lab Asia, and its companion space in Zurich, is a central infrastructure for research, education and communication at FCL. It is a collaborative, digitally augmented environment that serves a wide range of applications, such as participatory urban planning and design, stakeholder communication, information visualisation and discovery, remote teaching and conferencing. It includes a 33-megapixel video wall, three large displays with touch overlays, a number of smaller, mobile multi-touch enabled displays, and extensive video conferencing capabilities.

The CAVE
The CAVE is an immersive virtual reality system that provides real-time interaction with 3D environments. This system can be used by designers for visualising indoor and outdoor environments before construction to avoid potential missteps. For example, the CAVE facility allows researchers to anticipate the usability of different building designs with respect to the eventual patrons. This system consists of three projection walls, control interfaces for interacting with the virtual worlds, and various behavioural and physiological measurement devices.

Materials Laboratories
The Materials Laboratories, comprising the Advanced Fibre Composite Laboratory, the Alternative Sand Laboratory and the Shared Workshop, support the development of alternative construction materials. The Advanced Fibre Composite Laboratory supports research on innovative organic fibres. The Alternative Sand Laboratory supports research on reclaimed materials from otherwise wasted building rubble. Finally, the Shared Workshop is a collaborative production space equipped with CNC-router, laser-cutters and wood-processing machines.
Spin-Off Track

Many innovative ideas and technologies that emerged from the first phase of FCL showed commercial potential. A Spin-Off track was developed to bring these ideas and technologies to reality. Several of the research teams working in this area were supported by competitive proof-of-concept grants and/or industry funding. A number of resulting projects—such as the Advanced Fibre Composite project, and the Robotic Tiling project—are now well on their way to producing innovative marketable products.

Images: Geraldine Ee, 2017 / Lina Meisen, 2016
Collaborative Interactive Visualisation + Analysis Laboratory (CIVAL)
Increasing the impact of the FCL through visualisation and interaction-based applied research, including prototype development and research-support.

FCL has developed important insights into data capture, visualisation and simulation through research attached to the digitally augmented Value Lab Asia collaboration facility. This work is enhanced by the Collaborative Interactive Visualisation and Analysis Laboratory (CIVAL).

The facility supports FCL research through the development of cutting-edge visualisation and interaction techniques to facilitate the usage of ICT-based research infrastructure.

CIVAL works closely with projects that have specific visualisation and interaction requirements or whose research output can be directed towards further dissemination through prototype development. In addition, CIVAL helps to identify visualisation and interaction related synergies between projects. Thereby CIVAL is contributing to streamlining common efforts mainly through a software platform called Singapore Views. Singapore Views allows all researchers at Singapore-ETH Centre to showcase their research outputs in an integrated way via interactive 4D presentations in Value Lab Asia.

Specifically, the aims of the CIVAL are:

1 Strategic Prototype Development. To implement visualisation, interaction, simulation and visual analytics prototypes based on research project results with a high potential for non-academic dissemination (software tools, spin-off companies, and so on). The goals of these prototypes are to assist planners and architects to research on themes such as sustainable urban design, intelligent transportation system, financing, and efficient energy consumption as well as supporting effective and persuasive dissemination of their results.

2 Project Research Support. Such as collaborative interaction software, visualisation or visual analytics development.

3 Value Lab Asia Development. With additional technologies and specific software for leveraging the Value Lab infrastructure.

4 Virtual Reality Environment Development. In collaboration with specified projects and the SEC IT team.

5 Collaboration with Industry Partners. Such as Esri and the Financing Bodies (for example, URA, HDB).
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People
Government Agencies
- Agency for Science, Technology and Research (A*STAR)
- Building Construction Authority (BCA)
- Housing Development Board (HDB)
- Land Transport Authority (LTA)
- National Environment Agency (NEA)
- National Parks Board (NParks)
- Urban Redevelopment Authority (URA)

Universities and Research Institutes (Singapore-Based)
- Nanyang Technological University (NTU)
- National University of Singapore (NUS)
- Republic Polytechnic
- Singapore University of Technology and Design (SUTD)
- Singapore-MIT Alliance for Research and Technology (SMART)
- Technical University of Munich (TUM) CREATE
- Yale-NUS College

Universities and Research Institutes
- Chulalongkorn University
- Delft University of Technology (TU Delft)
- École Polytechnique Fédérale de Lausanne (EPFL)
- Harvard University
- Indian Institute for Human Settlements (IIHS)
- Indian Institute of Technology (IIT) Madras
- Institute of Technology Bandung (ITB)
- International Rice Research Institute (IRRI)
- London School of Economics (LSE)
- Massachusetts Institute of Technology (MIT)
- New York University (NYU)
- Northumbria University
- Princeton University
- Swiss Federal Laboratories for Materials Science and Technology (EMPA)
- Tarumanagara University (UNTAR)

Universities and Research Institutes
- The University of Hong Kong
- University College London (UCL)
- University of Applied Sciences and Arts Northwestern Switzerland (FHWN)
- University of British Columbia
- University of Cape Town
- University of Exeter
- University of Indonesia (UI)
- University of Leeds
- University of Witwatersrand

Industry
- ARUP
- Bouygues Construction
- Elmich
- Gunung Sewu Kencana
- LafargeHolcim
- LCS Optiroc
- MycoWorks
- Rehau
- ROB Technologies
- SAP Software Solutions
- Schindler
- Shell
- Siemens Building Technologies
- Sika Technology
- Tange Associates
- TROX Technik
- United World College (UWC) of South East Asia
- Vitra

Non-Governmental Organisations
- Bremen Overseas Research and Development Association (BORDA)
- Mercy Corps
- Komunitas Peduli Ciliwung (KPC)

Inter-Governmental Agencies
- World Bank
- Asian Development Bank
- United Nations (UN) Habitat
- 100 Resilient Cities (Rockefeller Foundation)
It is often said that Singapore transformed from ‘third world to first world in a single generation’. Evidence of this remarkable transformation is not hard to find in the city-state today. Singaporeans live in clean and well-maintained neighbourhoods. They commute to and from work with a minimum of fuss. Their children attend high quality schools. As Students they can study at top-ranked polytechnics and universities. Everyone can enjoy inexpensive and wonderful food, and quench their thirst from the tap with drinkable water. Healthcare is accessible and first rate. A range of public spaces—rivers, parks, plazas—are clean and well-used. People can access the city at all hours of the day and night without threat of harassment. Goods of all kinds can be bought in malls both modest and magnificent in design. And the city connects to the world through world class port and airport infrastructure.

Future generations will clearly benefit from the carefully laid urban foundations of Singapore. But the pressing question now is how to build upon those foundations. What form will a future Singapore take? What skills and knowledge will be required to make that future a reality and sustain it? More specifically, how does an increasingly affluent and sophisticated population grow well in the face of land constraints, demographics of ageing, environmental pressures, and needs of a knowledge-based economy? What new demands will this dynamic population make on its infrastructures, soft and hard? Will they involve even greater choice in housing, work, transport, leisure, life-style, and self-expression?

These are not questions that can be posed or answered in isolation. The fortunes of cities today are more than ever interconnected. And Singapore is a city that has always compensated for its lack of national hinterland by embracing the entrepôt spirit of openness and trade. As such, Singapore is both a global city and a regional hub. In particular, the role that Singapore plays in relationship to other parts of Asia is increasingly influential. It is a city that sits amid one of the most rapidly urbanising regions in the world. Roughly half the world’s population is contained in a territory within a six-hour flight from Singapore. Furthermore, in that regional surround the majority of the population is currently rural but by 2050 will be urban. What paradigms will inspire the cities that will house these future Asian urbanites? How will these new cities be planned? What systems will manage their electricity, water and waste supplies? How best might they integrate emerging technologies for environmental management, communication and transport? How should these new Asian cities be connected, both internally through rail, road, pedestrian and cycling networks, or externally through regional transport networks? Finally, what will be the motivating values for these new Asian urbanisms: economic growth? environmental sustainability? aspirational consumerism? humanitarianism? enlightened self-interest? social justice?

City builders in other parts of Asia often look to Singapore, be that begrudgingly or aspirationally. They do so precisely because of Singapore’s journey from first to third world, to use developmentalist terms. Singapore already has very good answers to many pressing urban questions. Politicians, mayors and planning authorities of Asian cities, in their turn, recognise in Singapore a motivation, example or even model to follow in their own efforts in managing urbanisation locally. The generation of Singaporeans who undertook the difficult transformation from third to first world now stand as shining examples to their own descendants. It could be that they will do so for the millions of people who aspire to improve their lives by moving to cities in India, China, and Southeast Asia.

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