FUTURE CITIES LABORATORY

Research proposal submitted to the National Research Foundation of Singapore (NRF)

SINGAPORE-ETH CENTER FOR GLOBAL ENVIRONMENTAL SUSTAINABILITY (SEC)

MAY 2008

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Future Cities Laboratory Vision

The Future Cities Laboratory will be established as a vibrant part of the Singapore-ETH Centre for Global Environmental Sustainability (SEC) and headed by an interdisciplinary team of researchers and designers from the Swiss Federal Institute of Technology (ETH Domain) and Singapore Universities (NUS and NTU).

Contemporary cities are environmentally, socially, and economically unsustainable. Pollution, rising temperatures, limited land and natural resources, congestion, social inequality, ageing of large sectors of the world population, poverty, informality, crime, and terrorism are some of the pressing problems contributing to a decrease in the quality of urban life. Present-day metropolitan agglomerations are man-made systems with the highest impact on global CO_2-production and climate change, and are therefore at the center of environmental research. New cities must be designed and existing cities transformed according to principles of sustainable development as outlined, for example, in the report of The World Commission on Environment and Development, the Global Agenda 21, the United Nations Millennium Goals. In the context of necessary economic, ecological, and social reorientation of the global community, construction must be reinvented and aligned with principles of sustainable development. Conventional approaches to the design, fabrication, and use of structures have to undergo significant changes in order to adhere to the needs of future generations. This transformation will no longer consist of singular improvements but must be integrally connected.

The goal of the Future Cities Laboratory is to provide international leadership in the design of sustainable urban systems – the transformation of existing cities as well as the building of new cities. To achieve this goal, it combines the knowledge, experience, and innovation capacity of members of the ETH Domain and Singapore institutions. It is a global think tank with local rooting in two of the world's most advanced urban societies.

Design Research Labs in Singapore and Switzerland are the test sites for the ideas, methods, and strategies that will be developed. The Stocks and Flows model – in combination with urban morphology – is selected as particularly applicable for the modelling and simulation of sustainable future cities. It integrates interdisciplinary knowledge areas at the small, medium, and large scales – at the level of buildings, urban districts, and regional territories.

The Future Cities Laboratory will form a unique, multifaceted, and integrated platform for the advancement of knowledge in the key disciplines dedicated to the formation of the human-made environment. Results will range from the development of a theoretical body of work to implementation strategies within professional practice – models, scenarios, planning guidelines, and best practices for sustainable development. Results will be co-developed with and applied by Singapore Agencies and Industries.

The Future Cities Laboratory will establish strategic and operational synergies with other research centres in Singapore, Government Agencies, and other current programs such as CENSAM and EM&M. Industry participation will be fostered with fast transition from research to product development – especially in the areas of building automation, energy systems, and construction materials. These innovations, in combination with new planning approaches, are of growing importance for the economic, social, and environmental impact of emerging cities in Asia and other parts of the world.

The Future Cities Laboratory will make pedagogic contributions to graduate and post-graduate education through the development of new didactic models, combining teaching, research, and practice – strengthening academic exchange between Singapore and Switzerland. The model of the Design Research Studio, understood as a platform for knowledge production through design, will play a significant role within this framework; one that has been successfully tested both at the ETH and NUS.

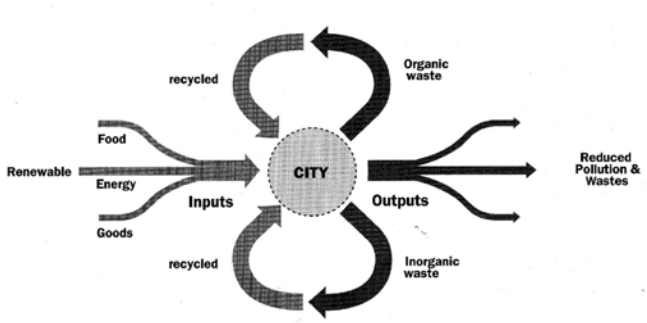
The long-term objective is to establish the Future Cities Laboratory as a center for global leadership in environmental design, promoting methods and techniques for achieving ecologically balanced urban settlements worldwide.

Think Tank – Cities and Sustainability

The Future Cities Laboratory is an interdisciplinary think tank dedicated to sustainable development and the advancement of knowledge in the key disciplines relevant to the formation of the built environment. The ambition is to promote future-oriented strategies in building technology, urban design, and territorial planning that implement new aptitudes regarding sustainability. Reaching beyond the realm of academia, the research is inspired by a mandate for innovation within practice and offers solutions for implementation: an inquiry directed toward practical performance. Using Singapore and other cities as case studies, the objective is to promote – through comparative analysis – methods and techniques for achieving ecologically balanced urban settlements worldwide.

Flux Model – Stocks and Flows

The Future Cities Laboratory advances a theoretical framework – identified as the Flux Model – to link the various streams and scales of the research. This model considers the city as a dynamic system, one delineated by stocks of resources and interrelated networks of material flows, including input and output cycles relative to long-term development. Considering that stocks, flows, and their transfer coefficients are time-dependent, the research will model the behaviour of urban systems according to changing parameters in time. At the core of the research is an investigation of the flux of people, energy, water, material, money, space, and information. These resource-flows will be considered both in terms of their physiological demands and morphological consequences. Ultimately, the impact of stocks and flows on the constitution of cities and the potential for steering their performance in view of sustainable development forms the main thrust of the endeavour.



Urban Metabolism, Richard Rogers, Cities for a Small Planet, *1996*

Research Method – Transdisciplinarity and Design

The Future Cities Laboratory conducts its research along two different, but nevertheless related, methods of investigation. The first trajectory follows the principle of in-depth academic work done in a specific field of enquiry and guided by tightly defined objectives – highlighting particular elements of the Flux Model and integrating input from supporting disciplines. The second trajectory situates the work in the context of so-called design research laboratories – a type of studio-workshop setting in which concepts are tested through the synthesis of individual findings from an array of relevant fields. Both approaches take advantage of the transdisciplinary disposition of the Laboratory and rely on empirical data gained from comparative analysis. Using Singapore as a primary case study relative to other urban territories – especially in Asia, Africa, and South America – will allow the research to address issues that are globally relevant to future city processes. Based on models developed at the ETH, NTU, and NUS for integrating research and practice, the Future Cities Laboratory will seek to create continuous feedback mechanisms among the interwoven projects. Various platforms including conferences, seminars, public lectures, regular informal presentations, monthly research meetings, printed publications (both internal and external), design studio reviews, and public exhibitions will help to ensure that the Future Cities Laboratory remains a coherent, vibrant, and effective research effort capable of integrating the projects' various findings. The methodology proposed herein is unusual but it is confidently believed that the structure of the Future Cities Laboratory will enable linkages between the more established scientific methods native to building technology research and those emerging in the fields of architectural and design research. This being the case, one of the major contributions of the Future Cities Laboratory will be methodological, as it will establish a model for connecting multiple strands of inquiry into one framework for the investigation of sustainable urban development.

Sliding Scales – Small, Medium, Large

The Future Cities Laboratory will be structured according different scales of analysis, ranging from the large territory of a region to the small scale of building assemblies – while taking into account, however, that the allocation of land, energy, material, monetary, and other resources must cut across distinctions of scale. For the purpose of the research, the inquiries will advance along three vectors: territorial planning (L-Scale), urban design (M-Scale), and building technology (S-Scale), aiming at sustainable developments of the city as an entity, of urban ensembles or neighborhoods, and of architectural structures. Central to this approach is the intermediate role of urban design as a bridge-discipline between regional planning and architecture. As measures at the small scale have an effect at the large scale, and vice versa, the sustained communication among the various levels of the investigation is paramount.

Expected Results – Practice and Theory

The Future Cities Laboratory aims at combining practice and theory. Understood as a research platform involving scholars, governmental agencies, and industry, the center will offer sets of concrete solutions and guidelines directed toward the sustainable development of buildings, districts, and regions. Conceived as tools to be deployed within practice, these proposals must improve the current ecological, economic, social, and aesthetic performance of cities. Using the interdisciplinary design research laboratories as testing platforms, the efficacy of the proposed solutions will be verified. At a more abstract level, the research aims at the production of knowledge at the forefront of the disciplines involved in the making of cities – a theory of practice. One of the key objectives of the laboratory is to chart an unprecedented theoretical body of work reframing building technology, urban design, and territorial planning in view of sustainable development. The results of the research – including practical outcomes and theoretical propositions – will form a basis for discourse and be scrutinized by members of the professional and scholarly communities.

Background and Motivation

For the first time in human history, more than 50% of the world's population live in urban regions. Cities are the largest, most complex, and most dynamic man-made systems. They are vibrant centers of cultural life and engines that drive the global economy. Yet, contemporary metropolitan territories are environmentally, socially, and economically unsustainable entities with the highest impact on CO_2 emissions and climate. The quality of urban life is threatened by such factors as pollution, rising temperatures, limited resources, social inequalities, and economic imbalances. Cities are therefore at the centre of global environmental sustainability research.

The overall planning of future cities is a challenge that can only be faced by interdisciplinary teams combining multitudes of backgrounds and expertise. City governments, for example, assemble an array of experts in their planning departments to address the problems encountered in the development of their territories. To a large degree, their efforts rely on results generated by scholarly work done in the context of research institutions. Both Switzerland and Singapore have been consistently considered models for quality of urban life due to their attractive city centers, social stability, high value creation, and clean environments. Research institutions in both places have contributed to these conditions through a strong tradition in planning – from the building scale to the territorial scale, including environmental, social, and economic aspects.

The ETH competence center, Network City and Landscape (NSL), for example, has made significant contributions to the design of new and transformation of existing cities. Similarly, Singapore's universities and governmental agencies have successfully addressed comparable urban challenges.

The idea of the Future Cities Laboratory is to merge these areas of expertise and developed knowledge, methods and instruments in an effort to create sustainable urban environments.

The objective of the Future Cities Laboratory is therefore to promote strategies for achieving long-term ecologically balanced urban settlements worldwide. Reaching beyond the confines of academic work, the research will have a direct impact on city planning and practice and will offer solutions for implementation. Traditional and separate academic or industrial research and development efforts cannot solve problems related to future city developments at the global level. For example, research findings from temperate climates cannot easily be applied in tropical climates and vice versa. The motivation of the Future Cities Laboratory is to combine competences in a unique manner achieve necessary breakthroughs.

Economic Impact

Future Cities will have short-, medium-, and long-term economic impacts on Singapore and Switzerland, including the surrounding regions. Asia, for instance, is experiencing one of the largest building and urbanization developments in history, creating an incredible market for sustainable design, planning, and construction industries. Education, research, and implementation are the necessary steps for value creation to be potentially exported to other parts of the world.

Specifically, it is the combination of capabilities on three different scales and seven parallel streams that will generate value.

- The People stream will produce interactive models based on population fluxes and increase the effectiveness of city development through dynamic scenario planning. The Energy stream will develop patents and products for intelligent and green building technology, one of the fastest growing business areas.

- The Water stream will lead to a better reuse and conservation of scarce water resources, thereby improving their availability and quality to increase land value.

- The Materials stream will contribute to value creation through new light-weight recycled concrete, ultra-high selectivity glazing, lifecycle optimization, and more efficient construction processes – including lower error ratios, higher quality and safety standards, expanded recycling capabilities, and reduction of transportation costs.

-The Capital stream will lead to affordable improvements to the quality of urban life in a combined effort to establish a balance between the private and public sectors, between investment opportunities and social stability.

- The Space stream will ensure efficient territorial organization, the long-term attractiveness of city development, reduce urban sprawl by focusing on high quality density, and offer strategies for transportation pollution reduction.

- The Information stream will provide a simulation and scenario-planning platform for all research projects, and create and maintain a long term data base and communication environment for Future Cities planning, crucial for any planning authority.

A Case for Singapore

The Future Cities Laboratory has its local roots in two of the world's most liveable cities according to various international ranking indexes. As Zurich is strengthening its position as one of Europe's promising metropolitan growth centers, so has Singapore established itself as one of the main urban hubs of Southeast Asia, while planning for sustained population increase. Additionally, over the next decades, a substantial number of new cities will emerge within a short flight's radius from Singapore. Integrated sustainability and affordability must be the prime characteristics of these cities. Singapore – with its rich and successful tradition in developing and implementing urban housing, design, and planning – is an ideal place for new city and territorial planning approaches.

ETH brings to this enterprise a wealth of methods and experience. The faculty members involved in the Future Cities Laboratory have proven their scientific and practical experience in the field, including Asia. They will guarantee that the Future Cities Laboratory will not only produce scientific and theoretical results, but will deliver guidelines of value for Singapore, its region, and other parts of the world.

Cities are framed by local conditions – the genius loci of place. As research and education are key to the further development of this project, ETH researchers have agreed to maintain a continuous and active presence in Singapore. They will lead the research streams and conduct design research studios together with their Singapore colleagues. Because the proposed research engages practice, a thorough knowledge of local circumstances, customs, and legal frameworks is fundamental. The ETH Department of Architecture already maintains an ongoing dialog with the NUS School of Design and Environment that resulted in student exchanges and the Inventioneering Architecture Exhibition in 2007. Similar ties are developing with NTU. In the framework of the Future Cities Laboratory, the ETH Department of Architecture anticipates a large number of Singapore faculty and students to conduct part of their research in Switzerland when appropriate and if necessary in order to generate a true partnership and synergies.

ETH Research Team

PRINCIPAL INVESTIGATOR	Area of Expertise
Prof. Em. Dr. Franz Oswald (program leader)	Urban networks / city design
Prof. Dr. Kay Axhausen	Transportation / urban mobility
Prof. Dr. Markus Boller	Water management
Prof. Dr. Michel Bierlaire	Transportation infrastructure
Prof. Kees Christiaanse	Urban design and economies
Prof. Christophe Girot	Landscape ecology and design
Prof. Dr. Armin Grün	4-D city cartography and simulation
Prof. Dr. Gerhard Schmitt	Information architecture and visualization
Prof. Dr. Ian Smith	Structural monitoring / applied computing
Prof. Dr. Luc van Gool	Computer vision and simulation
RESEARCH TEAM	
Prof. Dr. Marc Angélil	Mega-cities / political economy of territory
Prof. Andrea Deplazes	Building technology / construction materials
Asst. Prof. Fabio Gramazio	Digital fabrication / architectural design
Prof. Dr. Lino Guzzella	Energy conversion systems / thermotronics
Prof. Dr. Janet Hering	Water infrastructure and treatment
Prof. Ludger Hovestadt	CAAD / process design
Asst. Prof. Matthias Kohler	Digital Fabrication / architectural design
Prof. Dr. Vittorio Magnago Lampugnani	Urban design theory / urban density
Prof. Dr. Hansjürg Leibundgut	Sustainable building systems / engineering
Dr. Christian Schmid	Urban sociology / social geography
Tobias Bonwetsch	Digital fabrication
Dr. Remo Burkhard	Information management
Jan Halatsch	Computation
Dirk Hebel	Architectural and urban design
Kerstin Hoeger	City branding
Antje Kunze	Computer modelling
Jesse LeCavalier	Urban organization
Forrest Meggers	Low exergy
Mark Michaeli	Urban design
RESEARCH ADVISOR	
Prof. Em. Dr. Peter Baccini	Waste management / stocks and flows

Research Streams and Goals

The Future Cities Laboratory research priorities are concentrated in 7 streams as summarized in following table:

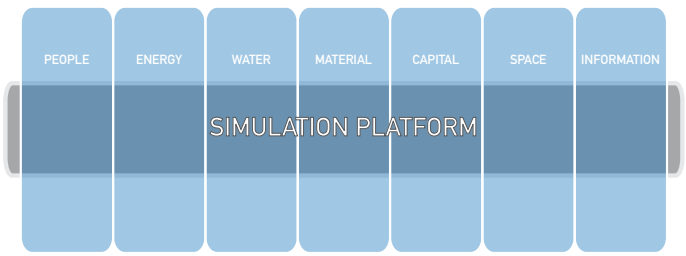
Research Stream	Goals	ETH Principal Investigators and Lead Researchers
Stocks and Flows of **People**	New knowledge about cities through Urban Sociology	Schmid, Angélil
Stocks and Flows of **Energy**	Massive CO_2 reduction through system integration and optimization	Leibundgut, Guzella, Hovestadt
Stocks and Flows of **Water**	Reuse of water in landscape architecture, new water concepts from micro to macro scale	Girot, Hering, Boller
Stocks and Flows of **Material**	Massive reduction of material and energy use, digitally fabricated high performance architecture, mining of urban material	Deplazes, Leibundgut, Gramazio, Kohler, Oswald
Stocks and Flows of **Capital**	Economic framework to ensure the Open City concept for future generations	Christiaanse
Stocks and Flows of **Space**	Long-term sustainability for large cities through new organizational concepts, transportation, and density	Angélil, Axhausen, Bierlaire, Lampugnani
Stocks and Flows of **Information**	Modelling and scenario simulation environment for all research streams and scales	Grün, Schmitt, Smith, van Gool

RESEARCH PROGRAM

1.00 INTRODUCTION
RESEARCH STREAMS

For the Future Cities Laboratory, seven research streams are identified acknowledging transitions in urban physiologies and morphologies worldwide. These provide a platform for addressing the challenge of how processes of urban formation can be managed in order to attain long-term sustainable conditions. Urbanism is understood in an expanded framework to include buildings, districts, and large-scale territories. Particularly at issue are operative strategies that can be deployed within the constraints determined by currently available resources. What feasible means, techniques, and methods can be brought into play in an innovative manner to increase the sustainable performance of the city?

The work will take place in twelve simultaneous and overlapping research projects grouped within the seven streams of the stocks and flows model, and investigated by specialized teams of scholars, students, agency representatives, and industry partners. While the individual projects will have a degree of autonomy, they will nonetheless interweave, overlap, and inform the collective work. It is in this arrangement that the Future Cities Laboratory will offer a groundbreaking venue for transdisciplinary urban research. In the following pages of the proposal, each of the twelve projects will be described schematically in order to identify the major research questions, methods, and anticipated outcomes.



Stocks and Flow Model forming the theoretical backbone of the Future Cities Laboratory. The various research streams are linked by means of the proposed Simulation Platform.

The chart on the next page summarizes the conceptual framework of the Future Cities Laboratory.

- The column on the far left lists the seven categories of stocks and flows that have been identified in collaboration with members of Singapore Universities and Agencies: the flux of people, energy, water, material, money, space, and information.
- Listed along the top row of the chart are the three scales of the investigation: building technology, urban design, and territorial planning.
- Within the matrix, the various research streams span horizontally across scale divisions.
- Vertical connections within the matrix will be orchestrated though the design research studios that will be able to selectively combine and synthesize the different strands of the endeavor.

Of greatest significance is the interaction among the various research streams and their integration enabled by the Future Cities Laboratory. Though the streams have their individual research foci, the organization of the undertaking as a whole will generate sustained contact among the members of the projects and in so doing will ensure that the various thrusts of the work are mutually informative and well connected. To further assist with this effort, platforms of different dispositions will be established such as external reviews, seminar presentations, internal workshops, and so on. Much of the interaction and integration will be enabled through the application of the research findings. As architecture and urbanism are fundamentally concerned with combining several types of input, they are especially well suited for this task. For example, one suggested design research studio will be able to test findings at the small scale by integrating them in a proposal for a built structure whose placement and constraints are in turn determined by findings at the larger scales (e.g. Urban Sociology, Spatial Density, and Transportation Infrastructure) and tested using the Simulation Platform.

Stocks and Flows of People
Since cities are, first and foremost, made for their inhabitants, the stocks and flows of people are listed first. Within this category, the topic of Urban Sociology considers developments in the demographic make-up of the social body and their impact on contemporary forms and processes of urbanization. Though this focus constitutes its own research stream, the relationship of subjects and groups to their surroundings will form a common denominator for all efforts of the Future Cities Laboratory.

Stocks and Flows of Energy
With sustainable city development forming the primary investigatory armature of the Future Cities Laboratory, the stocks and flows of energy must play a prominent role in the undertaking. Under the rubric of Low Exergy, the main focus will be on developing models and technologies for reducing emissions generated by the built environment. Exergy research occupies a position at the cutting edge of building science as it seeks to understand the energy transfer in any process and exposes differences in the quality of various states of potential energy sources.

Stocks and Flows of Water
The stocks and flows of water will have a significant impact on future city developments, especially in the case of Singapore. In this category, two research topics are proposed: Landscape & Ecology will address the environmental potential of water in the ecosystems of large agglomerations in order to offset the negative effects that cities have on their surroundings; Water Infrastructure will focus on the management of water resources at all scales of the built environment, including retention, collection, reuse, sewage, etc., in order to minimize water consumption and maximize the effectiveness of water systems.

Stocks and Flows of Material
As cities are physical artifacts and materialized in space, investigations into enhanced material performance, new means of construction, and innovative ways of accessing urban material stocks will play a significant role in future city research. Three specific trajectories are proposed with this category: The Construction & Materials project will investigate the environmental impact of materials and composite products throughout the life cycle of built structures. This research will be linked to the testing of automated processes of assembly investigated within the topic of Digital Fabrication. The third stream, Transforming and Mining Urban Stocks, will address the material resources currently embedded in the built environment reframing the question of waste management.

Stocks and Flows of Capital
Capital constitutes a primary force of urban formation. While cities generate money, they simultaneously require significant deployment of financial resources. City Design & Economy will investigate the role of monetary fluxes within urban design. By bringing together questions of urbanism with those of economics, this project-stream will asses the ramifications of specific financial models and real estate strategies on the constitution of the city body in an effort to strike a balance between control and laissez-faire, between the public and the private sectors, between local and global economies.

Stocks and Flows of Space
Space as a resource is a core consideration of the Future Cities Laboratory. Three project-streams within this category will examine particular aspects related to the management and design of urban space. Territorial Organization will address questions of spatial allocation, logistics, and functional performance of large territories in reference to emerging global challenges. Transportation Infrastructure will be geared toward developing means of optimizing flows of people, goods, and materials within urban systems. Spatial Density will investigate means of maximizing the capacity of limited spatial resources in view of qualitative demands.

Stocks and Flows of Information
The Simulation Platform will explore ways of interacting with stocks and flows of information while also providing a common base for all the research undertakings of the Future Cities Laboratory. One of the key aspects of current urban research encompasses scenario planning: designing potential future conditions according to varying constraints. By means of digital techniques, the effects of changing parameters over time will be played out and analyzed by so-called city engines. While this research stream constitutes a project in and of itself, it will provide a collective tool for use within the Future Cities Laboratory to enable the testing and communication of research findings.

The seven streams and twelve projects combine an array of key disciplines relevant to the formation of city territories. One of the primary objectives of the Future Cities Laboratory is the interaction of these disciplines, for it is only through their interface that new aptitudes regarding the sustainable development of contemporary urban settlements can arise.

S-LAB
BUILDING TECHNOLOGY

M-LA
URBA

STOCKS AND FLOWS OF **PEOPLE**

STOCKS AND FLOWS OF **ENERGY**

STOCKS AND FLOWS OF **WATER**

STOCKS AND FLOWS OF **MATERIALS**

STOCKS AND FLOWS OF **CAPITAL**

STOCKS AND FLOWS OF **SPACE**

STOCKS AND FLOWS OF **INFORMATION**

LOW EX
Hansjürg Leibundgut / SOH Yeng Chai / CAI Wenjian / HO Hiang K

Christophe Girot / Ja

WATE
Markus Boller / Janet Hering

CONSTRUCTION &
Andrea Deplazes / Hansjürg Leibundgut / CHEN Yan / CHIEW Sing-Ping

DIGITAL FABRICA
Fabio Gramazio / Matthias Kohler / HUANG Guangb

TRANSFOR
Franz Oswal

Kees Christiaanse

Vittorio Magnago Lampu

Armin Grün / Gerhard Schmitt / Ian Smith / CHAM Tat Jen

B
N DESIGN

L-LAB
TERRITORIAL PLANNING

URBAN SOCIOLOGY
Christian Schmid / Marc Angélil / Lai Choo MALONE-LEE / Kee Yong LIM / John HARRISON

ERGY
wee / THAM Kwok Wai / Chandra Sekhar / Nirmal KRISHNANI

LANDSCAPE & ECOLOGY
net Hering / LO Yat-Man, Edmond / NG Wun Jern / Perry YANG / Mike SAUNDERS / David Higgitt

R INFRASTRUCTURE
g / NG Wun Jern / Karina GIN / Mike SAUNDERS + tbd

MATERIALS
/ Joseph LIM Ee Man / CHEAH Kok Ming / KWAH Harn Wei

ATION
in / LEONG Kah Fai / Patrick CHIA

MING AND MINING URBAN STOCKS
ld / Susanto TENG / WANG Jing-Yuan / KWAH Harn Wei

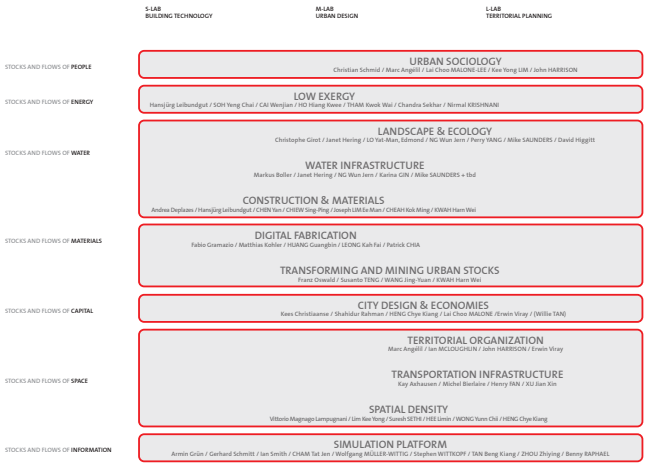
CITY DESIGN & ECONOMIES
/ Shahidur Rahman / HENG Chye Kiang / Lai Choo MALONE /Erwin Viray / (Willie TAN)

TERRITORIAL ORGANIZATION
Marc Angélil / Ian MCLOUGHLIN / John HARRISON / Erwin Viray

TRANSPORTATION INFRASTRUCTURE
Kay Axhausen / Michel Bierlaire / Henry FAN / XU Jian Xin

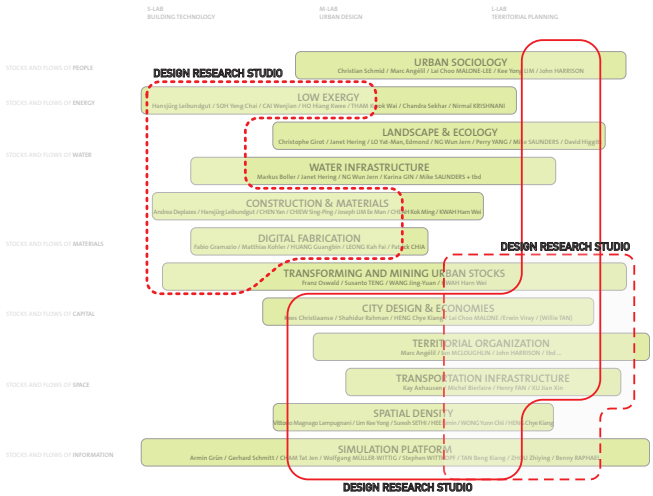
SPATIAL DENSITY
ugnani / Lim Kee Yong / Suresh SETHI / HEE Limin / WONG Yunn Chii / HENG Chye Kiang

SIMULATION PLATFORM
/ Wolfgang MÜLLER-WITTIG / Stephen WITTKOPF / TAN Beng Kiang / ZHOU Zhiying / Benny RAPHAEL

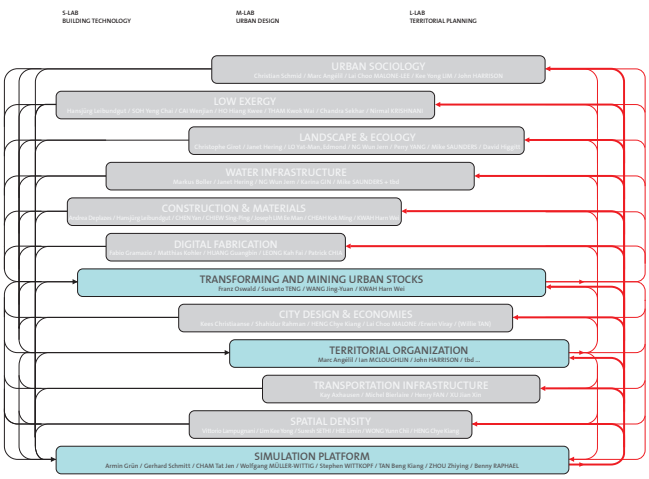


The seven research streams of the Stocks and Flow Model situate the research within a discourse on sustainability in view of the future state of the urban environment.

Three scales of the investigation structure the research according to disciplines that are relevant for the formation of the man-made environment: building technology, urban design, and territorial planning.



Design Research Studios establish the platform for discourse and negotiation between the various projects of the Future Cities Laboratory.



Feedback loops are set into place in order to test the findings of the individual projects – by means of the intermediate role of specific projects forming collective data pools.

		Research Goal	Research content	Research Scope
FUTURE CITIES		Provide international leadership in the design of sustainable Future Cities	Integrate interdisciplinary knowledge and tools related to small, medium, and large urban scales	Stocks and Flows model, investigation, simulation, application
PEOPLE PROJECT LEADER: Schmid LEAD PI: new prof. for Urban Design at D-ARCH	1.01 Urban Sociology	New comparative knowledge about cities through urban sociology – development of models for different cities and regions	Urban space as site for fluxes of people: migration, tourism, commuting – establishing connections between physical and social space	Comparative Case studies, model building
ENERGY PROJECT LEADER: Leibundgut LEAD PI: new prof. for Building Physics at D-ARCH	1.02 Low Exergy	Significant reduction of CO_2 output of buildings and city quarters through system integration and optimization	Develop and adapt Low Exergy Model and applications for tropical climate	Modeling, and simulation prototype construction, product verification, interaction of different mechanical systems
WATER LEAD PI: Boller & Girot	1.03 Landscape & Ecology	High quality landscape architecture and ecology through innovative use of water in landscape	Integrate landscape and water management on the building, city, and regional scale	Modeling and simulation, test planning
	1.04 Water Infrastructure	Develop, demonstrate and monitor appropriate water concepts for cities from micro to macro scale	Establish criteria, develop new techniques for rain water harvesting, water resistance of construction materials	Develop expert tool and process technologies, implement and monitor case studies

Innovation and Distinction	Leaders	Impact	Anticipated Results, Workflow and Milestones	Connections to Other Streams
Unique and intellectually complete and integrated Future Cities model to date	Oswald (Program Leader), Saunders, Heng, Pan	Models, scenarios, tools, guidelines and examples for sustainable transformation and growth of existing and planning of new cities	1. From Analysis to instant results 2. From the specific to the general and vice versa 3. From research to tools, guidelines, and implementation	
Reframing of Urban Sociology in view of the stocks and flow model, development of planning strategies for a multi-ethnic and mobile society	Schmid, Angélil, Higgitt, Malone-Lee, Lim	Interactive model based on fluxes of people increases effectiveness of urban development strategies through dynamic scenario planning	1. Analytical and theoretical framework 2. Comparison with world cities (Asia, Africa, South America, etc) 3. Outlook and urban potential for Singapore and other Asian cities	Territorial Organization, Transportation Infrastructure, Urban Density, City Design & Economies, Information
New development and application of Low Exergy model to cold and tropical climates	Leibundgut, Tham, Krishnani Soh, Cai, Ho	New technologies, patents, and products for building technology, strategies for an economy of means	1. Refine Low Exergy Concept in Switzerland 2. Adapt and apply Low Exergy concept to test space in Singapore 3. Develop large-scale applications for tropical climates	Construction & Materials, Digital Fabrication, Information, EM&M, CENSAM
Combine high quality landscape architecture with CO_2 fixing and creating dynamic processes	Girot, Hering, Yang, Saunders, Higgitt, Lo, Ng	Increase attractiveness and land value of city while providing large-scale CO_2-fixing and biomass generation	1. Landscape integration at the building scale 2. Landscape networks at the scales of neighborhoods and districts 3. Landscape infrastructure for entire regions	Water Infrastructure, Urban Sociology, Simulation Platform
Novel concepts to solve the problem of residual micro pollutants with nutrient recycling and bio energy production	Boller, Pronk, Saunders, Gin, Ng	Better use of scarce water resources, thereby increasing the quality and availability of water, increasing land value, develop new tools & implementation techniques	1. Expert decision tool 2. Processes studies in lab and full scale prototypes 3. Description and evaluation of water concept 4. Establish monitoring programs and their implementation	Landscape & Ecology, Low Exergy, Simulation Platform

		Research Goal	Research content	Research Scope
MATERIALS LEAD PI: Oswald	1.05 Construction & Materials	Massive reduction of material and energy use in construction for high performance buildings	Develop optimized construction methods and systems while minimizing life cycle waste	Develop new materials in cooperation with industry, test & apply to Swiss & Singapore constructions
	1.06 Digital Fabrication	Digitally fabricated high precision and high performance multi-storey architecture	Develop an integrated design and fabrication process directed towards an adoption of the ETH fabrication robot on-site with sensor systems and AI-methods for control	Develop and improve ETH Robots on site in Singapore, integrate seamlessly into the design process, design and fabrication toolbox
	1.07 Transforming and Mining Urban Stocks	Turning urban waste, building fabric, and built sites, from a major problem into a major resource for sustainable cities – mining the city	Designing new products and added value chains, designing new urban fabric, designing strategies for the re-use of sites	Perfect example for the Stocks and Flows model: Comparative case studies, field tests, monitoring and adoption
CAPITAL LEAD PI: Christiaanse	1.08 City Design and Economies	Ensure the Open City concept for future generations by exploring and designing suitable and adaptable urban structures as framework for social and economic interaction.	Generation of high quality urban environments through success optimization, efficiency of resources and balance of interests	Comparative case studies, model building and simulation, testing and monitoring of implementation

Innovation and Distinction	Leaders	Impact	Anticipated Results, Workflow and Milestones	Connections to Other Streams
Innovation in material re-use and light weight concrete construction in combination with high performance glazing	Deplazes, Leibundgut, Lim, Chea, Kwah, Chen Chiew	Massive increase of construction value creation through new light weight recycled concrete, ultra high selectivity glazing and life cycle optimization	1. Identify concrete recycling and ultra high selectivity glass potential 2. Apply in design research studio and test building 3. Monitor technology and improve findings in full-scale tests	Low Exergy, Urban Density, Digital Fabrication, Simulation Platform
Innovative combination of ETH's competence in digital fabrication from design to maintenance with long-term sustainability, propositions for a digital chain approach for the building industry	Gramazio and Kohler, Chia, Tham, Soh, Huang, Leong	High value creation in construction product and construction process through lower error ratio, improved quality, higher safety, reduction of necessary transport, architectural diversity	1. Develop additive and subtractive on-site robotic fabrication process in research design studio 2. Integrate AI methods and sensor systems 3. Apply in test construction as part of the digital chain 4. Explore feedback on design process	Construction & Materials, Low Exergy, Simulation Platform
New products without compromises in quality, new legislation, new strategies for the re-use of urban or non-urban sites	Oswald, Heng, Hsu, Kwah, Teng, Wang	Unprecedented savings in construction and recycling, strategies for transforming and mining urban stocks	1. Design, planning strategies, and implementation proposals based on case studies 2. Comparative studies for the re-use of urban waste 3. Establishment of scale-transcending criteria	Ecology, Low Exergy, Construction & Materials, Urban Sociology, Territorial Organization
Activating high quality and sustainable city design and economy not as contradictions, but as long term quality and livability guarantees	Christiaanse, Heng, Malone-Lee Viray, Rahman	Increasing the quality of living conditions in the Open City in a combined effort between economic framework setting and city planning	1. Defining the qualities of the Open City 2. Design Research Studios on the topic of the Open City 3. Development and testing of the economic framework in models and simulations	Urban Sociology, Territorial Organization, Spatial density, Simulation Platform

		Research Goal	Research content	Research Scope
SPACE PROJECT LEADER: Angélil LEAD PI: Axhausen	1.09 Territorial Organization	Ensure the long-term sustainability of large and mega-cities	Future Cities relevant territorial demographics, ecology, economy, logistics and governance development	Comparative studies, analysis, proposals, guidelines
	1.10 Transportation Infrastructure	Ensure optimal, safe and sustainable transportation for a growing and ageing population	Daily flows algorithm development short, medium, and long-term scenarios. Increase of simulation system robustness and accuracy	Simulation, planning and optimization system; development of new algorithms; Best practice comparison and application
	1.11 Spatial Density	Use Density as a key property for the future information society while guaranteeing social, economic and ecological sustainability: key challenges of the 21st century	Identification of quality-based future concepts in spatial density, including sociology, urban and regional economics, and urban architecture	Design research employing case studies, historical and anticipated models of density, ranging from buildings, districts, to the regional scale
INFORMATION LEAD PI: Grün & VanGool	1.12 Simulation Platform	Create and guarantee modelling and simulation environment for all research streams and scales	Remote satellite sensing, modelling, data base and virtual reality integration, Future Cities results communication environment	Modelling and simulation, virtual reality environment, scenario planning, integration of monitoring results

Innovation and Distinction	Leaders	Impact	Anticipated Results, Workflow and Milestones	Connections to Other Streams
Linking development potential of metropolitan regions with advances in urban and building design	Angélil, Cheok, Lim, McLaughlin Harrison	Long-term insurance of sustainable and economically attractive city development by embedding in large-scale territorial planning	1. Comparative studies of successful examples 2. Analysis and design of proposals in Design Research Studios 3. Establishment of guidelines	City Design & Economies, Transportation Infrastructure, Simulation Platform
Direct links and integration within the other components of the flux model, from physical construction to policy making	Axhausen, Bierlaire, Xu, Fan	Long term investment improvement, transportation pollution reduction, transportation and living quality improvement	1. Daily flows – short term, using multi-agent technology 2. Daily flows - medium term – policy making 3. Daily flows – long term integrating of networks between people, work place and planning	Territorial Organization, Simulation Platform, Urban Sociology
Promoting the concept of high quality architecture and urban design with the concept of density, leading to sustainable cities for the Information Society	Lampugnani, Hee, Zhu, Wong, Heng, Lim Sethi	Overcoming the negative side effects of urban sprawl, increasing the value of dense cities for living and working in conjunction with the other elements of the flux model	1. Parallel design research in Singapore and Switzerland on city quality and density 2. Urban structure, urban island, and building typology as development vectors 3. Handbook for dense architecture for specific topographic, climatic, social and cultural situations	Territorial Organization, Urban Sociology, City Design & Economies, Simulation Platform
Unprecedented building, city and territorial simulation and modelling platform with long-term impact on increasing the body of knowledge in Future Cities Design	Grün, Schmitt, Gool, Smith, Kwoh, Wittkopf, Tan, Zouh, Raphael, Mcloughlin Cham, Müller-Wittig	Creation and maintenance of a long term data base and communication environment for Future Cities planning, crucial for any planning authority	1. Seamless interaction with the ETH ValueLab, 4D Singapore software 2. Modelling, simulation and data base environment for all research streams 3. Scenario planning for building, city and regional scale 4. Advanced Future Cities communication system	Urban Sociology, Landscape & Ecology, Water and Infrastructure, City Design & Economies, Territorial Organization, Transportation Infrastructure

1.01 URBAN SOCIOLOGY

RESEARCH GOAL

The main goal of the research stream Urban Sociology is the analysis and evaluation of the contemporary forms of urbanization in order to identify the conditions of a sustainable urban development which meets the functional, social and emotional needs of the population.

Today, as a result of the manifold processes of urbanization, the differences between urban spaces are increasing. A great variety of urban cultures are developing, resulting in different models of urbanization. Even in the same country, profound differences in cultures and models of urbanization can be found. It is decisive to understand their origins, their pathways of development, and their possible impacts, in order to detect and explore the specific urban potentials that they contain.

The research takes into consideration the most recent contributions of social sciences to the analysis of global urbanization processes in the contemporary world. It follows a comparative approach with special interest on case studies of urban development in Asia and especially on Singapore.

RESEARCH CONTENT

Urbanization can be understood as a double-edged process: On the one hand, it is driven by migration from rural to urban areas. On the other hand, it is marked by the spread out of urban areas into the countryside. In both cases, the existing socio-spatial structure is deeply transformed. However, the result of this transformation process is not generic and uniform. On the contrary, recent analysis shows that today's urbanization is producing very different urban constellations and forms of urbanity.

In general terms, urban space can be analyzed as the site of meeting, encounter, and interaction. It is the place where all kinds of networks are coming together, thus producing a specific urban situation. The main focus of this research is on fluxes of people, the most important forms of which are migration, tourism, and commuting. It has become increasingly difficult to discriminate between these different forms of spatial mobility. Global networks of interaction evolve and give way to various forms of short-time migration, business travel, and even long range commuting by high-speed train or airplane. Furthermore, migration and spatial mobility involve very different social groups, such as the "global creative class" on the one hand, and low income groups and refugees – forming a kind of "global underclass" – on the other. As a result of these diverse forms of fluxes of people, urban space has become heterogeneous. Today's cities are thus characterized by differences: they are places, where different people with their individual backgrounds come together. Every urban space contains more or less marked differences in income and socio-economic status, cultural and ethnic background, life style, age groups, demographics, etc. It is crucial to understand, how these differences are produced, processed, and mediated.

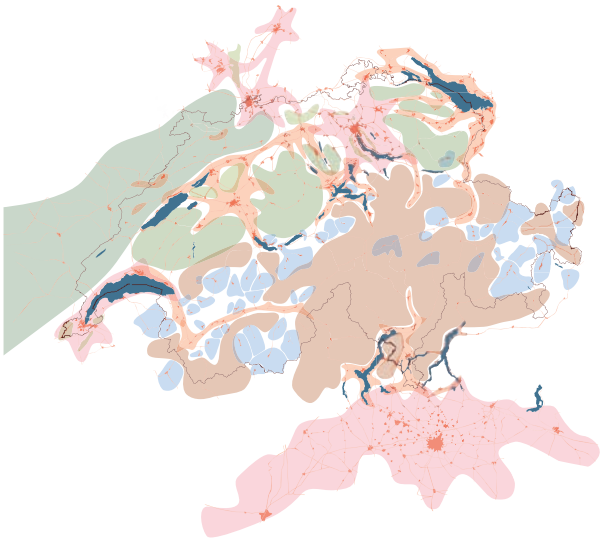
Differences must be understood dynamically. They are constantly produced and reproduced and result in specific local urban cultures and traditions. The extent of the reaction and the variety of its effects are thus crucial in defining the nature of any specific urban culture. These cultures involve socializing processes and are deeply inscribed in history. Through processes of marginalization and segregation the manifold characteristics of difference might be isolated and made unproductive, whereas a developed urban form transforms the juxtaposition of different elements into reactive opportunities producing all kinds of social inventions. This is why contemporary cities have become important places of creativity and innovation. Starting from this basic understanding of the urban, the research stream Urban Sociology follows a comparative approach on three different scales: the World, Asia, and Singapore. The aim of the research is to understand the range of possible urban development models and to analyze their implications. Special attention will be given to the analysis of urban potentials and the framing of future strategies. This perspective needs to take into account emergent demographic, cultural and socio-economic trends, which result of the transformation of the global economy, and influence how people will live, work and play in the future. In particular, the following concerns will be addressed from a people centered perspective:

- The requirements for ensuring a sustainable integration of various social groups and stakeholders relative to the active flux of human capital across local and national boundaries as a result of globalization.
- Implications for identity and embeddedness, and requirements to ensure acceptance, non-alienation and successful integration of a diverse socio-cultural mix of inhabitants.
- The global phenomenon of a growing aging population and the specific needs that this process involves.
- The pervasiveness of high-rise cities that fulfill density requirements but often inadvertently contribute to the segregation and isolation of communities and individuals.
- The growing importance of digital infrastructure and its potential recruitment to facilitate the anticipated fluxes of information, goods and human interaction.

INNOVATION

The proposed research stream provides innovative approaches mainly in the following fields:
First: The identification of specific models of urban development. This is a novel approach which helps to understand the specificity of the urban development of individual cities in the age of globalization. Urbanization is analysed as structured by the following forces: the physical pattern of previous periods of urbanization; inherited social structures modulating the urbanization processes; socialization and learning processes which reproduce as well as transform the individual pathways of urbanization
Second: The systematic comparison of urbanization models. Today, there are available ample of monographical studies on

urban development for individual cities, and also a growing number of readers and collections of case studies. Yet until today, the systematic comparative analysis of urban developments in different cities is only at the beginning. In order to detect and analyze the full range of possible development paths, and to avoid the "the trap of singularities", it is crucial to develop and apply comparative approaches.
Third: The transdisciplinary approach. This means the development, application and customization of a broad set of methods which are able to integrate the different aspects and factors of current urbanization processes and, at the same time, to integrate methods as statistical analysis, mapping, participative methods, stakeholder analyses, and inclusive design.
Forth: Singapore will be the central case study of the analysis.
As a result, the research stream will produce an important evaluation of its urban development and proposals for a sustainable urban future.



Typology of different forms of urbanization in Switzerland.
Published in: Roger Diener, Jacques Herzog, Marcel Meili, Pierre de Meuron, Christian Schmid: Switzerland – An urban Portrait. *Basel, 2005.*

IMPACT

The output of the research comprises both substantive and procedural knowledge that would enable the comprehensive address and satisfaction of people needs and to ensure the successful development of sustainable future cities from both socio-economic and environmental perspectives.

RESEARCH SCOPE AND MILESTONES

The main challenge of the research process lies in the comparative approach.
– The first step will be the development of a general analytical framework, which allows the comparative analysis of contemporary urbanization on a global scale. Accordingly, a methodological design has to be developed, which comprises a specific combination of methods, including statistical analysis, morphological analysis, mapping, and the analysis of the historical development.
– In the second step, the empirical research starts with an in-depth analysis of the established socio-cultural make up and identity vis-à-vis the anticipated future of urban development of Singapore. The aim of this step is to identify and to analyze the main aspects of the urbanization model of Singapore and to produce a first evaluation of its urban potentials.
– The third step consists in a parallel analysis and systematic comparison of 6 - 10 World Cities. The selection of the case studies (metropolitan regions predominantly located in Asia) aims to provide a wide variety of different urbanization models.
– The forth step includes a systematic evaluation of strengths and weaknesses of the analyzed urbanization models in order to ensure more humane designs of future cities. This step will also provide a special outlook for Singapore. In this respect, the research shall include in-depth analyses and subsequent accommodation of the needs of various stakeholders so as to maintain the integrity of established social structures ranging from the basic level of the individual to family units to communities and finally the nation.

LINKS TO OTHER RESEARCH STREAMS AND PROGRAMS

The research stream Urban Sociology provides a basic understanding of the cultural, social and economic forces involved in contemporary urbanization. Therefore, it contains strong links to the research streams "Landscape & Ecology", "City Design & Economy", "Territorial Organization", and "Spatial Density".

There are further links to and synergies with the research project "Specificity and Global Urbanization" of ETH Studio Basel and with the Swiss cooperation project in Architecture "Urban Systems & Urban Models" (partners: University of Lugano, EPF Lausanne, ETH Zurich). Both projects follow a marked international and comparative approach.

Core Research Team

Dr. Christian Schmid (D-ARCH, NSL)
Prof. Dr. Marc Angélil (D-ARCH, NSL)
Prof. David Higgitt, NUS
Dr. Malone-Lee Lai-Choo, NUS
Prof. Dr. Lim Kee Yong Lim, NTU

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.02 LOW EXERGY

GOALS AND CONTENT

The research into the field of low exergy will broaden the perspective of engineers and designers involved in the SEC Future Cities Laboratory and will influence the design of architecture and urban spaces in the future. The concept of exergy is essential if cities are going to use energy in a sustainable manner. The current use of combustion technology for heating and the dependence on large inefficient systems, both at the building scale as well as the city scale, does not make sense anymore. The research into low exergy design will prove that new technologies and systems are available that use resources both more efficiently and effectively.

More effective use of energy means that high quality sources such as fuels with high energy content and high temperature combustion should only be used in places where high temperature is needed – not in buildings. Building systems are only responsible for producing comfortable room temperature and humidity and do not require high energy-value fuels. Technologies are available that can efficiently and effectively move heat into – and in the case of cooling – out of buildings. These systems are optimized around both the quantity of energy used in the system as well as the quality of energy by using exergy analysis tools. The analysis and optimization of these systems will take place in the Future Cities Laboratory for the case of Singapore and its hot and humid tropical climate.

The collaboration between Singapore and Switzerland not only creates a platform for high quality research, but also a perfect spectrum of climate situations for the study of building systems that can function well and have a low exergy demand. The different city density also brings together unique perspectives on the level at which systems can be integrated and centralized or decentralized, thereby maximizing the potential performance benefits achieved via exergy analysis. There is a large potential for collaboration between NTU, NUS, and the ETH that will lead to optimized systems that address exergy and energy demand, indoor air quality and comfort, along with better monitoring and instrumentation. This will be done through modeling (parametric, CFD, etc.), laboratory experimentation, and finally via demonstration in projects. This would create a variety of opportunities for PhD thesis topics as well as for creation of new patents and products. This research will play an integral role in the design studio and the creation of a new landmark building that will implement new concepts created within this research.

INNOVATION AND IMPACT

A principal outcome of the collaboration will be the application of these low exergy concepts to the hot and humid climate. Technologies that are being developed for low exergy systems in the Swiss context will be studied for expansion into Singapore and merged with the large amount of research being done on air conditioning in Singapore. Some of these ideas include the use of decentralized ventilation systems, waste heat recovery, and localized energy storage. Decentralized ventilation systems integrated with other low exergy systems are currently being researched and developed at the GT Lab of Prof. Leibundgut at the ETH. These are also integrated into the architecture and construction concepts of Prof. Andrea Deplazes. A new concept is also being studied with Prof. Lino Guzzella to optimize the changing use of electrical power over time for buildings by using localized energy storage in batteries. All these systems under development at the ETH will be transferred to the conditions and requirements found in Singapore.

Along with the development of these new systems in the tropical climate will come new innovative ways to evaluate the acceptance of the system. With new improved sensors integrated into the system, and better ways to assess the response of people to their indoor environment, comfort will be optimized along with exergy demand. This will show the large potential impact of the new systems and concepts to occupant perception and productivity, improvements of which can have large economic value.

SCOPE AND COLLABORATION

Within the Future Cities Project this research will play a central role. It will be integrated directly with the work being done in the Construction and Materials and the Digital Fabrication research streams. It is important that the building systems being designed are also integrated into the building as a whole, therefore the material and construction types and digital processes should be considered as the technologies are developed. The systems are also fundamental to any energy considerations made as a part of all other research streams, whether it be in the simulation platform or in how the landscape and ecology systems ingrate with the internal building systems. The broad expertise being leveraged for the project from ETH, NTU, and NUS will produce a highly integrated view of cities that starts from the small scale building functions being evaluated in this research stream. As proposed by NTU, research into embedded computation within buildings will enable sensor networks to actively and cooperatively share information regarding climate, pollution, working patterns, and so on to minimize the energy expended in heating, cooling, lighting and ventilation. Many of the systems being developed, from the CO_2 controlled exhaust to the adaptive battery storage, will require expertise in the field of sensors and system networking and control. This will be an important area of collaboration with NTU, which will also

includes the availability of 120 square meters of laboratory space for experiments generously offered by Assoc. Prof. Cai Wenjian, along with input from his expertise in building air conditioning systems.

A framework has also been established with NUS for collaboration on the development and performance analysis of the new systems that will be under investigation. This will come from the expertise in the field of indoor environmental quality and comfort, which will be essential as the controlling factor in the optimization of air conditioning technology. This includes the availability the NUS Field Environmental Chambers, which are 80 square meter rooms with instrumentation for research into ventilation strategies along with potential study of energy or exergy demand. These will provide the capabilities to analyze the important relationship between optimized indoor environmental quality with low exergy systems. The Department of Building at the NUS has a wide range of appropriate expertise that will be welcomed in the development of this research thrust.

This research will be supported by three outstanding Professors at the ETH, who together see an immense mutual benefit for Singapore and the ETH in this research thrust. These beneficial outcomes will be the design and production of high performance low exergy components with the attached academic output and patents. This will be followed by the proof and deployment of these systems in Singapore and Zurich and eventually the many real future cities that span this projects broad climatic and spacial spectrum, thus producing benefits on a global scale.

GT Lab: the office and implementation space for low exergy technologies under development at the Chair of Building Systems headed by Professor Hansjürg Leibundgut.

LowEx Technology: decentralized ventilation system with exhaust integrated into ceiling panels and controlled for optimized removal by CO_2 sensors (left), and subsequent optimized air intake system coming directly through the facade in compact systems integrated into the floor (right).

RESULTS AND MILESTONES

This research will produce academic results as stated above, but it will also be a source of new products that have a direct impact on the performance of real building systems, and thus on real buildings and on cities as a whole. The major milestones of the project will include the creation and validation of initial models for the application of these new systems in the tropical climate. This will be followed by the experimental testing of these systems in the laboratory. Finally the the systems will be demonstrated in real projects, which should be realized as a part of the Building Design Studio.

The major results will be in the new products that will be brought to market. This will create real savings and improved performance in buildings. This clearly comes from reduced exergy and energy demand, but also from improved productivity of the occupants. These combine to create an enormous potential for making buildings and thus cities more sustainable and livable.

Core Research Team

Prof. Dr. Hansjürg Leibundgut (D-ARCH, HBT)
Prof. Andrea Deplazes (D-ARCH)
Prof. Chen Yan, NTU
Prof. Chew Sing-Ping, NTU
Prof. Joseph Lim Ee Man, NUS
Prof. Cheah Kok Ming, NUS
Prof. Kuah Harn Wei, NUS
Prof. Yang Perry Pei-Ju, NUS

Industrie Partners

Siemens PTE LTD
Intellisys

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.03 LANDSCAPE & ECOLOGY

The balance between landscape, water, and ecology has become an important aspect of sustainability for future cities. They operate together systemically and complement each other at various scales of urban complexity. Landscape ensures the topological integration of natural elements such as water, ground, and vegetation within the overall infrastructural framework of a city. The landscape framework provides amenity value for the inhabitants, and significantly increases the quality of an urban setting, providing space for leisure while improving overall microclimatic conditions through the appropriate use of water and vegetation. Landscape can allow for the recovery of rainwater and its storage at an urban level through a network of ponds, wetlands, waterways, and reservoirs, proactively reducing the risk of soil erosion and pollution while significantly enhancing possibilities for biodiversity. Ecology completes the landscape framework by ensuring a healthy and sustainable balance of natural elements such as water, earth, and air within each urban biome. Working with terrestrial plant and wetland ecologies, the landscape framework provides a broad palette of possible plant-associations capable of performing a variety of environmental tasks ranging from wildlife habitat to phyto-remedial treatment of contaminated soil, sediment, and water. Ecology coupled together with water resource management and landscape architecture brings the best possible guarantee for a sustainable natural environment within a city, capable of CO_2-fixing, increasing biomass, and generating dynamic processes, and recovery of nutrients.

At the scale of architecture, landscape, water, and ecology play a vital role in making buildings more pleasant, efficient, and environmentally friendly. The use of green roofs for energy efficiency, the recovery and storage of rain water and grey water, and the use of shade plants for improved thermal comfort, will play an increasingly important role in the organization of each living and working unit. Landscape architecture not only enhances the quality of life and the value of a building, it can also provide for the storage and percolation of rainwater for domestic use and recycle grey water for a variety of garden tasks. Research on the role of landscape architecture and water in improving the microclimate of living and working environments has developed significantly in recent decades. The ecological balance reached by each living and working unit within a city has immediate repercussions on the overall ecological balance of a city. But it is at the level of an entire neighborhood that landscape, water, and ecology become really effective together through a variety of synergies. Clusters of buildings, gardens, waterways, and streets can be worked into larger landscape units that include overall planting concepts for shade trees, while managing the recovery of rainwater water and grey water. Depending on the scale and density of each neighborhood, a variety of solutions dealing with water management, topology, and plantation can be worked out. Various approaches to landscape and water will mature over time and come to characterize the identity of an entire neighborhood. In terms of ecology, this also means that neighborhood landscapes will be able to propose a much broader and more continuous range of biodiversity. Each neighborhood unit could be conceived as a large urban cell dealing locally with issues of landscape, water, and ecology.

At the scale of an entire city or region the question of landscape, water, and ecology becomes more challenging because of the need to manage a coherent and continuous interface between the city, infrastructures, and outlying natural, coastal, and agricultural areas. The approach at this scale of intervention depends entirely on the particular topology of a given context and requires a much longer implementation process. In addition to the problems of immediate adjacency, the regional scale deals with landscape, water, and the environment in a systemic way. At this scale landscape construction integrates an overall topological approach that takes into account the amplitude and cycle of natural water levels in rivers and coastal oceans that affect the city, coupled with the management of urban waters. The modeling of the landscape, whether it be coastal or inland, has direct implications on the appropriate approach to natural water management and its impact on the stability and dynamic of the entire regional ecology. Research on a new topology for future cities – combined with innovative landscape structures, performing water systems, and appropriate ecological models – will become vital in coming decades. New topologies along coastal areas that allow for protection from natural cataclysms, while maintaining freshwater exchange and optimal ecological conditions in the environment, will need to be adapted to each urban situation. To reach such a goal, every scale of landscape, water, and ecology in future cities will need to be developed and integrated while maintaining the best possible value for the inhabitants. Water features, for example, could be combined with water treatment and storage.

In the context of the Future Cities Laboratory, the Landscape & Ecology research team could be well suited for a further integration of urban landscape design initiatives with certain agency-led initiatives such as the ABC Water Programme. As mentioned by Professor David Higgit (NUS), there has been a significant shift in policy regarding the quality of waterfronts and river catchments in Singapore, where the PUB has been seeking actively to “reimagine” the water environment for Singapore. This initiative could not only help improve the quality of water but also the quality of urban life and land value at target locations. This renewed interest in the landscapes of water could be an excellent opportunity to work at an operational level with various institutes and agencies in Singapore and to test a variety of landscape architectural approaches and innovative design solutions. Some projects may even engage a variety of community partnerships and user oriented perspectives together with local specialists. The goal would be to improve the quality of the city environment through appropriate landscape

design and water management, thus significantly improving the amenity value of a given place. Work within the domain of design would be built upon the ETH's extensive experience in studios with interactive models of large-scale urban landscapes which is able to blend topology, hydrology, infrastructure and vegetation with local culture in a series of innovative planning solutions. This approach should of course be adapted to the specific geographic context of Singapore, and would be based on available data about water quality and sediment management, as well as on a particular cultural approach to water. There will also be a need for substantial background information and experience concerning the choice and development of new urban water landscapes in Singapore. The project will, therefore, benefit tremendously from a collaboration with investigators in Singapore who are pursuing similar objectives with a similar approach to design. The choice of sites must be done very carefully in terms of location, population and available water data. If data is still lacking on sites that are considered strategically important to this project, as is the case for instance with the ecological enhancement of urban streams in Singapore, the research team will need to create links between the EAWAG and partner PUB agency in Singapore to provide appropriate data on water quality and management procedures. Such data collection and analysis on the quality and availability of water resources for a specific site will have to be synchronized to take place prior to the launching of a design studio. Active site analysis as well as the gathering of data on water quality and water management will help create a well informed and innovative approach to landscape design and the improvement of the aesthetics of urban river environments. We are therefore counting on the support of various institutes and agencies in Singapore that will help develop of new water monitoring and management tools that pertain to the landscape of the city. The collaboration could integrate an entire range of analytical indicators which in turn would inform the design process through up to date visualizing and landscape modeling techniques. In collaboration with NUS and NTU, research findings from other project streams like Water Infrastructure, Territorial Organization, and City Design & Economy could eventually be integrated into the Landscape and Ecology Design Research Studio.

Monterey Aquarium, Interior view, Monterey, California

Core Research Team
Prof. Christophe Girot (D-ARCH, NSL)
Prof. Dr. Janet Hering (EAWAG)
Prof. Dr. Michael Saunders, NUS
Assoc. Prof. Dr. David L. Higgitt, NUS
Asst. Prof. Dr. Yang P J, Perry, NUS
Prof. Dr. Ng Wun Jern, NTU
Lo Yat-Man, Edmond, NTU

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.04 WATER INFRASTRUCTURE

GOALS OF RESEARCH

Over the last 50 years, water management in urban areas of Western countries has developed into centralized supply and discharge systems consisting on one hand of a pressurized pipe system from one or a few water sources conveying water of potable quality to the consumers and on the other of mainly gravity collection systems transporting wastewater, stormwater and infiltration water to large treatment plants and finally to the receiving water which is usually further used as drinking water resource. This urban water cycle offers tremendous comfort to the consumer who gets water of potable quality for all purposes at any desired amount and time and he does not have to worry about the waste he puts into the water – it is flushed out of sight within seconds. Consumers do not need to take any responsibility for their water - this is a matter of centralized public or private organizations. These systems, however, suffer from several drawbacks leading to rethink the concepts of water supply, use and discharge of domestic settlements. One factor is the enormous price which has to be paid for this comfort. The supply and drainage pipe systems make up for more than 70% of the investment costs and ageing of assets asks for periodic ongoing investment into their renewal.

In order to change the traditional water concepts of Western countries, substantial changes in water management asking for different water infrastructure are the base for the proposed research goals:

1. Water storage, rainwater harvesting and semi-closed water cycles:
In recent years, additional arguments were brought up to make a distinction between water streams supplied for different uses and to separate waste streams according to their origin and constituents. Especially in areas and regions where water resources are not so abundant because of unfavorable climate or hydrogeology or fast population growth, rainwater harvesting and wastewater reuse are considered to be necessary elements of future urban water supply concepts.
2. Control of micropollutant mass flows:
On the waste stream side, experience with the traditional systems learned that they are not able to solve the ever increasing problems of residual micropollutants. Especially in rainwater harvesting and recycle systems, micropollutants contained in wastewater and from diffuse sources such as surface runoff from roads and buildings have to be controlled and minimized.
3. Nutrient recycle:
Substantial amounts of valuable nutrients such as phosphorus and nitrogen contained in human excretion are wasted to the receiving waters leading to eutrophication of inland and coastal waters. New ways of wastewater and nutrient handling from households will be developed to allow for sustainable nutrient use.
4. Energy and bioenergy production:
Energy is contained in organic wastes from households and in the wastewater. New technologies are developed to make use the energy, especially through bioenergy production in alternative water concepts of future cities. This energy will have to be included in the overall energy considerations of new buildings.

RESEARCH CONTENT

The research envisaged under the title “Water Infrastructure” within the Future Cities Laboratory has the following contents:
- propose appropriate water concepts for cities, smaller districts and buildings
- develop innovative technologies to convey, store and treat water and wastes in cities and especially add new technical elements to rainwater harvesting and water and wastewater reuse concepts
- establish criteria for long-term sustainability of construction materials in contact with water
- demonstrate the feasibility of selected water concepts in case studies together with architects
- monitor existing and new full scale water concepts with respect to human and environmental hazards and risks.

INNOVATION

New elements of water management in urban areas will be introduced in building construction and larger development areas. It will include centralized and decentralized water concepts including innovative water treatment technologies for the production of various levels of water quality produced from natural resources, rainwater harvesting and wastewater reuse. The research is understood from a global perspective leading to solutions for various locations of urban settlement. The research program will include implementation of new concepts in different countries under different climatic conditions. Singapore is an existing full scale example of innovative water concepts and will serve as a one of the case studies envisaged in this research.

IMPACT

Increasing water scarcicity due to population growth, resources water quality deterioration, climate change and other criteria ask for new water concepts and water infrastructure. Since water infrastructure in cities is a long-term investment, decisions for changes and applications of innovative new technical systems have to be taken today and realized as demonstration cases in new buildings,

developments, cities in order to start the paradigm shift from water and nutrient consumption to their conservation. Architects and engineers will profit from the expertise set up by the research stream. The results will offer managing designers and constructors of buildings and new developments to consider next to energy also new water concepts. These concepts will consider the needs for hygiene, water and nature protection, water conservation, local social and economical conditions on the base of present climate and water resource boundaries. The experience with realized full scale systems will serve as a base for further development of new water concepts towards increased sustainability.

RESEARCH SCOPE

The research plan includes 4 stages of investigations

(1) Elaboration of an expert tool for architects and engineers for the design of water concepts in buildings, settlements and larger developments

From a technology point of view, a large number of solutions to deal with water in cities are possible which do not only depend on technological feasibility but also strongly on several boundary conditions. Whereas water infrastructure may have to be based on regional or small scale household centered considerations, the appropriate water concepts are a consequence of large scale parameters such as climate, available water resources, water use and reuse (irrigation, industry, domestic), receiving waters, topography, existing infrastructure, economy, sociology, and others. The criteria leading to the identification of locally suitable concept patterns have to be studied and put into a decision tool structure which may guide architects and engineers through all options of potentially applicable urban water systems. This will allow defining alternative strategies for specific cases which can be discussed with stakeholders and decision makers to find the appropriate solution. The latter task is considered to be out of the scope of step 1 of this research plan.

A number of questions that have to be addressed under this project step are:
- Centralized, semi-centralized or decentralized supply, drainage and treatment systems?
- Is stromwater harvesting an option or a must?
- Is wastewater reuse an important element of domestic water systems and at which quality standard wastewater should be reused?
- Is nutrient removal (phosphorus, nitrogen) required for future water cycles and is nutrient recycle a feasible option?
- Should energy contained in wastewater and produced during treatment be recovered?
- How are multiple water and waste stream systems integrated into building design?

The study of new water concepts for buildings and cities will also allow identifying gaps in water and solids handling technology which is necessary to pursue the ideas of modern and sustainable urban water management. The development of these technologies is subject of project step 2.

(2) Development of innovative process technologies for existing and new water concepts

Step 2 of the project focuses strongly on research and development of new water treatment processes and eventually innovative water and waste conveying systems. Strong collaboration with NTU and NUS are expected since promising activities in process engineering take place in Singapore especially in membrane and nanotechnology applications for water and waste stream treatment. In this respect advances in membrane technology are of special interest because of its flexibility with reference to centralized or local application of modular systems and because membranes allow tailor-made solutions concerning required quality standards.Based on the perception that sewer-based wastewater management will probably not be able to solve the pressing water pollution control issues on an international level, new innovative research on in-house technologies and local retention and barrier systems is required. Based on Eawag's experience with urine separation, research on new technologies for these rather decentralized systems should be pursued from a technical as well as a socio-economic point of view. We consider step 2 as the most intense part of the project in which lab, pilot and full scale testing of potential process schemes will be performed mainly in Singapore.

(3) Implementation in case studies

The technical alternatives for novel water infrastructures in buildings and larger settlements which were sketched in stage 1 and components of which were tested in stage 2, are realized in practice. Several water concepts exist already and offer the chance to investigate them under full scale conditions. One major example is certainly the city of Singapore which represents an existing and newly established case of strong focus on or in future centralized rainwater harvesting. Numerous other cases of alternative water concepts exist already but have to be identified and classified according to their potential for application and further development. Other cases are established presently or will be constructed in near future e.g. in China and other countries. Information on realized technical solutions, design rules applied, operation experience and economic considerations has to be gathered and discussed in a comparative study. This approach will lead to a considerable gain of experience with new ways of dealing with water in cities and will be very valuable for reconsiderations in the further developments of water and waste flow concepts in larger cities.

4) Monitoring and quality assessment of existing systems
Stage 4 goes parallel with stage 3. The idea is to monitor the water quality within selected flow schemes with respect to commonly applied quality parameters but above all with some recently developed analytical tools to asses advanced and more sensitive criteria for water quality. Also in this respect intense collaboration with NUS and NTU on the development and application of innovative analytical tools will take place. This includes parameters such as enumeration of bacteria counts with the help of flow cytometry, identification of pathogens, viruses and protozoa, levels of assimilable organic carbon (AOC), biofilm formation potential, identification and quantification of natural and engineered nanoparticles, taste and odor compounds, identification of natural organic matter (NOM) with size exclusion chromatography (SEC), and eventually other within stage 4 newly developed analytical techniques. In addition a series of micropollutants will have to be followed through the systems. It is a great opportunity and challenge to get insight into various levels of water quality within the different water concepts and draw conclusions to what extent different water quality levels may be recommended for certain uses reaching from toilet flushing, textile washing, irrigation up to the requirements for drinking water. The results will help to refine and optimize new water concepts for the future.

RESULTS AND MILESTONES
The outcomes of the 4 project stages may be characterized as follows:

Stage 1: Expert decision tool for architects and engineers in form of a handbook and/or computer tool describing potentially feasible water concepts and their necessary infrastructure elements. This results of stage 1 will represent the first milestone.

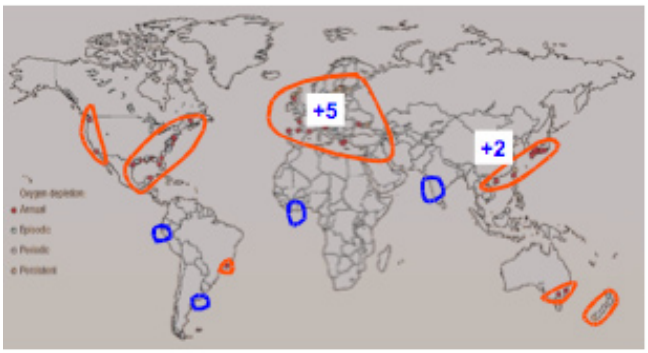
Stage 2: Stage 2 includes intense process studies on lab, pilot and full scale. Detailed reports on process engineering elements being part of centralized or decentralized flow schemes for water and certain waste treatment in domestic areas will result including description and evaluation of processes concerning design, treatment performance, separation mechanisms, economy, application potential. Process studies may be in the form of PhD thesis, postdoc and scientist reports.

Stage 3: Detailed description of realized full scale water systems including goals of the water concept (rainwater storage and use, wastewater re-use, interactions with building materials, etc.), inventory of present infrastructure, evaluation of system performance concerning design, operation, achievement of quantity and quality goals. Reports will result from different systems which may finally be compared and evaluated. The results will be substantial new information to refine the outcomes of stage 1.

Stage 4: Monitoring programs will be established and required quality control instruments at different points of the water systems have to be installed. Some of the new quality parameters will require new instrumentation at the universities labs in Singapore. Reports on water quality issues will be produced and conclusions for further development will be drawn.

LINKS TO OTHER RESEARCH STREAMS AND EM&M PROGRAM WITHIN THE FUTURE CITIES LABORATORY:
a) Urban sociology: The introduction of new water concepts, especially new ways of water handling on a personal level (household centered concepts) is a matter of public perception. New technical systems have to be accepted by the water consumers. Input from sociological methods concerning public perception is expected.
b) Low energy: The energy contained in water and wastewater should be included in energy concepts of buildings and developments. Coordination between the “Low Energy” and the “Water Infrastructure” streams is planned.
c) Landscape and Ecology: Water management on a larger scale is related strongly to urban water needs. Water supply depends strongly on amount, type and quality of available water resources. On the other hand, transport of wastewater to the receiving waters determines water ecology. Requirements concerning amounts and quality of water use, storage and discharge have to be set considering the interests of the different stakeholders.
d) Transforming and Mining Urban Socks: The construction materials of buildings in contact with water play an important role with respect to drinking water quality, to the quality of stormwater runoff and wastewater. Hazardous materials are often included in the materials and leach to receiving waters and soil. Mass balance and fate studies are necessary to evaluate the potential risks of these materials.

EM&M PROGRAM
a) The design of new water concepts relies strongly on hydrological data. Cooperation with respective streams in the EM&M Program is considered.
b) The development of new analytical methods and instruments are of crucial importance for the monitoring part of the “Water Infrastructure” stream. Coordination concerning analytical methods for the evaluation of water reuse and rainwater harvesting systems is planned.



A world map of UNEP shows that increasing numbers of so called "dead zones" of seawater appear mainly in coastal waters of densely populated areas and megacities. In 2006 about 200 dead zones were identified. The number is increasing by 50 more zones every 2 years.

Core Research Team
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Dr. Wouter Pronk (Support of PI, Engineering)
Prof. Dr. Ng Wun Jern, NTU
Karina GIN, NTU
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Potential Additional Researchers
Prof. Dr. Urs von Gunten (Water Chem. and Process Engin.)
Dr. Max Maurer (Engineering)
Dr. Kai Udert (Engineering)
Dr. Tove Larson (Engineering)
Dr. Ralph Kaegi (Particle resaearch)
Dr. Michael Burkhardt (Mass flow and material sceince)
Prof. Dr. Thomas Egli (Water microbiology)
Dr. Frederic Hammes (Water microbiology)

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.05 CONSTRUCTION & MATERIALS

GOALS AND CONTENT

In order for high performance buildings for the future to become a reality, there must first be a way to create them. This means that the required construction methods and the necessary materials have to be available and economical. In recent years the sky has become the limit in the design and implementation of buildings. The research in the Future Cities Laboratory will bring the vast knowledge and expertise of two leading countries together. Through the use of design studios and as well as collaboration on research, many complex construction problems will be solved in pursuit of more sustainable future cities.
The research into processes of construction and the use of materials in buildings will result in optimized systems that minimize waste. Singapore as an island exemplifies the concept of limited resources. Finding ways to use available materials, while minimizing the overall material demand, is essential. This must be complemented by innovative methods of recycling and reuse. The potential provided by the ideas found in digital fabrication will help to facilitate the implementation of this research.

The study of construction materials and products in an economy should essentially look at their flows and stocks. The qualities of theses materials determine the current material ecosystem metabolism of the economy. A historical account of these qualities will inform us of the evolution involved in this metabolism (which, when viewed from an economic perspective, can be interpreted as the materials' value chains). There can be two main ways of using this information: first, to define opportunities for technology to play a role to either respond to these evolutions or modify them; second, industrial ecology-driven policies can be devised and implemented to spur and support the creation of desirable technology innovation-pathways.

INNOVATION AND IMPACT

In order to achieve the above goals, this research-stream will include work towards more renewable or recycled components of concrete along with better integration with other aspects of the building system, which will minimize raw material usage. Singapore has shown some interest in moving away from the use of concrete because of a lack of raw materials. This would unfortunately lead to a great rise in dependence on steel. The aforementioned research will show ways to minimize overall material use and also reduce dependence on raw material. Replacing concrete with steel may reduce the overall quantity of material, but the impact of steel production and transport is easily overlooked. Research in these fields will help find the best solutions for building materials in Singapore. Steel has a great strength to weight and volume ratio, but the flexibility of concrete production, both in its production location and its basic substrates, allow a large array of potential improvements to be studied.
Other than concrete, the development of ultra high selectivity glazing systems, in conjunction with efficient lighting and shading techniques, will be investigated. In collaboration with a Swiss glazing manufacturer and a lab at a university in Basel, the ETH is studying the implementation of a new 'M' glass with a spectrum selectivity that is unmatched on the globe in performance. This would be of highly applicable in Singapore, where solar heating needs to be avoided during all seasons. The application of these technologies in Singapore as well as other future cities will have a large cumulative impact on the resource demand while improving building performance.

SCOPE AND COLLABORATION

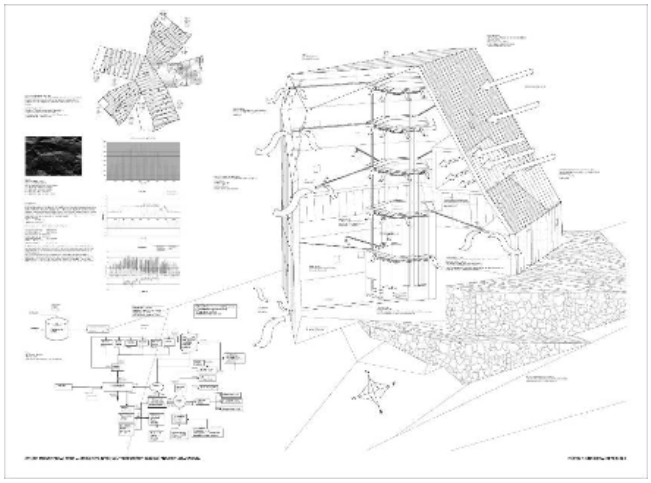
As a fundamental part of creating buildings this research stream is thus fundamentally linked to the rest of the Future Cities Project. The research will consist of studies into new materials, systems, and techniques for integrating building components and constructions. This integration is a requisite for the implementation of systems from the low exergy research stream, creating a link at the S-scale to the Low Exergy research, whereby new approaches can be optimized for use in improved building fabrication. The new materials being researched and implemented will provide an opportunity for collaboration with industries that will enable the implementation of the concepts at a broader scale. Being implemented at the broader scale also makes this research stream fundamental to the larger M and L scale parts of the Future Cities project.

There will also be many opportunities to link with NUS and NTU professors and researchers as this research stream will flow in parallel to the low exergy research. For example, the concepts of industrial ecology as studied by Prof. Kya Harn Wei of NUS will be applicable to this research looking into how waste streams from some industries can be used as feedstock for concrete production and other applications. The new and optimized building materials will have to integrate with the new building systems and technologies being developed. Therefore collaborations will also naturally be part of the process. New physical structures are expected to be developed in the first year and subsequently implemented in pilot buildings. The implementation will grow out of the involvement of the professors in a variety of building projects including potential work that could be organized in Singapore. This research will be supported by some of the best ETH Professors, who are committed to the project and find the collaboration with Singapore absolutely necessary for the global improvement of materials and construction to be integrated into future cities.

MILESTONES AND RESULTS

This project stream will produce a variety of research based academic outcomes, but more importantly it will produce technical results and physical methods that have an immediate impact on the the construction of buildings. The academic results include papers and conference presentations outlining the findings in the areas of concrete composition and usage. It will also include work in optimization of material usage through better integration with the design of building systems and services. The immediate outcomes will principally spring out from the implementation of the research in the design studio in which a new building will be designed and eventually constructed. The design and construction of this building will provide major milestones for the project. Another direct outcome will come from collaboration with Holcim. Extra support for work has already been discussed with Holcim in Singapore as there is a large potential for mutually beneficial research. Holcim is interested in working on innovative concrete technologies, including concrete with a reduced CO_2 footprint. These ideas would fit perfectly into the Construction and Materials project of the Future Cities Laboratory. It would also help forge relationships with industry that would be a source of additional funding, while also being an avenue for rapid implementation of concepts and ideas on the open market.

Sustainable structures require an understanding of the entire lifecylce of materials, products, and construction assemblies. The impacts of raw material production, processes of construction, and ultimately demolition need as much to be considered. The work on construction and materials in the Future Cities Laboratory will produce the needed technology and techniques to do so and move toward a more sustainable future.



The Monta Rosa Hut: Designed in the Studio Monte Rosa by the group of Andrea Deplazes. This projects demonstrates how the limits of material and construction can be pushed. Located high in the Alps and accessible only to hikers and climbers, its specific needs and location led to the discovery of new methods and systems. Similar research and design efforts will be undertaken in the the complex environment in Singapore.

Core Research Team

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Asst. Prof. Dr. Chen Yan, NTU
Joseph LIM Ee Man, NUS
Cheah Kok Ming, NUS
Kwah Harn Wei, NUS

Industrie Partners

Holcim LTD

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.06 DIGITAL FABRICATION

Digital fabrication of architectural components by means of computer numerically controlled (CNC) machines can be a factor in realizing high performance buildings. At present, the building industry is facing numerous structural problems. Its low labor efficiency, high accident rate and poor product quality, accompanied by the vanishing of a skilled workforce, demand the adoption of new technologies. Digital fabrication opens the possibility to economically produce complex and unique products of high quality.

In order to make full use of the potential of digital fabrication, it is necessary to not only look at the production side, but also to incorporate the logic of fabrication into the design process at an early stage. Hence, software-based design tools are required that allow for a direct fabrication of building elements from design data. The possibility of producing building components described digitally expands the spectrum of possibilities for construction and – through the introduction of material and production logic into the design process – explores new architectural expressions.

Within the broader scope of digital fabrication, this research project is particularly interested in additive fabrication processes. In its simplest way, this approach can be described as three-dimensional printing. This fabrication technique produces no waste, since all materials are deposited where needed. It also allows, unlike subtractive processes (i.e. milling, which limits the design to the definition of a surface), for a differentiated design of the component's cross-section. This allows, via selective placement and spatial distribution of different materials, to design and fabricate highly informed building components and thus realize complex designs that are fully optimized for their function (e.g. structural, thermal). In this way, digital fabrication can foster the production of integrated building elements in collaboration with both the research streams concerned with materials and construction methods and low exergy systems.

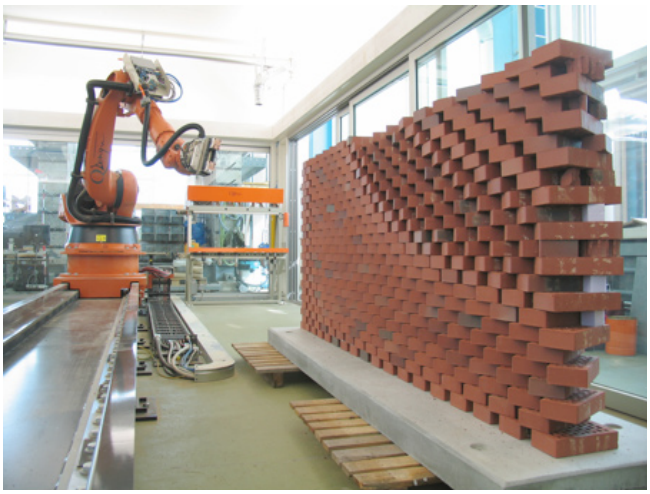
This research stream will take existing local Singapore conditions into account and compare them with similar ones Switzerland. A special focus will be on the consideration of local resources including recycled construction material. More than a transfer of research findings, this project will help identify basic principles and develop a ubiquitous framework for additive fabrication processes that is broadly applicable.

Apart from considering and optimizing found resources of Singapore's construction sector, it is also necessary to take the difference of building typology into account. In contrast to Switzerland, Singapore has limited amount of available space, which results in a demand for high-rise buildings. Therefore, another research topic would be to examine the requirements of digitally fabricated multi-storey architecture.

On the one hand, this research would address the potential of architectural diversity within a single building and how reconfigurations of modular material assets can facilitate a change of use over time. On the other hand, applying digital fabrication to high-rise buildings raises the question of material supply and logistics within highly dense surroundings and tight construction sites. Means to face these complex conditions could be to adapt the developed techniques for on-site use. Thus far, work has only been performed remotely in the laboratory. Regarding questions of mobility, some preliminary concepts have been developed for a mobile version of construction robots being used at the ETH Zurich. For an initial project, a fabrication facility is installed in a standard freight container, which can be easily transported and installed in situ.

The advantages of on-site fabrication include a lower error-ratio, an improved quality of work, an increase in human safety, and a reduction of necessary transport. The main focus of this research topic lies within sensor systems and the implementation of AI-methods for the control of fabrication robots.

Novel fabrication and design strategies are expected to emerge from this research that define new ways for undertaking construction and conceiving architecture. Research assistants and doctoral candidates making use of the mobile fabrication facility on location in Singapore will conduct the projects. Individual research topics will be integrated in seminars and design studios, exposing the students to new technologies and yielding important prototypical test cases.



In a matter of hours, a robot in the D-FAB lab at the ETH Zurich can create complex brick constructions, requiring delicate and precise placement of bricks to create forms that cannot be produced manually.

Core Research Team
Asst. Prof. Fabio Gramazio (D-ARCH)
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Assoc. Prof. Dr. Huang Guangbin, NTU
Assoc. Prof. Dr. Leong Kah Fai, NTU
Patrick Chia, NUS

Industrie Partners
Holcim LTD

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.07 TRANSFORMING & MINING URBAN STOCKS

A DESIGN APPROACH FOR USING AND RE-USING URBAN TERRITORIES AND WASTE

Urban Stocks is a phenomenon linked to all scales of the city. It includes all types of natural and manmade substances that comprise urban territories, such as soil (biomass, primary materials), water (lakes, rivers), forests (wood, oxygen), architectonic fabric (buildings, technical infrastructure), and daily waste. Urban Stocks are understood as basic elements of the urban metabolism and as locally available resources. Their use and re-use are key factors for creating identity, resource efficiency, and new added values to a specific urban system.

RESEARCH GOAL

Transforming and Mining Urban Stocks is part of a strategy towards sustainability and can significantly contribute – according to the overall objectives of the Future Cities Laboratory – to the quality of future urban regions on three scales:

L – Urban Regions & Sites:

- Investigating Design Strategies for Re-Using Old or Using New Urban Regions & Sites, including fallow land, forests, lakes, rivers, shores, obsolete industrial, military, or public service infrastructures.
- Developing appropriate models, data analyses, modelling instruments, and evaluation procedures concerning identity, resource efficiency, and added value.
- Designing various scenarios of urban development and their practical implementation.
- Preparing, practicing, and assessing new teaching and learning tools.

M – Urban Fabric & Neighbourhoods:

- Designing Transformations of the Urban Fabric & Neighbourhoods on the basis of Urban Stock and Material Flow Analysis (e.g. analysis of mineral building materials).
- Modelling life cycles of constructions and building complexes.
- Developing methodological instruments for the evaluation of identity and resource efficiency and added value.
- Designing scenarios and legislation for urban restructuring.
- Preparing, practicing, and assessing relevant teaching and learning tools.

S – Objects & Products:

- Designing New Objects & Products and Added Value Chains from Waste on the basis of waste analysis to private and public households.
- Investigating prototypes of new products and technological processes, including business oriented production and impact on waste management.
- Adapting methodological instruments and tools to proposed objects & products for quality control and manufacturing, among other things.
- Preparing, practicing, and assessing relevant teaching and learning tools.

L, M, & S

- Comparative Studies: Combining the work of the three scales for a Comprehensive Strategy of Future Cities Development. This includes comparative studies on the basis of interdisciplinary criteria concerning Transforming and Mining Urban Stocks of three different urban systems, Zurich Metropolitan Region and Lugano Metropolitan Region (Switzerland), Singapore Metropolitan Region, and Addis Ababa (Ethiopia) or Mumbai (India).

RESEARCH CONTENT

The content of interdisciplinary and transdisciplinary work is guided by three initial research questions:

1. How does the metabolism of the existing Urban Stocks on L, M, and S scales contribute to the identity, resource efficiency, and new added values of the defined urban system (in Switzerland, Singapore, and Ethiopia or India)?

2. How should one – in short, medium, and long term – transform Urban Stocks in order to create a higher degree of identity, improved resource efficiency, and new added values on L, M, and S scales?

3. How is the impact registered – in different and contemporary urban cultures – on the metabolism of Urban Stocks at L, M, and S scales? And how can they exchange and learn from each other?

The research approach pertaining to urban stocks distinguishes itself in several instances from conventional research into natural resource deposits. In a conceptual sense, however, analogies exist between the two. Urban stocks must therefore be first analyzed in similar terms to those of natural stocks. Subsequently, one would model the behavior of urban stocks and flows in order, for example, to evaluate – in terms of social, ecological, and economic criteria – which measures or projects need to be realized to optimize their use.

INNOVATION

Today, resource efficiency, combined with the creation of added value and identity, plays a minor role in professional practice. Adequate information on flows of urban stocks, such as their quantities and values, is currently difficult to find. Research on such issues has only recently been initiated.

Consequently, it is difficult to evaluate whether the resources contained in existing buildings, infrastructures, urban districts, and accumulated consumer waste are being used efficiently. Nor are there adequate understandings of the necessary initial steps needed in order, for example, to raise the level of material efficiency.

For a comprehensive understanding of the system, one must identify and evaluate – as precisely as possible – the stocks and flows of materials, their use and exchange value. This is a possible way to better understand the complex relationships and reciprocal dependencies within urban systems. On this basis, one might be able to design proposals that are focused on the efficient transformation of urban stocks while channeling their material flows, if necessary.

Urban waste processes can be redirected away from the conventional models of landfill and incineration toward more sustainable solutions – mining the city.

IMPACT

Instruments for the evaluation of the efficient use of materials, or resources in general, are currently only understood in a preliminary way. There are a series of existing instruments, such as eco-balancing, that allow comparison and evaluation of the environmental effects of the production of specific products and materials. However, such instruments are only partially applicable when it comes to evaluating their efficient use over time. The deployment of material flow analysis, linked with static and dynamic models, allow for the quantification of a system and the identification of major potentials for optimization. Through models and scenarios, one can estimate the effects of possible measures, interventions, and projects. With this, the foundations are laid for prospective and performative resource management according to societal demands. Potential users and stakeholders include politicians, public agencies, real estate owners, and recycling companies. At their disposal are new strategic instruments that can demonstrate the long-term effects of their decision-making processes regarding resource management.

RESEARCH SCOPE

The primary objective is to develop a dynamic and adaptable model for urban resource management and to generate strategies for transforming and mining urban stocks. This model will be generated from – and tested in – the contexts of three comparative case studies: Singapore, Switzerland, and Ethiopia or India. It is the purpose of the project to provide answers to the above-mentioned key questions, in terms of both content and method. While one can rely on proven instruments, these will also require expansion in order to address the complex and heterogeneous set of questions raised by the interdisciplinary research group of the Future Cities Laboratory.

The resource management model will include – in addition to quantifiable criteria such as Resource Efficiency and Added Value – also the specific qualitative criterion of identity. On this combined basis, one will manage to address the complexity of urban systems by means of design.

Lifecycle analysis constitutes an additional aspect of the resource model, for example that of building materials and their assembly in composite products. For questions relating to sustainable development, it becomes increasingly important to be aware of urban stocks, including urban districts, buildings, materials, and waste. Lifecycle analysis (LCA) and lifecycle cost analysis (LCC) are therefore frequently used instruments. The basis of such models is material flow analysis (MFA). With this tool it is possible to evaluate, from specific perspectives, the reuse of existing building materials or to examine new construction products in view of their environmental impact.
- What are the consequences of contemporary building practices on future generations?
- How can we improve planning and construction processes of today's landscapes, urban districts, buildings, and artifacts?
- In short, how can the urban edifice be conceived in relation to different long-term scenarios?

The answers to these questions will contribute to an improved system understanding of the urban edifice and are considered prerequisites for the implementation of sustainable resource management criteria.

The main motivation for the proposed comparative research aligns with the historically unprecedented fact that, in order to cover its own resource demands, each urban system is part of a global network and no longer exclusively related to its own hinterland. As this phenomenon is causing cross-border material flows and economic and cultural exchanges, the research itself has to encompass cross-border comparative studies.

LINKS TO OTHER RESEARCH STREAMS IN FUTURE CITIES LAB
Transforming and Mining of Urban Stocks can be linked to most of the other research projects.

RESULTS AND MILESTONES
Research work is aimed at results for three different types of urban systems (Singapore, Switzerland, Ethiopia or India). They will include:

L – Measuring and biographic (historic) describing of selected Urban Stocks and respective SWOT-analysis (Strengths Weaknesses Options Threats), scenarios and design proposals concerning identity and resource efficiency by various modelling techniques (mathematical, physical and visual representation) with detailed criteria and tools of assessment. Teaching and learning material including the assessment of studio work, handbooks for professional practice.

M – Measuring and qualification of selected building complexes and building material, stock flow and life cycle analysis by short, middle and long term modelling, alternative scenarios for efficient resource management including programming and designing the key projects to the proposed scenarios, the criteria and tools of assessment. Teaching and learning material including the assessment of studio work and editing of handbooks for professional practice.

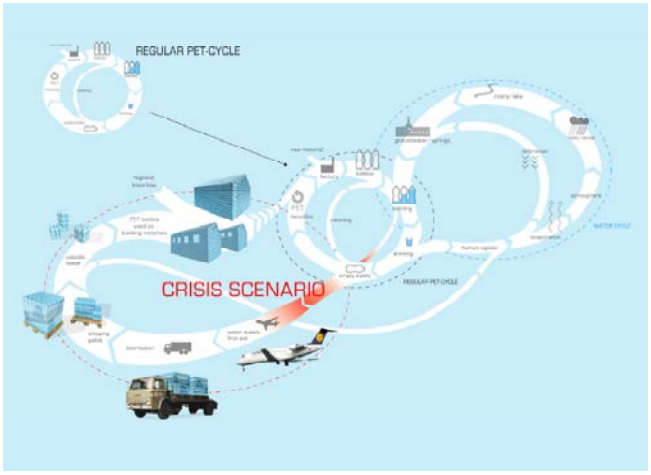
S – Measuring and qualification of daily waste, SWOT-analysis concerning recycling, proposals for new products and new added value chains, prototypes for a variety of new objects, including specification of quality standards and quality examination, proposals and tools for improving waste management. Teaching and learning material including the assessment of studio work and editing handbooks for professional practice.

Comparative studies are methodologically seen as loops for checking and balancing the separate phases of interdisciplinary and transdisciplinary research work. The results mentioned above are basic for comparing the three different urban systems through empirical data of Urban Stocks to L-, M-, S- scale. They represent innovative tools and can serve for finding new options to create specific urban identity by resource efficiency and added value.

The imminent agenda in 2008/9:
- Consolidating and completing the research proposal with members of ETH, NUS, and NTU.
- Establishing the cooperation with public agencies of the three countries mentioned above.
- Defining working procedure and milestones.

Acknowledgement is due to Dr. Stefan Rubli, Lecturer at EAWAG/ETH, for the spontaneous interest and competent support in preparing this proposal.

Use and re-use of urban stocks as key factors for creating resource efficiency, added value, and identity at the large, medium, and small scales of urban systems.



Added value through the introduction of additional recyclig circuits for PET and PP bottles. Dirk Hebel, Jörg Stollmann and Tobias Klauser, UNITED_BOTTLE, 2007

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Kwah Harn Wei Hck, NUS (to be confirmed)

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.08 CITY DESIGN & ECONOMIES

URBAN DESIGN LAB

To meet the urgent demand for sustainable development of our urban environments, what we need today more than ever is an attitude oriented towards consensus and productivity among the actors in urban transformation processes (public hand, investors, interest groups, users, etc) in order to be able to understand and influence spatial phenomena in their context of cause and effect. With the focus on design strategies and instruments in urban space, the Urban Design Lab concentrates on the observation and exploration of contemporary urban phenomena. The strategies and design tools that are derived from these investigations are aimed at the production of intelligent and sustainable urban 'breeding grounds' on which both existing and new urban structures can unfold – structures that are flexible and adaptive in their respective context, without losing identity and specificity, and thus contribute to the emergence of a dynamic balance of urbanity.

The potentials that lie in the collaboration of all actors should be extensively exploited by means of success optimization, acceleration of projects, efficiency of resources, and balance of interests in order to create high-quality urban environments. The urban designer and the architect play a central role in these processes. By means of proactive designs, new strategies and procedures, they will confront themselves with the changing problems occurring in our cities and develop new instruments for the urban design discipline. When wanting to invent and test new instruments, we need to question established sets of values and procedures. Instead of simply relying on the design of fixed visions and static architectural and urban structures, aspects like adaptability or 'reversibility' become decisive criteria for sustainable design. Thus, the natural dynamic change of a city is disclosed as a wide potential for an open urban development. In this sense, the urban plan consists of a balanced relationship of design and strategic deliberations in the sense of a control & laissez-faire, whereby the guarantee of a productive openness may prevail over restrictive planning instruments. The complementary interaction between the 3 different project levels is of crucial significance: The spatial concept in the form of adaptable urban structures, stakeholder management as well as participation and communication concepts must all provide the necessary flexibility to deal with the unforeseen. This ensures sustainable development of the area, which can take place almost without any regulatory intervention and virtually drives itself forward.

To date, the majority of architectural and urban projects deemed exemplary in terms of sustainability have been rated primarily from a technological perspective. But sustainable urban design implies much more than this. Thus, we use the term sustainability more broadly, mainly to refer to the design discipline – design that factors in urban and social sustainability. From this non-technological view, we focus on factors influencing social behavior and spatial organization, which are obviously vital in determining the sustainability of urban concentrations, such as land-use, traces and identity, mix-use and scale, urban and building typology, public space network and mobility, catalyst effects of the relation between public and private, program and activation scenarios.

SUSTAINING THE OPEN CITY

One of the main topics the Urban Design Lab will work on is the idea of 'the Open City'. Since its original meaning of 'safe haven' within a war zone, the term 'Open City' has been used to describe an urban condition in which people can live in freedom. The Urban Design Lab wants to explore the Open City as a stage of the manifold — an arena in which diverse social and ethnic groups can coexist, interact, and generate complex relations and networks that consequentially stimulate sustainable urban structures. The multicultural Open City is not an entropic soup, a mixture of everyone and everything, but a network of public spaces in which a multitude of communities such as a new town, a university campus, a business district, a shopping center, or a Chinatown can be accommodated. The Open City is not literally a city, but a condition of a city or district, a dynamic balance between integrative and destructive forces, which productively exploits the potential of the complex overlay of a multitude of social environments, networks and economies with its specific constraints and opportunities. As a breeding ground for the development of knowledge, innovation, and growth, it constitutes an essential achievement of human culture and therefore needs to be stimulated and protected.

However, its delicate balance is continuously being questioned by an increase of differences: functional differentiation, social segregation, spatial fragmentation and difference in scale. This threat is greater than the result of differences between rich and poor, conflicts between ethnic groups, or the construction of gated compounds. Naturally, the Open City is on the verge of falling apart under the influence of its own market mechanisms like free settlement decision and mobility of persons and goods. As a result, dynamic systems of urban diversity with active public spaces threaten to become archipelagos of introverted enclaves, separated by residual space and infrastructural corridors. These phenomena appear worldwide: in the new Asian metropolis, in the Western suburb, in the post-socialist city, and in poor neighborhoods of the Third World. As these phenomena proliferate, there is an urgent need to research the characteristics and influences that constitute an Open City.

DETAILED RESEARCH PLAN

In accordance with global trends, also Singapore is suffering of a spatial production that is subject to increasing seclusion,

functional, spatial and social segregation and increase of scale. This trend threatens to destroy intricate and sensible urban structures and communities. As the economy is the main driver of urban development, we will research the Open City with a strong reference to investment and governance patterns, and try to develop alternative strategies and models that re-conciliate socially sustainable and economically vibrant conditions. To carry out this research, we will select specific urban districts in the Singapore agglomeration and produce strategies, tools and guidelines in communication with local stakeholders.

OBJECTIVES
How to develop design strategies, tools and guidelines to stimulate the emergence and stabilisation of socially sustainable urban districts? The following criteria will be investigated on their effect on the urban environment:
- Mixed use, density and human scale
- Urban fabric as framework for socioeconomic activites
- Activating public space networks
- Transition between public and private to stimulates diversity
- Creation of identity and historical references
- Sustainability of the Urban Fabric
- Urban typologies and topologies
- Urban catalysts, pioneer programmes in the industry
- Hubs, MUDs and Valley concepts for spatial development

STRUCTURE AND DURATION
The City Design and Economy programme runs 3 years or 6 semesters.Within this period the PhD students will carry out their research.(amount is subject to further evaluation)

In addition, a group of students (regular urban design master students, Post-Doc) per semester participates in the Design Research Studio. A design studio runs for one year, consisting of a basic studio in the first semester, and an in-depth studio in the second. In the second semester also a new studio is founded with the same topic but different location. This results in a structure in which always two related studios run parallel. At the end of the 3-year period, the material of the 6 studios will be integrated into a comprehensive publication. The studios serve as an information-source for the specific Ph D themes. For gathering basic material and knowledge ETH's Institute of Urban Design plans to run a Special Design and Urban Research Studio on the above stated topic in fall semester 2008. The studio held in Zurich will be developed in close cooperation with the partners in Singapore and contains a one-week field-workshop in Singapore. If possible it integrates joint workshops or parallel studios at NUS. In spring semester 2009 the materials will be compiled and condensed in a project draft for the scientific work carried out in Singapore starting from Fall 2009.

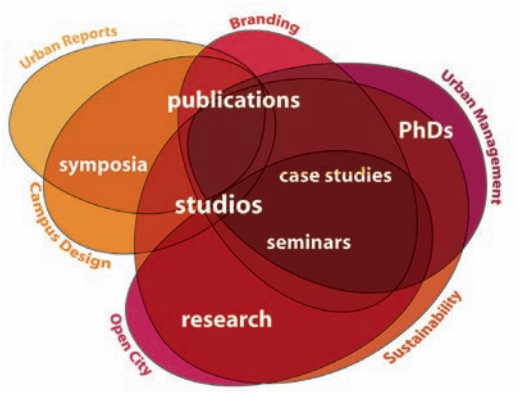


Diagram of the Urban Design Lab structure

ELEMENTS
1. Thematic 5 day input-workshops.
2. Lecture series, with guests from other disciplines
3. Design Research Studio "Open City"
4. Master and PhD Critics with Future Cities review panel.
5. Symposium, publication and exhibition.
6. StartUp Research and Design Studio in 2008

DELIVERABLES
- Research Publications (scientific journals, papers, PhD theses)
- Urban Design Reader of all lectures and critics

Core Research Team
Prof. Kees Christiaanse (D-ARCH, NSL)
Prof. Dr. Heng Chye Kiang, NUS
Asst. Prof. Dr. Erwin Viray, NUS
Dr. Malone-Lee Lai-Choo, NUS
Prof. Dr. Rahman Shahidur, NTU

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.09 TERRITORIAL ORGANIZATION

RESEARCH GOAL

The research stream "Territorial Organization" addresses large metropolitan regions and the challenges they face. The focus of the work is on megacities, currently understood as unsustainable entities. Based on comparative analysis of case studies in Asia, Africa, and South America, transitions in urban physiologies and morphologies will be examined. Five themes will provide a platform for addressing the challenges of how processes of urban formation can be managed in order to attain long-term sustainable conditions. Urbanism is here understood in an expanded framework to include social, economic, and ecological considerations as well as the design of policies and terms of governance for the making of the physical environment. Particularly at issue are operative strategies that can be deployed within the constraints determined by currently available resources. What feasible means, techniques, and methods can be brought into play to increase the performance of the city? The goal of this research stream is to produce methodologically innovative approaches – summarized in a set of applicable guidelines – for handling the future developments of metropolitan regions. The findings will be recorded in various formats including guidelines, design propositions, and theoretical models.

RESEARCH CONTENT

Considering that cities are highly complex entities, an approach will be adopted that understands them as dynamic systems driven by multi-faceted forces at work. Traditional models of urbanism are often confined by a bias in favor of formal and spatial conditions, thus neglecting an array of other factors. In order to overcome this limitation, the proposed project will foreground a series of domains contributing to the formation of territories through the identification of five research themes, normally at the margins of the discipline: territorial demographics, territorial ecology, territorial economy, territorial logistics, and territorial governance. Based on the comparative analysis of a series of large metropolitan regions in different parts of the world, questions of spatial organization will be investigated and strategies identified for their future transformation in time. Of significance within this project will be the interaction and mutual dependence of multiple parameters embodied in the physical constitution of the city.

a. Territorial Demographics (fluxes of people)

re-group – nurture social diversity!

What are the ramifications of manifold collectivities on the territorial organization of future city regions? Contemporary urbanism is marked by convention, where the user is assumed to be a generic subject. What ensues from this condition is a tension between the norm and that considered to be outside the norm. Cities today are confronted with rapidly changing demographics, i.e., the ageing of wide sections of the population, ethnic diversity, increasing poverty, and more varied social strata. This presents an opportunity to not only question established standards, but to implement a shift away from an understanding of the city through the lens of a universal subject towards a differentiated understanding of urbanism. Potential themes: Urban Poverty / Migration / Urban Gerontology / Social Engineering / etc.

b. Territorial Ecology (fluxes of energy)

re-energize – halt pollution!

What are the consequences of realigned energy strategies for the organization of urban regions? Large cities generate their own climate; more often than not countering balanced natural conditions. The depletion of material resources, the accumulation of waste, the over-expenditure of non-renewable energy, heat island effects, and air pollution are direct consequences of the predatory expansion of urbanization. What are the energy inputs and outputs of entire metropolitan regions? Efforts within building technology need to be supplemented with measures at the territorial level.
Potential themes: Energy Fluxes / Landscape / Heat Islands / etc.

c. Territorial Economy (fluxes of money)

re-finance – achieve equilibrium!

What actions are needed to achieve equilibrium between state control and the wants of the private sector, and what effect would such measures have on city organization? Capital constitutes a primary force of urban formation. While cities generate money, they at the same time require a significant deployment of financial resources. One might speak of a political economy of territory, of the impact of specific monetary models on the make-up of the city body. Sustainable development frequently presents a conflict vis-à-vis widespread economic needs. The current state of capitalism actually works to sustain asymmetries of resources. If the environment is shaped by capital flows, then environmental justice requires a re-channeling of these flows, where accumulation gives way to distribution.
Potential themes: Fluxes in Economies / Real Estate / Branding / etc.

d. Territorial Logistics (fluxes of goods)

re-route – minimize material flows!

What are the residual opportunities offered by improved logistics on the territorial organization of future city regions? The movement within territories of goods, products and materials – including waste – carry a great potential for increased ecological and economic efficiency. Optimized organizational logistics addressing the life-cycle of materials and creative solutions within every step of production and use-chains are important in realizing this potential. The development of innovative logistical approaches both within and across sectors plays a key role in minimizing material flows. Open and closed loop systems – both within the private and public sector – must be appropriately considered in order to not overstretch the carrying capacity of the environment. As acknowledged by the work of The Logistics Institute at NUS, logistics can be seen as an ecological system whose equilibrium must be maintained.
Potential themes: Commodity Fluxes / Waste / Logistics Protocols / etc.

e. Territorial Governance (regulating fluxes)

re-institute: formalize stakeholder involvement!

What are the necessary actions and regulations needed to strengthen civic engagement and what effects will such measures have on the organization and management of future city regions? Contemporary cities are comprised of parallel forms of social alliance, some legal

and established, others outside the sway of official purview. The intermingling of formal and informal modes of organization promotes a split condition, leaving its traces in the very fabric of the city. Whereas traditional urban design is inclined to follow both formal and top-down routes, the current situation demands a bifurcated sensibility attuned to a balance between official control and participatory agency. Considering that sustainable development necessitates official policies for accomplishing an ecologically balanced environment, strategies need to be developed to formalize stakeholder involvement.
Potential themes: Informality / Participation / Regulations / etc.

Each of these five categories will provide a vector for in-depth research projects but will simultaneously intertwine with each other in the context of workshop seminars and design research studios. Through processes of situating, reading, investigating, disseminating, and implementing, the research work will begin with comparative studies, proceed through analysis to proposals that will be communicated through various platforms and ultimately establish guidelines for action. The work will be linked to other research streams of the Future Cities Laboratory (e.g. Urban Sociology, Landscape & Ecology, City Design & Economies, Transforming and Mining Urban Stocks, and Simulation Platform).

INNOVATION

- Through the cross-pollination of research fields, the Territorial Organization stream will inform and reframe the discipline of urbanism. The system approach – understanding the city as a complex body – combined with the stocks and flows model will recast urban theory. The transdisciplinary logic guiding this urban research will become a model method for other fields of knowledge production.

- The specific case of Singapore, described as a "system of systems" by Prof. Lui Pao Chen, will play a significant role within this endeavor, for it presents a well-documented, precise, and successful example of territorial organization. While Singapore's territorial organization can still be improved, it will act as a model for other cities in the world. As the city-state is optimally located within Southeast Asia, it allows for comparative studies of cities within the region, including Bangkok, Jakarta, Kuala Lumpur, Manila, etc. Here questions of urban prototypes will be raised in order to be applied in other contexts.

- The research stream will offer new methods for combining various forms of urban inquiry and research in general by foregrounding design laboratories as platforms for innovation and synthesis. Design research will be complemented by interdisciplinary workshop seminars and in-depth theoretical work done at the doctoral level. This opportunity is afforded by the unique organization of the Future Cities Laboratory as an umbrella bringing multiple strands of research together.

- A key outcome of the territorial organization project will be techniques for visualizing complex systems, thus enriching traditional cartographic modes of representation through the layering of interconnected information and time-based considerations – including both soft and hard data. These means must transcend mere representation and become instrumental as design tools to be deployed in scenario planning and communication processes.

- Of foremost importance is the identification of strategies with long-term impact on the organization of sustainable territories. Based on analysis of best practices, collected from case studies in various parts of the world, a catalog of prototypical urban strategies and tactics will be assembled in a "how-to manual" for implementation.

IMPACT

The impact of the research will be registered at several levels. Beyond the innovations mentioned above, the following additional contributions are envisioned:

- At the urban planning level of Singapore, the innovative cartographic practices undertaken in conjunction with local colleagues and agencies will offer new vantage points from which to understand the city as a complex system in motion and will identify future possibilities for development according to sustainability mandates.

- At the global level, the work will strengthen the position of Singapore as a model for sustainable urban development as it will offer more effective forms of territorial organization in terms of social, economic, and environmental considerations.

- In terms of international scholarly discourse, the work produced will contribute significantly to on-going dialogues on sustainable urbanism through publications, conferences, design research studio outcomes, etc. The Future Cities Laboratory will become synonymous with forward-thinking transdisciplinary urban research.

- At the level of stewardship, the design research studios will help to inspire the next generation of architects, engineers, planners, etc. to pursue a sustainable future and act responsibly within their discipline. In this, the research includes educational objectives.

RESEARCH METHOD & LINKS TO OTHER FCL PROJECTS

While research can use diagnostic techniques of analysis to trace the past evolution of urban systems in order to understand present conditions, it must also project and anticipate future developments. Of significance for the research is not only the focus on physical products but also the interest in the design of processes.
One of the key points of current urban research encompasses scenario planning: designing potential future conditions according to varying constraints. By means of analogue and digital techniques, the long-term effect of changing parameters can be tested and analyzed. Examples include shrinking and growing scenarios, the rate of developmental speed, questions of density, migration from rural to urban areas, changes in the demographic constitution of the social body, the allocation or lack of energy and monetary resources, the integration of public transportation systems, etc. Such an approach mandates – beyond transdisciplinary cooperation – the interaction with governmental institutions. The territorial organization research stream will provide, in conjunction with the simulation platform, the necessary stage for negotiations between stakeholders and will offer the grounds for decision and policy making, encouraging the implementation of research findings within practice.

The inquiry into territorial organization will be guided by three interrelated research methods, understood as platforms for dialogue and innovation: in-depth theoretical work, design laboratory experiments, and interdisciplinary seminar workshops. In-depth theoretical work at the doctoral level will engage in a thorough investigation of phenomena related to the five research themes mentioned above: territorial demographics, territorial ecology, territorial economy, territorial logistics, and territorial governance.

The work will also be conducted in so-called Design Research Studios involving experts, faculty, and students from various universities and disciplines – NUS, NTU, ETH, MIT, and the new Center for Livable Cities (CLC). While working with existing conditions, the inquiries will be projective, anticipating upcoming challenges and potential developments. Comparative analysis with other cities will situate the findings within an international framework. Central to this work is an investigation into novel modes of cartographic representation of territories for both analysis and design – maps that not only function as a mirror of a given territory but as a compass to guide future trajectories.

In order to link the various strands of the Future Cities Laboratory, periodic workshop seminars will be organized around specific themes, stressing the need for exchange and synthesis. As part of these seminars, participants will not only present their research findings but also engage in small local investigations of urban phenomena resulting, for example, in sets of explanatory diagrams, manifestoes, and instant design propositions.

RESULTS AND MILESTONES

- Doctoral Dissertations (5 Ph.D. projects over 3 year period)
This work includes in-depth academic research into the five themes of the territorial organization stream, periodic reviews of work in progress, presentations at international conferences, publication of articles, and the final defense of the findings.

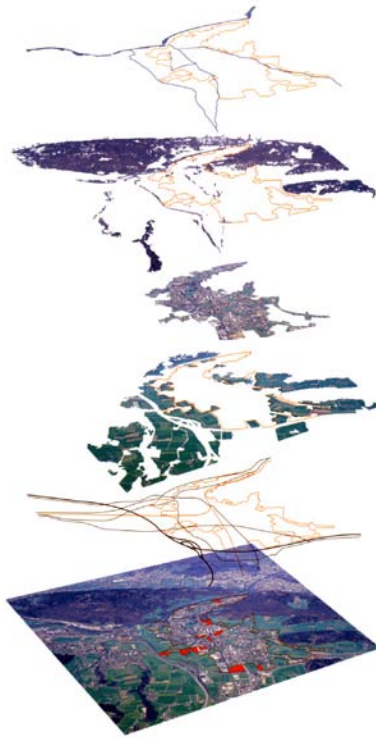
- Design Research Studio (1 per year over 3 year period)
This work includes the definition of a design brief per studio, the organization of reviews with external guests, and the publication of findings, including the results of the re-mapping of the territories, such as that of Singapore, in a comprehensive atlas.

- Seminar Workshops (10 meetings per year over 3 year period)
This works includes the organization of an on-going series of seminars, combining presentation of statements and debates. Participants will include students, members of the FCL research teams, and invited guests. The outcomes will be published in periodic dossiers.

- Exhibition of Urban Projects (3 over 3 year period)
The work done in the design research studios will be presented in the form of a public exhibition to be staged in Singapore and possibly integrated in a larger traveling exhibition featuring FCL outcomes.

- Catalog of Prototypical Urban Strategies (1 over 3 year period)
Based on the analysis of best practices collected from case studies in various parts of the world, a catalog of prototypical urban strategies and tactics will be assembled in a "how-to manual" for implementation.

- International Conference (1 over 3 year period)
A series small pre-conferences will be held to prepare content and new formats of presentation culminating in a large international symposium and the publication of conference proceedings in book format.



Analyzing urban territories as interwoven networks of flows allows for new understanding and new planning proposals to emerge (source: Oswald and Baccini, 2003).

Core Research Team
Prof. Dr. Marc Angélil (D-ARCH, NSL)
Assoc. Prof. Dr. Ian McLoughlin, NTU
Asst. Prof. Dr. John Harrison, NTU
Asst. Prof. Dr. Erwin Viray, NUS

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.10 TRANSPORTATION INFRASTRUCTURE

DAILY FLOWS: (S)HORT, (M)EDIUM, (L)ONG TERM

RESEARCH GOAL

The Prime Minister of Singapore has recently identified three priority areas for Singapore in 2008: university education, health care and land transport. We want to advance research on the third issue in its complexity, which derives from the demands of managing, planning and optimising the flow of people and goods at different time scale and in its interaction with all elements of the future city. The short term refers here to the day-to-day management and optimisation of the given flows with the given infrastructure; the medium term relaxes these givens by allowing change across all degrees of freedom of the systems (population, infrastructure, land use, regulation and pricing), but still taking the given situation as the starting point; in the long term it becomes possible to consider the changes required to achieve overarching policy goals and to account for their benefits and costs.

RESEARCH CONTENT

As described above, the research will focus on three different, but interacting time scale and horizons.

(S)hort term: real-time management
- We propose to develop new advanced systems for the management of urban transportation in Singapore using advanced technology for real-time monitoring. The challenge is to provide efficient transportation solutions over short time horizons for a system working at the capacity limit at many locations and during many periods. The project will be articulated around a simulation laboratory that will be used for planning purposes as well as for real-time management. This laboratory will be built on existing tools such as MATSIM, Multi-Agent Transport Simulation Toolkit (Balmer et al., 2005). To the extent feasible, we will make use of the existing video detection cameras of the Expressway Monitoring and Advisory System (EMAS), Junction Eye (J-Eye) at key intersections, and the Electronic Road Pricing (ERP) system.

(M)edium Term: simulation-based optimisation
- The simulation of travel demand and traffic flow (using our open-source MATSIM-T agent-based simulation, see www.matsim.org) will be used first to follow the interactions of agents over simulated time without imposing equilibrium conditions in any one time-step. We will then explore how the generalised costs of travel can be reduced further while accounting for the tight environmental and social constraints of a highly productive society, such as Singapore's. The simulation system will be expanded to account for the uniquely differentiated ERP system, the flow of goods and the intense environmental interactions. This will be matched with a robust and fast simulation-based optimisation algorithm, to be developed from ongoing research at EPF Lausanne, to identify possible optimal control strategies for regulation and pricing of flows, speeds and stocks (here parked vehicles). A second analysis will integrate the responses of the heterogeneous agents into the optimisation sketched above. Its scope is a massive computational and conceptual challenge, which will require new approaches.

(L)ong term
- This work will address one current weakness of the model system: the lack of a description of the networks between people, people and firms and between firms. The social capital embedded in these networks enables and constrains the choices of the actors. Drawing on on-going work at ETH Zürich, we will conduct new original survey work to understand the size, geography, valuations and robustness of these networks in Singapore and beyond. The history of the city has placed it in a unique "world city" – situation between multiple cultures, which makes it arguably the most interesting of the world cities to conduct this research in. The insights will be used to improve the understanding and models of residential, workplace and daily location choice, but also of customer/supplier relationships between firms. The interaction between the daily flows and the built environment is well understood in theoretical terms and at larger spatial scales. Missing is a better understanding of the interactions between the actors, who supply the built environment and the associated services. This opens further degree of freedom in the design and optimisation of the systems and will be explored in parallel streams of work.

The agent-based simulation MATSIM-T (see www.matsim.org) provides the platform in which such an exploration could take place. Based on a detailed analysis of the literature on the behaviour of such agents, new qualitative and quantitative survey work in Singapore, we would integrate such agents into the simulation; agents which have sophisticated internal models of the (simulated) outside reality, on which they base their choices. In the first instance, we would consider retailers and providers of consumer services, such as restaurants, barbers and doctors, but also real estate developers. The consumer response to these changes in terms of destination choice and residential location will be included as well. UrbanSim (www.urbansim.org) (Waddell, 2002) is an open-source project, which achieves speed and detail through the use of sectoral market-clearing mechanisms. Its implementation is a crucial building block of the analyses of the long term policy impacts. We will employ MATSIM-T (www.matsim.org) or a locally implemented aggregate transport model to provide the required transport-based accessibility measures. The policy tests will be coordinated with authorities in Singapore. They will involve both UrbanSim and the enriched and expanded MATSIM-T.

INNOVATION

Five points stand out:

• The integration of the three time horizons (short, medium and long) is a significant methodological innovation that will enable a global analysis of complex issues related to mobility in the future, as the various modules of the system can be integrated, as the issue concerned requires.

• The choices of the firms imply the provision of new capacities and therefore changes in the spatial structure of the economy. The unsatisfactorily understood co-evolution of these processes is here opened up to experiments and analysis.

• Optimisation methods designed for large-scale mobility simulation simply do not exist today. The design of this method will justify even more the use of agent-based simulation for the analysis of the dynamics of future cities, extending the methodology to other fields than mobility (energy, telecommunication, waste management, etc.)

• Integration of parcel level land use and travel demand and behaviour modelling at different time-scales

• Policy tests for a large scale system under explicit testing of stability of the simulation results, multiple equilibria and heterogenous demand and supply side agents

IMPACT

Short-term – Operational impact. The control of traffic flow in the short term is crucial for how the citizens and visitors experience an urban environment. It allows reacting quickly to unpredictable events.

Medium-term – Tactical impact. From a medium term horizons, we derive the generalised costs of moving persons, goods and information. Policy making is interested to lower these generalised costs of movement as these induce more efficient labour and goods markets. Policy making also requires a detailed account of the winners and losers of any change in the supply, regulation and costs of transport infrastructure and services.

Long-term – Strategic impact. For policy making over time-horizons of decades we need an account of the daily flows and the form and structure of the urban environment. The development of a spatially-detailed path-oriented land use-transport model for Singapore and the relevant neighbouring parts of Southeast Asia will provide new insight into the policy risks.

The modelling efforts here complement the efforts of the simulation platform proposed. It will be a crucial element of it, as the movement between buildings and the demand for activities satisfied by these building is the central element of the evaluation of a project.

RESEARCH SCOPE

We need to develop:

• the capability to forecast the short term evolution of the transportation system by capturing its dynamic nature (this capability is often referred to as real-time Dynamic Traffic Assignment);

• the capability to monitor the transportation system and collect data, both to capture local variations in real-time, and the global evolution of traffic patterns;

• the capability to provide anticipatory and consistent route guidance and information to travellers (this capability is often referred to as Advanced Traveller Information System);

• the capability to model the charging for various externalities such as congestion and emissions through optimal tolls through the expansion and calibration of the scheduling model of MATSIM;

• the capability to model the control the capacities of the network via variable speed limit signs, traffic lights, lane use signs, ramp metering. etc. (this capability is often referred to as Advanced Traffic Management System) and also its integration into MATSIM.

• the capability to model the operation of public transportation in an efficient and coordinated way, also inside MATSIM

• the social network and mobility biography network suitable for the challenging international environment of Singapore. Its conduct and analysis will inform the agent's behavioural models.

• supply-side agents with an internal "mental map" of their environment and the new algorithms describing their dynamic response and planning to the evolution of the environment

• the optimisation tools able to respond dynamically to the evolution of the system while improving the outcome a) during the course of the development path, as well as b) for a stipulated target year.

LINKS TO OTHER RESEARCH STREAMS IN FUTURE CITIES

The simulation at these three levels interacts with a number of the other streams, both a tool to test the scenarios and policies developed there, as well as a source of data, which can usefully be shared or used in their respective scenarios.

The most obvious and prominent links is with the simulation platform, which will be used for the visualisation of our results and as a mechanism to describe and capture scenarios for evaluation. The work on low energy, landscape and ecology, territorial organisation and city design and economy will potentially use the simulations to evaluate their scenarios and policy ideas. The system will be strictly modular, so that they can add capabilities, as desired and necessary. This stream will support this work. The simulation platform will provide the necessary computing resources.

DATA REQUIREMENTS

This stream of work requires suitable data to speed up the implementation of the systems envisaged. We assume that government agencies of Singapore will be able to provide us these free of charge for use inside the project , as and when required:

For the MATSIM-based work:
- Teleatlas/Navtech or comparable network data
- Capacity estimates by link type (from local assignment model)
- Geocoded census data (parcel or at a fine grid level - 50*50, 100*100, 250*250 m).
- Parcel level data on buildings (size, volume) and their uses (by industry).
- Traffic signal data (average effective greens by stream for a representative time-period)
- Pricing data (parking, ERP, public transport tariffs by link or origin-destination)
- Commuter matrix at zonal or finer resolution (from the census, tax record or employment register)
- Recent travel diary survey data
- Car ownership (models)
- Mode choice model

For the land-use model:
- Land prices by parcel (recent sample).]
- Rents/prices and description of the associated housing (recent sample)
- [Hedonic equations for rent/mortgage costs and/or land prices]
- [Location choice models for households and firms]
- Historic land use and price information for calibration

If the data is not available, we will have to undertake the relevant data collection, or use other less suitable data sets. The additional resources for data collection will need to be found or accommodated through scaled down objectives. We are happy to support the authorities in Singapore in the collation of the data items or the estimation of the necessary models.

RESULTS AND MILESTONES

The software products will be developed under GNU public licence and the code will be available at a suitable archive (e.g. www.sourceforge.net). The data and the results produced with the data remain property of the data owners. Academic publication of the project will be permitted.

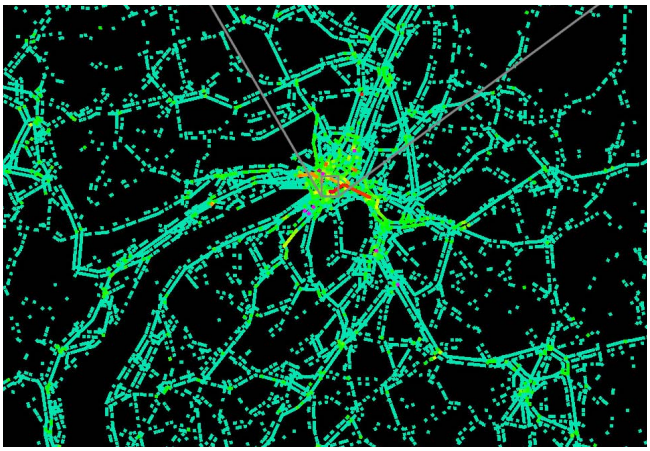
(S)hort term:
Month 12: Inclusion of ATMS and ATIS into the on-line version of MATSIM (DTA).
Month 24: Integrated (joint) behavioural models for mode, departure time and route choice in response to traffic information and guidance
Month 36: Algorithm(s) to generate consistent anticipatory route guidance
Month 48: Off-line prototype of the system
Month 58: On-line prototype of the system
Month 60: System and data documentation and archiving

(M)edium term:
Month 9:MATSIM-T implementation for Singapore including initial data collation and archiving
Month 15: Extension of the scheduling model for the ERP and other pricing mechanism of Singapore
Month 24: Path-dependent MATSIM-T simulation and analysis of the stability and uniqueness of the paths
Month 30: Inclusion of parking search into the traffic flow simulation
Month 36: Robust optimisation algorithm of the supply and pricing regime
Month 48: Test of the stability of the optimisation with heterogenous agents, including models of the heterogenous preferences in activity performance and scheduling
Month 58: Report on the policy tests
Month 60: Final report, data archiving, software documentation

(L)ong term:
Month 9:Design of the production survey of the social networks between persons, persons and firms, and firms
Month 12: Initial implementation of the supply-side agents and sensitivity test of the system
Month 15: Social network survey completed
Month 24: Revised supply-side agents incorporating the social network structures
Month 36: Policy tests with the expanded MATSIM-T system

General:
Month 15: Dummy version of UrbanSim including collation of the necessary data sets
Month 24: Models of location choices of households and firm, land and rental values and development decisions
Month 33: Initial validation of the UrbanSim implementation
Month 36: Automatic exchange of MATSIM-T/UrbanSim
Month 48: Policy tests and their analysis
Month 56: Final set of policy tests
Month 56: Analysis of stability of the co-evolutionary system
Month 60: Final report, data archiving, documentation

The project results will be published in an on-going series of working papers to allow immediate access, but primarily in the relevant leading journals, e.g. Transportation Research (A, B, C, E), Transportation Science, Transportation, Networks and Spatial Economics, Urban Studies, Environment and Planning, Urban Economics, Progress in Human Geography, Social Networks and others. We will maintain an active presence in the important conference series, e.g. the regular meetings of TRB, EAST, ETC, Informs, IATBR, RSA and others.



Dynamic traffic pattern simulation

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The specific composition of the research team including potential agencies and industries, such as the Ministry of Transport, will be clarified at the beginning of the project.

1.11 SPATIAL DENSITY

For the first time in the history of humanity, more than half of the world's population is now living in cities, and the city is going through a renaissance as a focal point for economic growth and innovative capacity. Cites are also playing the main part in the worldwide competition for sites for investment and talent. This competition is particularly strong in Europe, where the cities have come under severe pressure to renovate during the new wave of globalisation. The American metropolises, and the new "global cities" in Asia in particular, are disputing the economic and cultural supremacy of the West's historic large cities. Urban density has a key role to play in this challenge. Density creates spatial vicinity between the widest possible range of skills and resources and promotes a creative combination of the two. These qualities will become more important in the future information economy. Our research interest focusses on the question how dense a modern urban situation is both possible and necessary to create specific spatial qualities including sociological criteria of the cultural contexts of Singapore and Europe (Switzerland).

Hardly any other concept in the recent history of the city has led at different times to such different interpretations and evaluations as the concept of urban density. In the second half of the 19th century, density was synonymous with overcrowded apartments and unhygienic living conditions, while at the beginning of the 20th century, dense urban conditions were often associated with social and political unrest. It was only in the second half of the 20th century that urban density became synonymous with urban variety and richness of experience. Until today only a few scientific research projects tried to collect data for an international comparison of the conditions and consequences of urban density. This research will examine and classify selected urban situations to analyse the reciprocal relationship between urban typology and social factors. In order to achieve the highest urban density in combination with an urban structure of highest quality in terms of sociological implications, economic requirements and urban design, it is necessary to examine the different levels and meanings of "density" – as the density of inhabitants, of interaction or employees, the building density.

The aim of the project is to specify and put into concrete terms the concept of urban density and the mechanisms it is based on – using points of view involving sociology, regional and urban economics, law, and above all urban architecture. Typical case studies are to be selected and analysed for this purpose. Three levels of criteria will be used in the process – that of urban structure, that of the urban island, and that of building typology. The focus will be on domestic building, but office buildings, factories and public buildings will also be included in the analysis. In addition to built and free space, urban green areas will also be taken into account. Special attention will be given to the aspect of sustainability, as well as to the quality of life. The result will be a systematic handbook for dense architecture that will be usable in practical city planning work in a variety of ways, depending on each specific topographic, climatic, social and cultural situation.

The concept of urban density has become a central consideration once again today for interpreting and preparing various urban design situations. In debates regarding the organisation of the information society in the urban sphere, the potential for creativity and added value of the dense, mixed-use city is becoming increasingly important. From the planning point of view, the hope is that skillful structural redesigning of existing domestic developments will lead to greater socio-economic efficiency in the areas occupied by cities and conurbations, as well as greater sustainability in the design of the infrastructure and landscape. The research, which has to be carried out in close collaboration with our partners in Singapore, links urban design issues with sociological statements, statements on legal issues involved in architecture, and statements connected with the urban and regional economy. The project will provide an eminent contribution to regional and urban planning in establishing and discussing scientific criteria for the precise creation of urban density.

Social and economic influences are closely related to the architectural environment. Residential densities in the city are not least an expression of dynamic consumer behavior that has a direct effect on the structure of the city. The ways in which this influences investor behavior are also a topic of the study. In view of the changing patterns of centrality and urbanity, research studies on urban design are in turn developing the conceptual basis for an unprejudiced description of urban situations. For this purpose, sociostructural data material is set in the context of urban structure and urban design. At first a careful selection of case studies has to be made in Singapore and Zurich. These case studies must follow scientific criteria, allowing a productive comparison of the different situations. Careful but nevertheless analytic description, measurements of selected spatial areas, observations and analysis of the sociological are to be carried out subsequently.

Specific concerns that will be addressed in the project would include the following:

- Correlation between the density of inhabitants, the density of the employees and the building density.

- Relationship of dependence between urban structure, building typology and density and its influence on the behaviour of inhabitants and employees.

- Optimal distribution of social and functional space to mitigate potential adverse effects of density. In this respect, people centric requirements pertaining to the quality of life, work and play should be considered in a holistic approach to a solution.

- Analyses of performance shaping factors to enable differentiation between conceptions of city design as comprising the specification of a network of self contained units vs the functional integration of specialized zones of socio-economic activity. Such conceptions would have implicit effects in terms of social and environmental sustainability, e.g. the need to commute. Orthogonal factors, in particular the emergence of digital infrastructures, should be included in the analyses to examine their potential to alleviate the pressures of spatial densification.

- Application of physical and psychological design approaches and techniques to reduce the negative effects of densification, e.g. blurring the boundaries of real and perceived space by designing and introducing virtual spaces for life, work and play so as to overcome the constraints of physically restricted spaces imposed by densification. In addition, methodological development and customisation of existing human factors techniques such as stakeholder analyses, participative and inclusive design, shall be included in the research to ensure comprehensive capture of people centric requirements and needs for a total design solution that meets the functional, social and emotive needs of the population; to engender a sense of ownership of the process and solution; and finally to assure a better communal acceptance of a solution for spatial densification.

- Analyses and subsequent accommodation by appropriate spatial density design of the needs of various stakeholders so as to maintain the integrity of social structures ranging from the basic level of the individual to family units to communities and finally the nation.

The project will be conducted in parallel in Zurich and Singapore. University research assistants and doctoral candidates, as well as undergraduate students, will carry out the research for it under the direction of Prof. Vittorio Magnago Lampugnani. It is planned that the project will take five years. Following a preliminary report a symposium will be organised soon in order to discuss the criteria of the research. The research will combine different methods like textual analysis, diagrams, plans and photographs. The handbook

Cover image from the book Urban Density, *edited by Vittorio Magnago Lampugnani, Thomas Keller, and Benjamin Buser (Verlag Neue Zürcher Zeitung, 2007).*

will be published in English. The results of the research will not only be coordinated with the other Future Cities research projects, but will also influence them through the periodic exchange of data and insights. At the same time, the project will profit significantly from the other parallel research efforts undertaken within the Future Cities Laboratory. In particular, the present research theme complements the Urban Sociology research theme of this Future Cities Research Programme which is planning to examine a wider variety of different models of urbanisation or could collaborate with "City design & economy.

Core Research Team

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The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

1.12 SIMULATION PLATFORM

4D STATIC AND DYNAMIC CITY MODELING

RESEARCH GOALS

The Simulation platform will become a unique infrastructure for the analysis, simulation, visualization, and design of future cities, especially for Singapore and the region. It consists of a physical space with state-of-the art hardware and software components and new intuitive human-computer interaction devices. The simulation platform forms the basis for data acquisition, storage, administration, processing, analysis, and representation (visualization, simulation and animation) for the Future Cities Laboratory projects.

The three research thrusts of this project are: (1) analysis and simulation: Research into further developments and innovations in automated data acquisition, modeling, analysis, as well as simulating, visualizing and interacting with data from current and future cities, (2) urban design and scenario planning: Research into new interactive methods to support collaborative urban design over distances and scenario planning based on defined case studies performed together with NUS, NTU and the relevant agencies, (3) Knowledge transfer: Research on new ways to synthesize, communicate and interact with the essential knowledge and findings from the S-M-L projects for purposes such as decision making, education, training, demonstration, publicity, public dialogue both within and outside of Singapore.

RESEARCH CONTENT

We are listing here 9 topics for research and development, which form the key contents of the future activities of the simulation platform.

1. "4D Singapore": Semi-automated generation of city models of Singapore from aerial, satellite and terrestrial images, laser-scans and other available primary data, with change detection and updating of databases. 3D city models consist of buildings, other man-made structures, Digital Terrain Models, and, according to the purpose of use, may also include vegetation (trees and bushes), traffic elements, utility objects, etc. The generation of city-wide high-resolution 3D models requires a certain amount of automation. We plan to further enhance the automation capabilities in reality-based city modeling. Beside the creation of virgin databases another aspect of particular interest is the updating of existing databases. The land- and cityscapes are changing at a fast pace. Therefore another dimension (time) has to be added, resulting in the notion of 4D city models. As models become both more extensive and more detailed this requires efficient techniques of detecting changes and updating existing datasets appropriately. This also touches the problem of combining existing realities with planned objects in joint models. The 4D Singapore Model will be linked to a new database that structures essential data with relevance to the analysis of urban systems and the urban planning process. This database integrates the findings of the Future Cities Laboratory projects.

2. Augmenting simulations with measurements. Modeling and simulation are common threads that run across the entire Future Cities project. Simulations involve several modeling assumptions and are fraught with different types of errors. The goal of this part of research is to improve the reliability of simulations through the use of measurements and multiple-model system identification techniques. System identification involves evaluating the state of a system and estimating the values of system parameters using measurements. This is usually done through minimizing the errors between model predictions and measurements. Model predictions are obtained through simulations. Measurements help estimate actual responses of the system. By comparing the predicted and actual responses, a set of candidate models can be selected. However, due to the abductive nature of the task (this requires inferring causes from effects), solutions are likely to be non-unique. Our recent research has resulted in a system identification methodology that makes use of advanced machine learning techniques for improving the reliability. This methodology will be adapted, improved and applied to various simulation tasks in the project.

3. For consistent and non-redundant data management a GIS is required. The GIS not only provides for data storage and administration, but also has intrinsic capabilities for data analysis. Here research questions related to extensions of GIS functions towards 3D and 4D functionalities have to be addressed.

4. Codified knowledge integrated into the "City Engine": One of our central goals is the elaboration of codified knowledge from studying past, current and future best practices, and from the new insights of the entire Future Cities Laboratory Project. We will then proceed with integration of the corresponding rules into an application (e.g., City Engine) for purposes such as simulation and visualization of scenarios.

5. Collaborative planning methods: Development of new methods and applications for collaborative planning across time and space, such as interactive tables/terrain model boards, immersive 3D mixed reality displays with tangible user interface objects.

6. Mobile infrastructure and computer vision approach for object and people recognition. This includes the studying of the dynamics of a city, e.g. in all flow-related activities. The flow of traffic, materials, and people are typical examples.

7. Simulation toolbox for building simulations. Creating a workbench with the best available tools for building simulations, in close collaboration with the S-Lab project partners.
8. Access to a supercomputer and infrastructure for high-end simulation of future city planning scenarios probably integrated in a GRID arrangement.

9. An eye-catching and highly educational interactive exhibit: A new interactive mobile physical space with novel interaction techniques for the traveling exhibition.

INNOVATION AND DISTINCTION

This work will result in an unprecedented building, city and territorial simulation and modelling platform with long-term impact on increasing the body of knowledge in Future Cities Design.
We will generate unique datasets for simulation and analysis. It will be for the first time worldwide that many different problem domains (streams) are cooperating so closely with each other, focused at one particular overwriting problem ("Future Cities") and using one common hard- and software platform for their work. This will create synergies which, at this point, can be hardly described in detail. The knock-on effects of new approaches can never fully be predicted.

Multiple-model system identification using machine learning techniques is a new concept. This project offers a unique opportunity to apply such methodologies at much larger scales and to diverse domains. This project can have, if properly set up and executed, model character not only for the larger region but for the whole world.

IMPACT

There are many uses of 4D city models, for example: Environmental protection, car navigation, planning (buildings, roads, location), mobile communication, LBS, energy (such as solar), tourism, real estate, architecture, building preservation, insurances (risk assessments), natural hazards, homeland security, police, emergency services, and waste management. Most of these require the data in a dynamic mode. This project will for the first time address this issue in a focused and comprehensive way. We will create and maintain a long term data base and communication environment for Future Cities planning, crucial for any planning authority.
We see as an option the development a system for Location-Based Services (LBS). This allows for the next generation of PDA/phone-based on-line navigation through the city and information retrieval concerning objects of interest. It can be linked to projects such as Singapore iN2015 and IDM projects.
The impact of our work stretches beyond the streams defined in our SEC project. Other possible and useful applications of the "City Engine" could be: Conservation of national heritage and cultural identity, environmental modeling and man-made hazards (e.g. CO2 emission and consumption), homeland and private security. The impact of the work on augmenting simulations with measurements will be mainly scientific. The primary outcome will be the development of a methodology that can be used to improve the reliability of simulations in many domains. Fully developed prototypes that implement the methodology in selected areas will be available for researchers and this will further enhance the capabilities of simulation systems. Commercial GIS are not designed towards use for 3D and 4D city modeling. Here we have the unique opportunity to develop a Spatial Information System for the sole application in city modeling. This could become an important reference for the future of GIS. Our work in collaborative planning includes a physical lab: An infrastructure with interactive displays customized for the 4D Singapore application and collaborative planning. The SmartSpace technology of NUS could be integrated here as well as the Shared Design Space concept currently being developed in the laboratory of Dr. Zhou Zhi Ying.

In addition we will take the lead (hopefully worldwide) in applying computer vision techniques to the study of city dynamics. This will result in a workbench with the best available tools for building simulation and in presentatons of our work to colleagues, stakeholders and the public, in an attractive and highly educational interactive exhibit.

RESEARCH SCOPE

We need to
• Develop efficient automation-friendly methods for data acquisition for reality-based city models at different scales and resolutions: For the full city (Large), for some sections (Middle) and for individual buildings (Small).
• Turn acquired data into highly compact yet equally descriptive and semantically structured models, that yield support for more realistic simulation, for more effective Level-of-Detail visualization, etc.
• Research novel techniques for the updating of static city models and for the integration existing and planned objects.
• Find solutions for the integration of dynamic processes, as well as for their visualization and simulation/animation.
• Develop prototypes for day lighting and energy simulations using commonly available simulation engines such as Radiance and EnergyPlus. Based on the experiences in developing these prototypes, the methodology will be adaptively refined and generalized. Other potential areas of application and testing will be identified during this period.
• Study and further develop the integration of codified knowledge into the "City Engine". Development of pilot procedures for making use of this customized City Engine

application in specific processes in urban design, especially collaborative urban design and scenario planning.
• Development of new methods and applications for collaborative planning across time and space.
• Establish and improve a computer vision approach for object and people recognition and crowd movement modeling

LINKS TO OTHER RESEARCH STREAMS IN FUTURE CITIES

The simulation platform development will basically follow two strands of activity: It comes with its own research agenda, in order to move the methods of data generation, modelling, simulation and analysis forward, but it also will serve as a platform to support all the other research streams. It is envisioned that there will be a close cooperation with the individual stream members in the data and task definition phase as well as in the processing phase. As defined earlier there will be different scales in the applications (Small-Medium-Large) all of which will be covered by the simulation platform. However, some of the streams will surely make use of the simulation platform more extensively than others. For instance, the results obtained in the Augmented Simulations sub-project are directly applicable to the Transportation Infrastructure and Low Exergy. These are areas where the multi-model system identification methodology can be applied for improving the reliability of simulations.
We expect that the demands for support and cooperation will come from the individual streams themselves. We will then conceptually discuss the required technical procedures, define the costs involved and in close cooperation establish the data acquisition (where required), the integration, and the data processing workflow.

DATA REQUIREMENTS

There will be a base dataset, consisting of the full 3D city model of Singapore, including buildings, terrain, vegetation and other objects of interest. This dataset however can only be generated if appropriate primary sensor data becomes accessible, as for instance satellite images, aerial images and/or LiDAR data.
This dataset can be augmented with information from existing databases (maps, digital archives, statistics, reports, etc.), as they become available. Here we must count on the support of Government agencies and private companies.
Also, data which is necessary for object and people recognition will be generated on-site. In addition, data will come in from the various streams, as those get into their working mode.
Of course, data is essential for the simulation platform and every effort should be made to acquire the necessary datasets.

RESULTS, WORKFLOW AND MILESTONES

As main results we see:
1. Seamless interaction with the ETH ValueLab, 4D Singapore software
2. Establishment of modelling, simulation and data base environment for all research streams
3. Scenario planning for building, city and regional scale
4. Advanced Future Cities communication system

The workflow will consist of the following components:
1. Setting up the hard- and software for data collection, modelling and visualization/animation.
2. Defining the requirements of the various streams in terms of type and amount of data, data formats, modelling approaches, analysis and simulation functions
3. Investigating into the best way of collecting this data (what is already available? what has too be generated and how?)
4. Testing the software with some pilot datasets
5. Further developing methodological components
6. Realizing the own research agenda

Milestones have to be defined in cooperation with the streams. This is a rolling planning and realization issue.

Scenario planning with interactive tables and screens (Source: Chair for Information Architecture)

Reality-based modeling of a city (Source: Prof. Armin Grün, ETH Zürich)

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Benny RAPHAEL, NUS

The specific composition of the research team including potential agencies and industries will be clarified at the beginning of the project.

DESIGN RESEARCH STUDIOS

2.00 DESIGN RESEARCH STUDIOS
INTRODUCTION

Contemporary city design requires distinct methods. State-of-the-art research in architecture, urbanism, and planning has recently advanced the instrument of the Design Research Studio as the place of investigatory work – a type of workshop setting, in which ideas and concepts are tested in physical and digital models, plans, diagrams, statistics, renderings, animations, and the like – with design as the core discipline integrating the findings of other fields of inquiry.

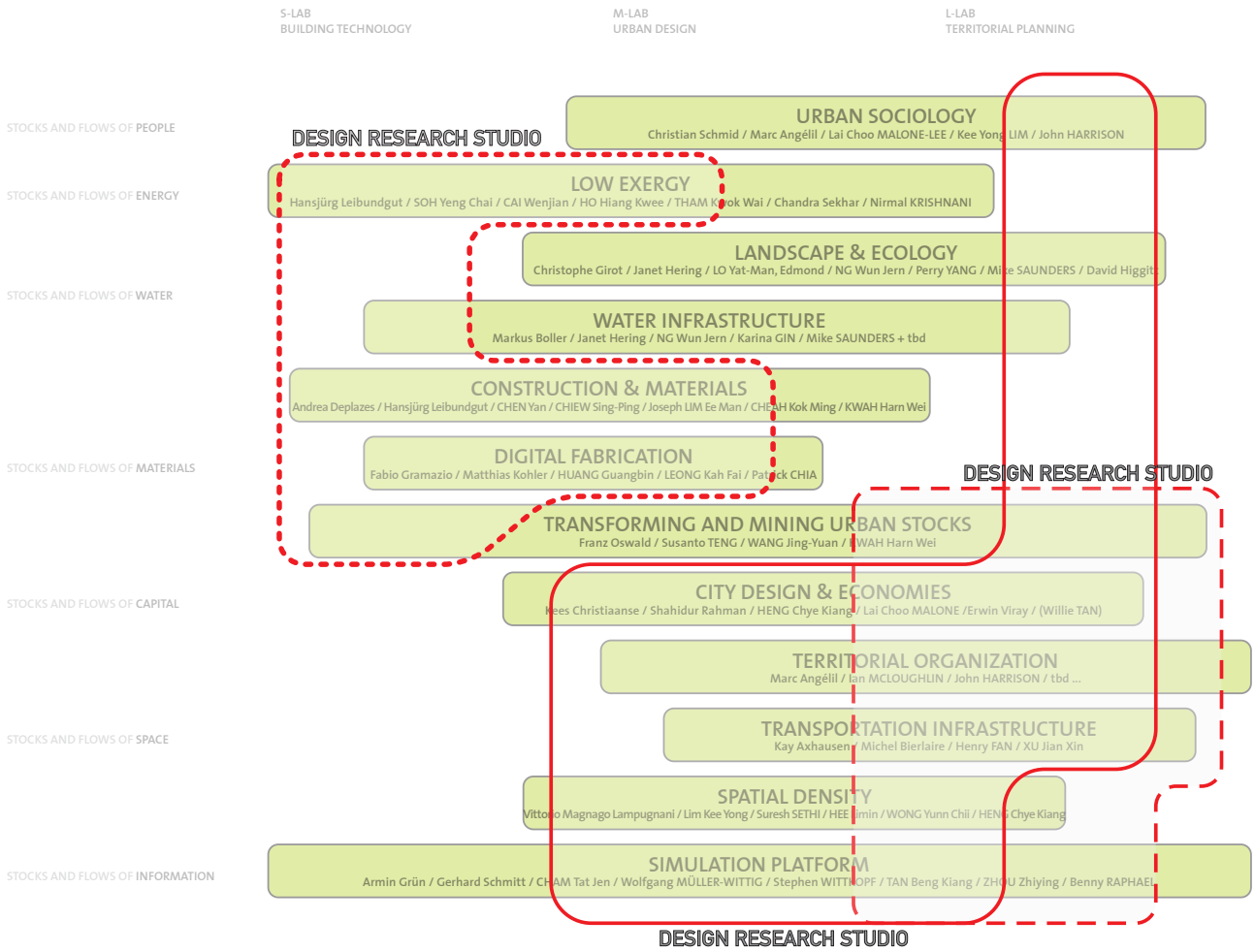
Such studios will provide the framework for teaching at the Master and Ph.D. levels as well as act as platforms for contacts with city officials and industry representatives. Structured according to the different scales of the investigation, design studios at the S-, M-, and L-Labs will link various project-streams in order to synthesize their findings. Using Singapore and other cities as comparative case studies, various hypotheses and propositions for their future development will be assessed through design. While working with real conditions, explorations will need to be speculative and projective, predicting forthcoming challenges and identifying potential solutions.

An important objective is to foresee how urban assemblies might evolve in the future. As cities are in a constant state of flux, the design of anticipated developments – rehearsed and examined in Design Research Studios – offers a viable means to identify and possibly direct prospective urban transformations. Considering that cities are complex entities and the results of multifaceted forces at work, design studios must be driven by interdisciplinary team collaborations. The crossing of disciplinary boundaries is precisely what needs to be promoted and practiced. Herein, research must bring questions of method and procedure to the forefront that can be transferred to other conditions, while still focusing on proposals for specific solutions. Studios are, in this sense, places of knowledge production, exposing design – whether of buildings or entire territories – to an array of methods from other disciplines deemed significant to the work at hand.

These studios will be essential facilities of the Future Cities Laboratory and will be considered instruments, showpieces, interactive demonstration environments, and examples for future research efforts. They will contain models at different scales, time-based displays for the simulation of urban patterns, and advanced robots to test entire digital chains. The studio-laboratories need to be spacious enough to allow the parallel treatment of relevant research and development work.

As stated by the architecture and urban design faculty of NUS, there is significant interest in collaboratively exploring the possibilities offered by design research: “The design studio represents a special category of creative activity. Its research content, though nebulous to many, is nonetheless apparent and significant. NUS_Design agrees with the ETH faculty that the products and processes that ensue from design studios can be cast as research. For this reason, NUS_Design supports the idea of design as research in both testing and application. It is in this spirit of research, understood as a type of ‘newsearch’ for spaces, forms, and content, that NUS_Design offers its platform for collaboration.”

Enabled by the collaboration among NUS, NTU, and the ETH, the Design Research Studio will be one of the primary conduits through which the research findings from the project streams will be channeled. By building upon successful past models – like that of Studio Monte Rosa at the ETH in which a group of students incorporated cutting-edge sustainable building technology to design and construct a small hostel in a remote mountain site – the Future Cities Laboratory will use the studios to facilitate exchange, integration, and communication among the simultaneous research projects.



The Design Research Studios will weave together the findings from the various research streams.
The bubbles are used here only to illustrate the organizational concept underlying the studios.

2.01 STUDIO DESCRIPTIONS
L-LAB, M-LAB, S-LAB

Currently, five inaugural design research studios are being proposed to initiate this process of collaboration, engaging the scales of territories, districts, and buildings.

Territorial Planning (L-Lab): Rural Studio
proposed by Wong Yunn Chii and Tay Kheng Soon (NUS)
potential collaborators: Franz Oswald, Marc Angélil, Dirk Hebel, and Jesse LeCavalier (ETH)

Cities cannot be dealt with independently from their rural hinterland. The fundamental underpinning of this design research studio is that urban environments depend on the development of their rural surroundings. Migration from the countryside to cities presents one of the paramount challenges in contemporary urbanism, contributing in part to increased social iniquities and economic disparities as well as the formation of urban slums that fail to provide basic needs for their inhabitants. Based on the thesis that improved rural conditions will ameliorate the current state of informal urban settlements, this design studio explores ways to redress inequities through the reorganization of space, work, and material logistics in both the city and the countryside. The project proposal takes a regional perspective on the urban question.

The goal of the studio is to create a multi-disciplinary and intra-regional platform aiming for potential resolutions of the discrepancies between urban and rural areas. The studio is not only directed toward the design of physical structures, but also toward the design of processes, such as the forming of policies and terms of governance for the making of the physical environment. Of significance within this context is the fact that the problem of poverty in general has been largely overlooked by developmental and nation-building efforts in the recent past, whether in South East Asia or other regions of the world. Disparities in urban and rural areas present clear evidence that something needs to be done.

NUS_Design and ETH can collectively form the catalyst in the effort to address these challenges in the context of South East Asia in order to augment the work done by ASEAN member governments and NGOs operating within the region. As the outcome of the research will offer general principles and processes for mitigating the negative effects of migration, the results will serve as models, potentially to be tested in other areas of the world.

Landscape and Ecology (L-Lab): Water Studio
proposed by Christophe Girot, Janet Hering, Alexandre Kapellos and James Melsom (ETH)
potential collaborators: TBD

Landscape and Ecology are an integral part of the modern city, when they are in balance they reflect the quality of life of an environment, when not they signal a need for attention and repair. Water is the fundamental element through which this design studio will operate, whether in terms of the recovery, management and scenography of landscapes and their respective topography. The studio will be based on the thesis that the improvement of riverfront conditions in Singapore can contribute positively to the value of a neighbourhood, improving significantly the quality of life of the inhabitants while restoring a natural environment better adapted to the city. Water can become the prime indicator of improved environmental quality and balance in the urban landscape system. The studio project will chose a key location on the Singapore riverfront, as target study area and will compile available scientific data concerning water management and environmental monitoring about this place. There will also be a need for cultural indicators in Singapore, and other Southeast Asian cities about the potential use of riverfronts as areas of public and private amenity. The goal is to introduce an entirely new topological approach in landscape design for the revival of riverfronts in Singapore. It will be based on parametric design methods developed at the ETH involving advanced topological modelling and visualizing techniques enabling a variety of flow and growth simulation. The studio in Landscape and Ecology will be done in conjunction with EAWAG specialists and in collaboration with expert groups from NUS and NTU, to help determine and organize scientific factors about the water environment in Singapore into a comprehensive whole. The same will apply to the study of cultural factors about riverfront culture in Singapore, were relevant data sampling about the topic will be crucial. Results from this studio should serve as a basis of communication and reference, for the future selection of operative riverfront projects in Singapore.

NUS Design and ETH will work hand in hand in a combined effort towards the development and management of this landscape and ecology design studio. It will require the combination of a strong topological approach using parametric methods of landscape design, and the compilation of a solid scientific database about water and the environment in Singapore. Only then will the studio be able to formulate a project that works environmentally and fits with the expectations of a local culture of riverfronts. The methodological results of this first studio will serve as a reference model and open the way for subsequent landscape and ecology studios to take place at NUS.

Urban Design (M-Lab): Sustaining the Open City

proposed by Kees Christiaanse, Kerstin Hoeger and Mark Michaeli (ETH)
potential collaborators: Heng Chye Kiang, Lai Choo Malonee Lee (NUS), Perry Yang (NUS)

Within the scope of the Urban Design Research Studio, researchers and students work in close collaboration on central topics of the Urban Design Lab. PhD work, seminars, symposia and publications are integrated with the aim to create complementary and cumulative outputs. Typical contemporary situations of urban design will be investigated by exemplary projects in Singapore and its surrounding territories. As laboratories embedded in their specific context, these case studies are stimulating discussions of up-to-date problems of the discipline and thus enabling students to grasp an insight into inner logics and methodological approach to urban design tasks.

Since 2003, the Institute of Kees Christiaanse at the ETH Zurich has gained valuable experience from Urban Design Research Studios conducted at various locations such as London, Istanbul, Zurich, Berlin, Rotterdam, Yokohama, and Moscow. Developed in close contact with local stakeholders and academic institutions, the results of these studios are contributing to projects of the local authorities and actors. The benefits caused by that cross-fertilization are obvious: On the one hand, the students can take advantage of being involved into real projects by gathering professional experience and expertise. On the other hand, academic research and teaching programs can provide not only on-the-edge knowledge but also enormous working power and experience to local planning institutions. Within this academic think tank situation and thus not under a permanent threat set by the constraints and needs of daily business in a planning agency. The discussion of urgent, yet explosive urban tasks can be established, which can inform the reality of future urban development processes.

For these reasons, the design and research work in Singapore will be conducted as a combination of academic teaching and scientific survey program in studio workshops, on-site field studies and seminaries with local experts, stakeholders and partner institutions. The aim is rather the evaluation of strategic possibilities and necessities, which allow for robust and flexible, though quality-oriented urban concepts for the future, than the development of determinated master plans. The studios will not only emphasize the formal aspects of urban design as a kind of cities 'hardware', but integrate questions of use and program as well as legal situation and stakeholders interests, as the 'software' and 'orgware' of the specific site.

Design Research Studios environment at the Department of Architecture of the ETH Zurich

Urban Design (M-Lab): Creative Spaces

proposed by Gerhard Schmitt and Remo Burkhard (ETH)
potential collaborators: Perry Yang, Erwin Viray, Limin Hee, Lai Choo Malone-Lee, Limin Hee (NUS); Cham Tat Jen (NTU)

Singapore can be understood as one of the leading hubs in Asia for creative industries. The city-state strengthens its global position through new strategies such as the creative industry development strategy masterplan 2015 (work in progress), the new media masterplan, the interactive digital media or the iN2015 initiatives, and new knowledge hubs such as the CREATE Campus, NTU's Cleantech Hub or Fusionopolis.

The purpose of this design research studio is to identify prototypical strategies for (1) attracting global talents from the creative industries to settle down in Singapore and (2) the development of city districts capable of addressing multiple demands relevant to the formation of contemporary city neighborhoods and the provision of multiple uses. Of foremost importance is the claim that future urban ensembles must adhere to the premises of the "open city," understood as a porous amalgam of interrelated urban sectors with distinguishable qualities. Therefore this studio will closely interact with the Design Research Studio proposed by Kees Christiaanse and his team.

Using scenario planning as a method, the studio will test the transformation of a specific brief in the context of multiple and diverse sites, which will be identified together with URA, HDB, JTC, NUS, DesignSingapore Council (MICA), Industry and others. The premise is that the interface between a generic program and a specific site will produce qualities contributing to the identity of place. Here the Simulation Platform (See Research Stream 12 of the Future Cities Laboratory) will provide the necessary means for visualizing, communicating, and assessing the studio proposals. Examples for scenarios include the retrofitting of existing districts, the integration of new workspaces into high-density housing areas, new educational facilities for exporting the creative and design thinking to emerging Asian markets, distributed small scale interventions for improved orientation, museum of the future to establish awareness for the creative industries etc.

The project requires the interaction of multiple stakeholders such as experts from different disciplines, public agencies, and private industries. As the design research work is directed toward practical applications and contribution to the economic growth of Singapore, collaborations with DesignSingapore Council (MICA), EBD, Spring, JTC, will play a significant role in the course of the studio, especially in the preparation and review phase. We would like to interact with them from the very beginning to the very end to guarantee an integrated and synergetic research. Todo so, we will organize semi-annual workshops with these agencies. We also propose to be in a constant close dialogue with a main contact person in all of the above agencies.

Today, we think that the design research studio will probably be structured as a "special studio" with a modular credit point system. The design research studio is proposed to last one academic year (two semesters) and is limited to about 12 master students from the department of architecture at NUS and ETH. The students will do a series of field studies, interviews and comparative studies with other creative hubs, such as Zurich, Bangkok, Tokyo.

Building Design (S-Lab): Low-Ex Studio

proposed by Andrea Deplazes, Hansjürg Leibundgut, Fabio Gramazio, Matthias Kohler, Tobias Bonwetsch, Forrest Meggers (ETH)
potential collaborators: YC Soh, Cai Wenjian, Chen Yan (NTU); Tham Kwok Wai and Department of Building (NUS)

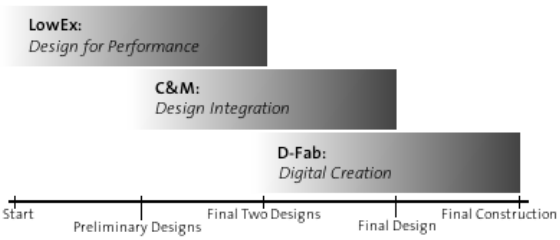
This design studio will create a landmark building in Singapore for the Future Cities Laboratory. This will take place in 3 staggered parallel tracks starting from preliminary performance design to final integrated design to optimized construction process. It will demonstrate the use of unique and pioneering tools, methods, and systems being utilized and developed in the Low Exergy (LowEx), Construction and Materials (C&M), and Digital Fabrication (D-Fab) groups FIGURE?

The studio is facilitated by the LowEx, C&M, and D-Fab teams. Each team will manage one of the three overlapping tracks. This will guide the design from the very preliminary concepts to the final construction while constantly providing the necessary consideration and integration of the ideas from the three research streams.

The studio will begin with a focus on design for performance from the LowEx team. Here students will use innovative new tools that provide information on build performance in the earliest stages of design. This information is integrated into quick parametric modeling tools, and most importantly the information is provided in easy-to-read graphics. This will allow the students to come up with a variety of potential high performance solutions for the building design.

The second block will include the integration of these design solutions into complete building designs in a group managed by the C&M team. The LowEx group will continue and work closely with the C&M group in this second block, at the end of which a selection will be made of the two best complete designs. These will have been fully analyzed for system performance by the LowEx group and will have been optimized for material and resource usage while integrating modern design techniques by the C&M group. In the 3rd block the D-Fab group will consider how the designs presented can be optimally constructed using digital fabrication techniques. The C&M will also continue into the 3rd block continuing to optimize the design for these construction options, working closely with the D-Fab group. At the end of the 3rd block the final design will be selected, and in the fourth and final block the D-Fab group will create the plan for the final construction of the building, which will subsequently be built. This will utilize the flexibility provided by use of industrial robots, allowing complex integrated systems to be easily constructed with little labor.

The three research areas will guide the implementation in the studio of their research advancements simultaneously providing valuable teaching while also creating a platform for demostration. Each group will guide focused sessions and lectures on their topics. Some of these initial ideas could be implemented in the CREATE Building. Informal discussions have taken place already with the architects from Perkins+Will. The full studio will result in the creation of a new building; one that demonstrates the full potential of the Future Cities Project research. This landmark building will be one of the best of the best and a guiding symbol for all future cities of the world.



EXPECTED RESULTS

3.00 EXPECTED RESULTS & KEY PERFORMANCE INDICATORS

Understood as a research platform involving scholars, governmental agencies, and industry, the Future Cities Laboratory will offer sets of guidelines directed toward the sustainable development of buildings, districts, and regions. Conceived as tools to be deployed within professional practice in order to attain sustainable conditions, these guidelines must comply with specific criteria addressing a quantum leap in ecological, economic, social, and aesthetic performance. Each set of guidelines will be structured according to specific process-phases and will include analytical, design, communication, implementation, and evaluation tools.

Following the adage that "Rome was not built in a day," the research will foreground the role of processes, gradual change, and transformation of city environments. Here, the urban fabric is understood not as a fixed entity, but as a varying and adaptable system. Time-based techniques and process-oriented approaches will drive the inquiry. Advanced instruments such as urban prototyping models and simulation platforms will be developed. These are to be used in the design of metropolitan settlements, establishing the base for consensus through discourse. Such instruments and techniques, while incorporating complexity, conflict, and contradiction, must nurture communication and provide experts, professionals, state agencies, interest groups, and the general public with information and knowledge visualization.

At a more abstract level, the research aims at the production of knowledge at the forefront of the disciplines involved in the making of cities – a theory of practice. This work will be exposed to the scholarly community and scrutinized by peers within the field. One of the key objectives of the Future Cities Laboratory is to chart an unprecedented theoretical body of work reframing building technology, urban design, and territorial planning in view of sustainable development.

Expected outcomes will progress along five vectors: the identification of design tools, implementation guidelines, assessment methods, educational models, and scholarly results.

Design Tools
So-called toolboxes, to be used by multiple stakeholders in the design of buildings, districts, and regions, will be developed to help identify and structure future courses of action. The toolboxes comprise kits of parts, suggesting specific methods and techniques that can be put to work in order to foreground the necessary parameters and conflicts in the production of urban settlements. They are conceived as vehicles for addressing the processes involved in the long-term development of cities. Various types can be distinguished, such as analytical, design, and communication tools.

Implementation Guidelines
The Future Cities Laboratory will provide implementation guidelines directed toward the sustainable development of cities. These guiding principles will set specific objectives for professional practice, the construction trade, and governmental agencies. Various types of guidelines will be produced and established, such as Sustainability Guidelines for Buildings, Sustainability Guidelines for Neighborhoods, and Sustainability Planning Guidelines.

Assessment Methods
Various evaluation systems for sustainable buildings currently exist, such as the LEED-rating (Leadership in Energy and Environmental Design) put forth by the US Green Building Council, the BREEAM-rating in Great Britain (Building Research Establishment Environmental Assessment Method), and the Minergie-ratings in Switzerland (Minergie-P and Minergie-Eco). Such instruments are key in order to provide guidance for the manufacturing of products, for the design phase, for construction, for use of buildings, and the post-construction phase. Similar instruments need to be developed for urban areas addressing questions of transportation, heat-island effects, stormwater management, brownfield redevelopment, waste management, density, etc. Assessment methods need to be created for the master planning of large developments and entire urban regions.

Educational Models
Sustainability requires a long-term perspective. As know-how must be transferred from generation to generation, a significant aim of the Future Cities Laboratory is to provide the educational framework that provides a steady flow of well-trained professionals – architects, engineers, urban and landscape designers, regional planners, and territorial managers – for both the public and private sector. Additionally, ideal conditions need to be created for scholars and doctoral students to produce knowledge at the forefront of their fields. It is in these respects that the Future Cities Laboratory ought to evolve as one of the leading teaching and research institutions worldwide and provide proof, through conferences, publications, and exhibitions, of its high level of expertise.

Key Performance Indicators
In agreement with international practice, each track will require to be evaluated by an independent advisory board at several points during the work in order to incorporate additional considerations and make necessary adjustments. Quality management will cover: content, products, organization, time, budget, and communication. For each component of the Future Cities Laboratory, a specific quality procedure will be defined based on milestones and deliverables, activity-specific risks and corrective actions. Key performance indicators have been provisionally identified in order to set benchmarks for the development of the work – in terms of quantitative and qualitative objectives. Those benchmarks will be further specified in collaboration with the advisory board upon the initiation of the project.

Research / Design
- Doctoral Research: approximately 36 dissertations (3 per research stream, over the duration of the Future Cities Laboratory program)
- Design Research Studios: approximately 90 students (15 students per design
research studio per semester – total of 30 students per year for a 3-year period)

- Urban Simulation Platform: Space with large interactive displays that will support the research efforts of the various projects and can subsequently be integrated to enrich local planning processes. The Future Cities Laboratory team will provide instruction and orientation for these new tools and software applications.

- R&D projects with local industries, agencies and authorities with expected cash funding for specific projects (a minimum of S$ 1 Million in private sector funding is set as a goal for the first 3 years).

Publications
- *Academic Articles and Journal publications – a minimum of* 24 are expected (2-3 per research stream)

- Conference Papers to be presented and published – approximately 48 (2-6 per research stream)

- Book Publications of scholarly work – approximately 6 books should be published at the international level

- Interim publications in the form of news pamplets will be published documenting the intermediate advances of the research and design work.

Academic Exchange / Public Outreach
- Design Reviews and Workshops with international guests, combined with small exhibitions, approximately 10 (2 per Design Research Studio per year, for a 5-year period)

- Public and recorded lectures at various venues linked to the Future Cities Laboratory by prominent members of the design and research communities.

- Various workshops will be held in Singapore, and Switzerland

- ETH will invite assistant, associate or full professors from NUS and NTU for mid-term (3-6 months) research stays in Switzerland.

- Exchange programs for interested Master and PhD students in the Architecture Departments of NUS, NTU and ETH.

- Public Exhibition with catalogue of work after the first three years. This exhibition will travel to leading universities and will aid in the dissemination of the findings of the Future Cities Laboratory. The funding of this exhibition is not included in our budget.

- International Conferences and Symposia, including proceedings – a total of 3 are being considered (2 in Singapore and 1 in Switzerland, each with 80-100 participants)

3.01 TIMEFRAME

In 2007 and 2008, a series of workshops were organized in Singapore and Zurich to identify the key members of the team. Based on an exchange of information on the state of urban research, a preliminary framework for the collaboration was established. Agreement was reached on the core disciplines of the program as well the role of ancillary fields of inquiry. The central themes, methods, and deliverables were outlined and a preliminary time frame established in view of the research objectives. The Future Cities Laboratory will begin in 2008/09 and develop along three partially overlapping tracks.

Track 1: from analysis to instant results 2008-2010

To accelerate the work progress, three parallel Design Research Laboratories will be launched in Singapore (in all probability at NUS), working with students and faculty in the three core disciplines outlined above: building technology, urban design, and territorial planning. In this phase, analysis and design are not to be treated as separate entities, but will be merged to instantaneously test potential findings. Current conditions in Singapore will be analyzed and directly translated into design propositions. While emphasis will be placed on design, fields of inquiry – necessitating further depth – will be identified within auxiliary disciplines and conducted as doctoral work. The preliminary results will be shown in an exhibition, accompanied by publications and a series of symposia, exposing methods and findings to the local community of experts.

Track 2: from the specific to the general 2009-2011

While the case studies of track 1 primarily pertain to Singapore, the second trajectory will compare the results to a series of parallel studies addressing other contexts and conditions. Such an approach mandates a more abstract understanding of basic principles that can be transferred to other places and regions of the world. Moving from the specific to the general, a thoroughly scientific agenda will guide the approach. In this phase of the work the design investigations will be directly informed by findings from subsidiary disciplines. Such a course of action will reframe the particular contributions for Singapore in view of common sets of rules for sustainable construction, urban design, and planning. These results will be presented at an international conference in Singapore, sharing the work with the top scholars in the field. A series of research papers are to be published in scientific journals.

Track 3: from research to implementation 2010-2013

The specific case studies (track 1) and general sustainability principles (track 2) will offer the grounds for the development of strategies to be pursued in collaboration with the public and the private sector. Implementation guidelines, assessment methods, and rating systems for sustainable cities, neighborhoods, and buildings are produced and evaluated. The modeling platform and urban tool box will be tested in the context of Singapore – with the involvement of local planning authorities and industry partners. Communication instruments using various visualization techniques will be presented. Strategies will be identified and recommendations made for their realization. Specific pilot projects will be designed, planned, and ultimately built. A series of events will be scheduled showcasing the work to the general public and the press. At this point, the future of the Future Cities Laboratory must be carefully planned and the necessary vectors set to be sustainably maintained.

The Future Cities Laboratory will be evaluated by an independent advisory board. Quality control will cover content, deliverables, organization, time, budget, and communication. For each component of the project, a procedure will be defined based on achieved milestones and quality performance indicators.

STRUCTURE & GOVERNANCE

4.00 OVERVIEW

The Future Cities program shares structure and governance with the EM&M Program.

SEC Legal Agreement

The Future Cities program will be implemented within the SEC Legal Agreement, covering the definition of all issues related to:

- IP protection, including the protection of (i) IP generated in the Future Cities program, (ii) pre-existing knowledge, (iii) IP generated during the program but outside of the program's activities, and (iv) IP generated after the program termination
- liability of the Program Leader and of the Lead PIs for activities conducted in Singapore
- severance and close-down clauses
- evaluation criteria and measures of success at SEC level
- legal implications related to the implementation of the program activities in Singapore

SEC Finance Plan

The Future Cities program will be implemented in accordance with the SEC Finance Plan, covering the operational implementation of the SEC and the relation with the participating institutions in the ETH domain.

Future Cities governing bodies and processes

The Future Cities Program is directed by a Program Leader. He/She reports to the SEC Director and to the SEC Governing Board, and is a member in the SEC Management Committee. He/she is in charge of the interlinked elements of research, infrastructure and faculty.

- The Future Cities Program will be structured in seven Priority Themes. Each Priority Theme will be guided by one or more Lead Principal Investigators.
- The Lead Principal Investigators and the Program Leader form the Program Committee, in charge of managing the program.
- The Program Consortium is formed by all PIs, and oversees the scientific definition of the research plan.
- The Visiting Committee, composed by renown specialists in the field, assists the Program Leader and the Program Committee in the implementation and yearly evaluation of the Future Cities program, in building up the research portfolio and in assessing its broader impact and visibility.
- The legal documents regulating all Future Cities program activities will be the Consortium Agreement and the Workplan. All PIs composing the Future Cities Consortium will sign the Consortium Agreement.

4.01 HIRING & MOBILITY

Hiring of faculty, research personnel & PhD students

- To complement and work closely together with the existing faculty and expertise in Singapore and ETH, new faculty – mainly emerging young leaders at the rank of assistant professors – can be hired temporarily within Future Cities, but only in full agreement with the strategic development plans of the institutions involved.
- Rights and responsibilities, as well as the long term consequences for faculty financed through Future Cities will be carefully defined and procedures established for faculty searches and hiring with participation from all relevant institutions. Faculty hired for Future Cities with an ETH affiliation will be selected and appointed following existing regulations and procedures at ETH institutions.
- Postdoctoral Fellows, engineers and technical personnel will be hired in Singapore and at ETH institutions, following the research activities approved in the Workplan.
- Doctoral students will be hired in Singapore and in Switzerland. Each PhD will be registered in one of the participating institutions, either in Singapore or in Switzerland, will be supervised by a local faculty member and will receive his/her degree according to the regulations of the own institution.
- Joint supervision of doctoral students by faculty members from Singapore and from an ETH institution will be encouraged. Temporary appointments of ETH faculties as associated members of the faculty at Singapore universities, and vice versa, will be considered, to strengthen the inter-school cooperation and to facilitate the joint supervision of doctoral students. Future Cities will work with the student administrations at universities in Singapore to facilitate the appointment of doctoral students supported by the Future Cities program, while adhering to the academic regulations.
- A structured program will allow individual distinguished scholars from participating institutes from Singapore and Switzerland as well as from other key institutions worldwide to actively collaborate in the research programs.
- The SEC Legal Agreement will protect the on-going signed contracts with PhD students, research personnel and temporary faculty appointments, at any time of the program and in case of close- down of the program.

Mobility

A key element for the success of the Future Cities program will be a structured mobility program, to facilitate the scientific exchange and participation of research personnel, faculties and graduate students. The mobility program will be facilitated by the SEC Logistics.

4.2 WORKPLAN

Future Cities Workplan and Consortium Agreement

The Workplan and the Consortium Agreement are the main instruments to govern the implementation of the Program.

• The Workplan and the Consortium Agreement will be prepared following the approval of the SEC Legal Agreement and Business Plan by NRF and the signature of the Future Cities proposal. They are submitted to the SEC Governing Board.

• The Workplan contains a detailed explanation of the proposed design research studios, experimental approaches, methods and expected results. For each Priority Theme, it provides a multi-year implementation plan and the roles of each participant (including doctoral students). It specifies appropriate ways and parameters to monitor the success and impact of the program. It indicates concrete and measurable milestones for each activity and for the whole program, and a synthetic description of the deliverables. It describes the timeline for the entire program and indicates major human resources, instruments, and infrastructure that are available to the participating partners and that are essential for achieving the goals of the program. It gives a description of the overall plan to disseminate, promote and exploit the knowledge derived from the program within and beyond the consortium, e.g. publications, patents, conferences, exhibitions, workshops and web-based activities.

• The Consortium Agreement is signed by the Principal Investigators, responsible for all research activities and the financial provisions. It describes how the project will be managed, the decision-making structure and procedures to be used, the distribution of rights and responsibilities, the communication flow within the Consortium and toward SEC, the mechanisms for approval of the yearly activities and budget within the approved Workplan. It contains in Annex the Workplan.

4.3 LOGISTICS

SEC Logistics

Future Cities will rely on the central SEC Logistics to cover all administrative functions having legal implications in Singapore as well as crosscutting activities relevant for all Programs. Among these:

• Accommodation, travel and logistical support to allow a smooth and successful participation of ETH faculty and researchers in Singapore-based activities and conversely the participation of for Singapore faculty and researchers in to participate in ETH-based activities.
• The residency program for participating ETH PIs.
• Personnel hiring and management.
• Administrative, financial, reporting, program evaluation and QA procedures.
• Facility management, where appropriate, for the building space used by Future Cities in Singapore, in cooperation with the local entity owning/operating said buildings.
• Organization of a structured mobility program to enable graduate students (Master and PhD) to spend exchange semesters and research periods as part of their curriculum at institutions in the other country.
• Coordination of outreach activities and public events, including an annual, highly visible Future Cities event, which will rotate between Switzerland and Singapore.
• Institutional contacts with NRF, the Swiss House Singapore, the Singapore universities, industry and other partners relevant for the Program development.

Future Cities Logistics

Future Cities will set up its dedicated management and logistics in Singapore and in Switzerland, to cover for internal program management and coordination.

RESEARCH TEAM

FUTURE CITIES LABORATORY CORE RESEARCH TEAM

PRINCIPAL INVESTIGATORS

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Prof. Dr. Michel Bierlaire
Prof. Dr. Markus Boller
Prof. Kees Christiaanse
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Prof. Dr. Armin Grün
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Future Cities Laboratory core research team, arranged by institutional affiliation.

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SINGAPORE AGENCIES

MINISTRY OF NATIONAL DEVELOPMENT (MND)

BUILDING AND CONSTRUCTION AUTHORITY (BCA)

HOUSING DEVELOPMENT BOARD (HDB)

MINSTRY OF THE ENVIRONMENT AND WATER RESOURCES (MEWR)

NATIONAL ENVIRONMENT AGENCY (NEA)

PUBLIC UTILITIES BOARD (PUB)

MARITIME AND PORT AUTHORITY (MPA)

DESIGN SINGAPORE COUNCIL

NANYANG WATER AND ENVIRONMENT RESEARCH INSTITUTE (NEWRI)

NUS ENVIRONMENT RESEARCH INSTITUTE (NERI)

CENTER FOR ENVIRONMENTAL SENSING AND MONITORING (CENSAM)

JTC CORPORATION

INDUSTRY PARTNERS

HOLCIM LTD

SIEMENS PTE LTD

INTELLISYS (Lim Hock Beng, representative)

We would like to thank the agencies for participating in the workshops in January 2008. We plan to organize semi-annual workshops in the future and define topics and platforms together with the involved parties. Depending on the interest we plan to set up an effective process to give inputs at any moment in time and to get access to the work in progress.

We would like to express our gratitude to the following colleagues for participating in the workshops and conversations necessary for developing this proposal. Once the project has been initiated, and in continued collaboration, the specific involvement of various colleagues will be further specified.

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Marc M. Angélil has been Full Professor of Architecture and Design at the Institute for Urban Design at ETH Zurich since 1997 and is responsible for first-year design classes in the Department of Architecture.
From 1982 to 1987 he was assistant professor at the Harvard University Graduate School of Design, and from 1987 to 1994 associate professor at the University of Southern California in Los Angeles. In 1994 he was named assistant professor of Architecture and Design at the ETH Zurich. His research activities deal with the contemporary developments in urban design. In addition to his academic activities, Marc M. Angélil is a practicing architect with his office agps architecture in Los Angeles and Zurich.

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Kay Axhausen has been Full Professor of Transport Planning at the Institute for Transport Planning and Systems (IVT) since 1999. He is currrently the director of the MSc course Spatial Development and Infrastructure Systems. Born 1958 he studied Civil Engineering at the Universität (TH) Karlsruhe and the University of Wisconsin, Madison from 1978-1984. He completed his doctoral dissertation at theUniversität (TH) Karlsruhe in 1988. Following a post as a research officer at the Transport Studies Unit (University of Oxford) he worked as a lecturer and senior lecturer in transport at the Imperial College of Science, Technology and Medicine, London from 1991. He was appointed to the chair in road transport at the Leopold-Franzens-Universität, Innsbruck in 1995.

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Prof. Dr. Michel Bierlaire

Michel Bierlaire holds a MSc and a PhD in Mathematical Sciences from the Facultés Universitaires Notre-Dame de la Paix, Namur, Belgium (University of Namur). Between 1995 and 1998, he was research associate and project manager at the Intelligent Transportation Systems Program of the Massachusetts Institute of Technology (Cambridge, Ma, USA). Between 1998 and 2006, he was a junior faculty in the Operations Research group ROSO within the Institute of Mathematics at EPFL. In 2006, he was appointed associate professor in the School of Architecture, Civil and Environmental Engineering at EPFL, where he became the director of the Transport and Mobility laboratory. His main expertise is in the design, development and applications of models and algorithms for the design, analysis and management of transportation systems. Namely, he has been active in demand modeling (discrete choice models, estimation of origin-destination matrices) and Dynamic Traffic Management Systems.

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Markus Boller is an environmental engineer focused on technical systems in urban water management. He received a Diploma degree from the ETH Zurich in Rural Engineering and Surveying in as well as a postgraduate Diploma from the Technical University of Delft in Sanitary Engineering. After completing his PhD at the ETH in Zurich he went on to become the head of the Engineering Science Department at Eawag from 1985 to 2000 and subsequently the heat of the department for urban water management where he has worked since 2000. He has taught many lectures and is interested in the development of novel concepts for water and wastewater treatment including the transfer of these into practical applications. He played a key role in the innovative systems designed and implemented in the Eawag Forum Kriesbach building, one of the most high performance buildings in Switzerland.

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Christiaanse studied Architecture at the Delft University of Technology where his graduation project was awarded the Berlage Flag. Between 1980 and 1989, Christiaanse worked for the Office for Metropolitan Architecture in Rotterdam, becoming a partner in 1983. In 1989, he started his own firm in Rotterdam, Ir. Kees Christiaanse Architects & Planners, which was renamed KCAP Architects & Planners in 2002. From 1996 until 2003 he was professor of Architecture and Urban Design at the Berlin University of Technology. He is currently a Professor of Urban Design at the ETH Zurich. He regularly acts as a jury member for international competitions, and is the author of several publications about architecture and urban design.

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Since October 1997 Andrea Deplazes has been Assistant Professor of Architecture and Construction in the Department of Architecture at the ETH Zurich and was elected Full Professor in 2002. He was the Dean of the Department of Architecture from 2005-2007 and is in charge of the second-year Construction Lecture Series and Design Studio. He is a partner in the architectural firm of Bearth & Deplazes in Chur. The firm is engaged in a broad spectrum of architectural design activities, including public and institutional projects, urban design, housing, and industrial buildings, with special focus on wood construction. Between 1989 and 1997, Andrea Deplazes was assistant professor of design and construction at the College of Technology in Chur. In research, his main interest was in prefabrication systems in wood.

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Prof. Armin Grün has been Full Professor of Photogrammetry at the Institute of Geodesy and Photogrammetry at the ETH Zurich since August 1984 and serves currently as Head of Institute. In his research he focuses on automatic and semiautomatic extraction of objects from aerial and satellite images, reality-based 3D city modeling, reality-based generation of VR/VE, 3D processing of high-resolution satellite imagery and UAV photogrammetry. He is editorial advisor for several scientific publications, has published over 350 articles and conference papers, is the author or co-author of more than 21 books and conference volumes, and has received numerous international awards and fellowships. Since July 2000 he is the Chairman of the International Scientific Advisory Committee of the International Society for Photogrammetry and Remote Sensing (ISPRS). He is also the co-founder of CyberCity Inc, a company specializing in the generation of 3D city models, with offices in Zurich and Los Angeles.

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Lino Guzzella has been full professor of thermotronics at ETH Zurich since 1999. He is the head of the Institute of Measurement and Control. After receiving his mechanical engineering diploma in 1981 and his doctoral degree in 1986 from ETH, he held several positions in industry and academia. With his group he focuses in research on novel approaches in system dynamics and control of energy conversion systems. Prof. Guzzella has received numerous awards and has published more than 100 research articles as well as two textbooks. Prof. Guzzella is editor of the IFAC Control Engineering Practice Journal and was associate editor of several other journals. He is also a member of many international and national research committees and is a consultant to several tier-one automotive companies and holds patents in that area.

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Janet Hering, born in 1958 in the USA, received degrees from Cornell and Harvard Universities in chemistry before getting her PhD at MIT in 1988 in oceanography. She went on to become Professor of Environmental Science and Engineering at the California Institute of Technology (Caltech) and Executive Officer at Keck Laboratories for Bioengineering. She became director of Eawag in January 2007 as well as a Professor of Environmental Biogeochemistry in the Department of Civil, Environmental, and Geomatic Engineering at the ETH Zurich. Janet Hering specialises in water treatment techniques, and in the biogeochemical behaviour of trace metals. Janet Hering was a member of the editorial advisory board of the journal "Environmental Science and Technology" and is herself the author diverse publications in major scientific journals as well as books, proceedings, and reports. She has been the recipient of numerous awards and served on many evaluation committees. Along with her research credentials, Janet Hering is also involved in consulting work and she holds an patent in environmental technology.

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Ludger Hovestadt has been full professor for architecture and CAAD since July 1, 2000. He studied architecture at the RWTH Aachen (D) and the HfG in Vienna (A) under Prof. Holzbauer. Upon completion of his diploma in 1987, he worked as a scientific researcher with Prof. F. Haller and Prof. N. Kohler at the Technical University Karlsruhe (D) where he received his doctorate in 1994. Between 1997 and 2000, Dr. Hovestadt was a visiting professor for the department CAAD at the University of Kaiserslautern (D). His research projects are therefore not technological experiments e.g. Virtual Reality, but look for a historical anchor and show a concrete use for current building practice. However, they do not lose the character of basic research in the specific research landscape of architecture and building industry. To increase the effect of his research, Ludger Hovestadt is co-founder of several companies, and thus receives important feedback.

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Vittorio Magnago Lampugnani has been Full Professor of the History of Urban Design at the Swiss Federal Institute of Technology in Zurich since 1994 where he was dean of the faculty from 1998 - 2001. He has held positions at Harvard University, the University of Navarra and the Politecnico in Milan. Prof. Lampugnani served as the director of the German Architecture Museum in Frankfurt am Main from 1990-1995 and has organized several exhibitions, symposia and conference series. Since 2000 he has been a member of the editorial committee of „The Harvard Design Magazine" and was the editor of Domus from 1990 – 1995. Many of his architectural publications have been translated into English including: Architecture of the 20th century in Drawings, Architecture and City Planning in the 20th century; Encyclopaedia of 20th Century Architecture; and Museums for a New Millenium. Concepts, Projects, Buildings (with Angeli Sachs). Prof. Lampugnani has had his own architectural practice since 1980 whose projects include the urban design for the Novartis Campus in Basel, Switzerland.

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Hansjürg Leibundgut has been Professor of Building Services at the Institute of Building Technology of the ETH Zurich since September 2005. After 4 years' industrial experience in the R&D sector of absorption refrigeration technology, he transferred to Zurich's cantonal administration and was soon appointed to a senior position with responsibility for energy, air quality and technology in 1,500 public buildings. In 1989, he returned to the private sector and became partner and senior engineer with Amstein + Walthert AG. Within this company, he developed the specialist areas of HLKSE (HVAC, plumbing and electricity = house technology), facility management, dynamic building simulation, etc. and supervised more than 100 projects for a wide variety of architects. Due to a lack of suitable construction components, he developed various new products in conjunction with Swiss industrial partners.

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Christian Schmid has been a lecturer for sociology at the ETH Zurich Department of Architecture since 2001. Since 1999, he has been scientific researcher at the ETH Studio Basel (Prof. Roger Diener, Prof. Jacques Herzog, Prof. Marcel Meili, Prof. Pierre de Meuron) and was the scientific director of the research project „A Portrait of Urban Switzerland" and co-author of the supporting publication in 2005. He received his PhD at the Institute of Geography of the University of Jena for his research on Henri Lefebvre. He has organized several conferences and research projects including the 7th INURA conference „Possible Urban Worlds." He recently was a co-editor of the publication *Space, Difference, Everyday Life: Reading Henri Lefebvre* (Routledge 2008).

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Gerhard Schmitt is Professor for Architecture and Information Architecture at ETH Zurich. As Vice President for Planning and Logistics, he directs the development of ETH's strategy and planning. He is responsible for Human Resources and for providing the infrastructure for ETH's 8'800 employees and 13'500 students in more than 200 buildings on two major campuses. In 2003, he initiated the concept for Science City, ETH's new campus in Zurich; in 2004, the development of the master plan, and in 2006 an international competition for its urban design concept. Gerhard Schmitt established the Computer Aided Architectural Design (CAAD) curriculum, research program and infrastructure at ETH since 1988. He taught Computer-Aided Architectural Design and conducted CAAD research at Carnegie Mellon University from 1984 to 1988 and was Visiting Professor at the GSD at Harvard University from 1993 to 1994.

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Luc Van Gool is a Full Professor at ETH Zurich since the fall of 1998. He is head of the Computer Vision Laboratory. In 1991 he became an assistant professor at the University of Leuven and in 1996, full professor. In 1998 he became a full professor at the ETH in Zuerich, where he now also is the head of the Computer Vision group at the department of Electrical Engineering. With his research teams, Luc Van Gool is a partner in several national and international projects that range from fundamental research to application-driven developments. His major research interests include 2D and 3D object recognition, texture analysis, range acquisition, stereo-vision, robot vision, and optical flow. Luc Van Gool has been a member of the program committees of several leading international conferences, including the ICCV, ECCV, and CVPR. In 1998 he received a David Marr Prize at the International Conference on Computer Vision. He is also a cofounder and director of the company Eyetronics, that specialises on 3D modeling and animation, mainly for the entertainment industry and medical applications. The „ShapeSnatcher‘ product received one of the EU „EITP“ prizes.in 1998.

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Remo Burkhard studied architecture at ETH with a specialization in urban design. At the ETH he wrote a PhD thesis on Knowledge Visualization. He was co-author of the ETH Science City Project and involved in the Strategic Planning Process 2008-2011 of the ETH Zurich. He was a Project Manager at the University of St. Gallen, a business university, in the Institute for Media and Communications Management and was consulting leading industries on knowledge management and interactive digital media. This competence center was 100 percent financed through research projects and third party funds. Remo Burkhard is also founding partner of a company with eleven employees and a market leader in Switzerland when it comes to visualize knowledge. In his company he was involved in three larger urban design and city planning projects for the city of Davos.

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Jan Halatsch graduated from the Technical University of Dresden in 2004. He works with computer graphics for his current postgraduate masters in Computer and Information Science at the University of Konstanz. Since 2006 Jan holds a position as a research and teaching assistant at the Chair for Information Architecture. He is a project manager for the Value Lab at the ETH Zurich. As an information architect Jan gained working experience in various architecture and media related fields. He is also a feature writer for the digital content creation magazine Digital Production. He is currently working, teaching and publishing shape-grammar-based modeling, crowd simulation and design theory related to knowledge architecture and to sustainable architecture.

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Dirk Hebel is currently teaching at the chair of Prof. Marc Angélil at the Department of Architecture of the ETH. He has also been visiting professor at the American University of Sharjah, Syracuse University, and Princeton University. His research at the Department and the Institute of Urban Design addresses both the city and the human body as socio-biological constructs in order to develop new modes of inquiry into the urban field. Dirk Hebel also practices architecture with his firm, INSTANT, founded in 2002 with his partner Jörg Stollmann. INSTANT works at the intersection of architecture, nature, technology and communication. Recent projects include the award winning project UNITED_BOTTLE, the international traveling exhibition "INVENTIONEERING_ARCHITECTURE" and the installation "ON_AIR" in Berlin.
In 2007 INSTANT received the Van Alen Institute Fellowship Award, the Red Dot Design Award for Best Conceptual Design and the LANXESS Award Singapore.

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Kerstin Hoeger is lecturer and senior researcher at ETH Zurich's Institute for Urban Design. She studied architecture at TU Berlin, MIT, and Harvard's GSD. In addition to her practical work, she has been teaching studios, seminars, and master classes at ETH Zurich since 1999. In her present design and research, she focuses on campus planning, corporate urbanism, and urban (re)activation projects. She is author of the book 'Campus and the City' (2007) and currently works on the publication 'Branding and the City'. Hoeger has been a regular speaker at international conferences as well as guest lecturer, critic and consultant at many public and private institutions.

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Jesse LeCavalier holds a Bachelor of Arts from Brown University and a Master of Architecture from the University of California, Berkeley. He is currently pursuing a doctoral degree at the Swiss Federal Institute of Technology Zürich and teaching the 1st Year Design Studio. Before coming to the ETH, he spent two years working at agps architecture in Los Angeles and was primarily involved with the design of the new Children's Museum of Los Angeles. While an architecture student, Jesse LeCavalier was the recipient of the John K. Branner Traveling Fellowship and the Norman Patterson Prize. As student at Brown University, he graduated magna cum laude and also received several awards. Aside from his current research and teaching, he is also a contributor to different architectural publications including the Swiss journal architheses.

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Forrest Meggers

Forrest Meggers studied physics and mechanical engineering at the University of Iowa, graduating with high distinction in May, 2003 with a Bachelor of Science in Engineering in the field of Mechanical Engineering. In May 2005 he received his Master of Science in Environmental Engineering with a thesis completed on sustainable building technologies. As a result of collaboration on his thesis project, he took a research position at Columbia University working for Dr. James Hansen at NASA Goddard Institute for Space Studies on potential greenhouse gas emission reductions from changes in building technologies.
In the fall of 2005, Forrest Meggers became a co-author on a book on global change and sustainability with former advisor, Jerry Schnoor, and President of the ETH Board, Alexander J.B. Zehnder in Zurich, Switzerland. With Prof. Hansjürg Leibundgut he began his PhD at the ETH in the Chair of Building Systems of the Insitute for Building Technologies. He is also a member of the United States Green Building Council where he serves on the Education Steering Committee and he is a LEED Accredited Professional.

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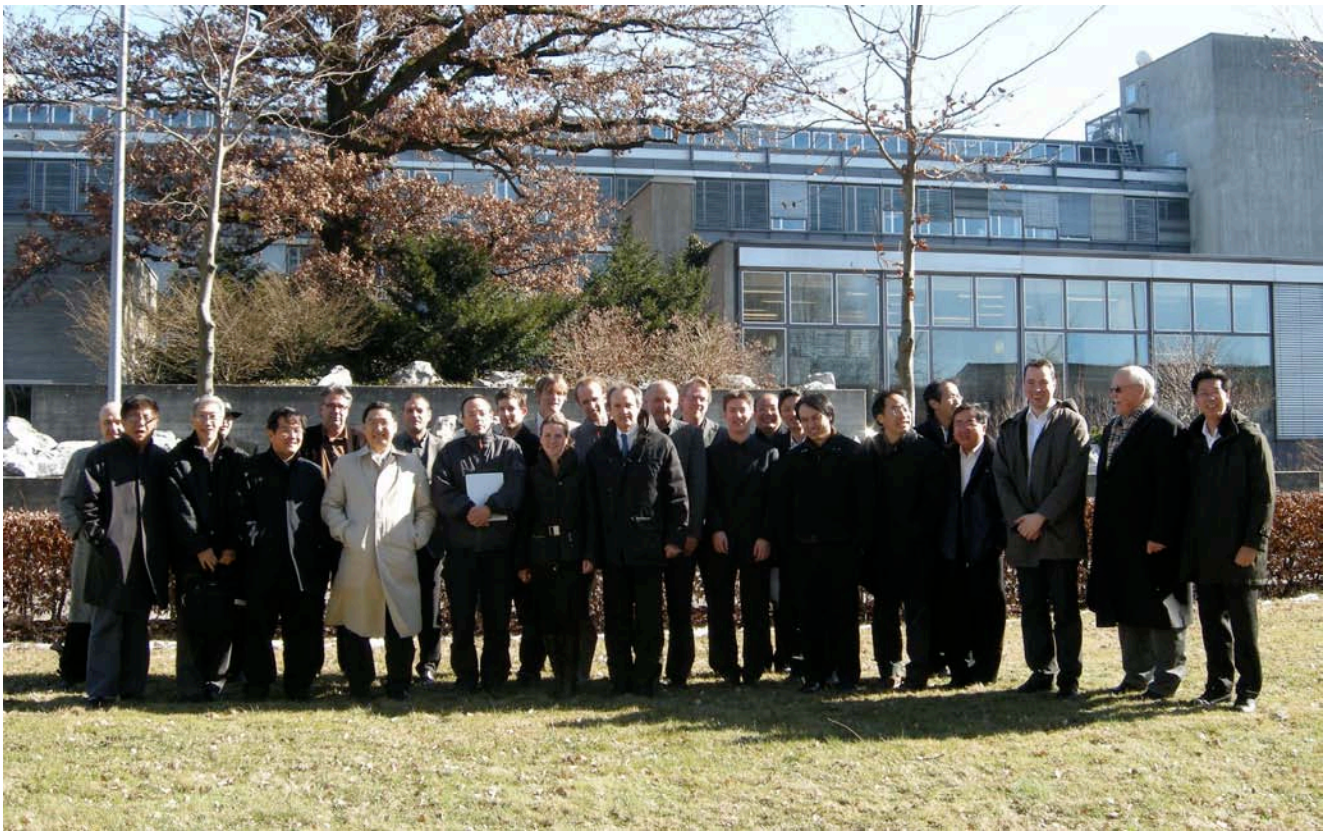

SEC Workshop, Zuerich 03/2008, Team Photo

SEC Workshop, Zuerich 03/2008, Sience City Construction Site