

AGS Urban Futures Seminar

ETH Zurich, Switzerland

Understanding
the Dimensions of
Urban Futures
Research: Tackling
Complex Reality





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Contents

Introduction to the AGS Urban Futures initiative

An ecologist's view on urban complexity 3

Peter Edwards, AGS Faculty Coordinator at ETH Zurich

New approaches to understanding complexity

Science of cities = Big science 5

Adrienne Grêt-Regamey, Planning of Landscape and
Urban Systems (PLUS), ETH Zurich

Case studies of interdisciplinary research projects on urban futures: process and lessons learned

Research in water and sanitation for developing countries 7

Christoph Lüthi, Swiss Federal Institute of Aquatic Science and
Technology (Eawag)

Developing strategies to maintain landscape qualities 9

with urban growth: a case study from Switzerland

Silvia Tobias, Swiss Federal Institute of Forest, Snow, and
Landscape (WSL)

Complexity, sustainability, and the city-computable? 12

Darren Robinson, Solar Energy and Building Physics Lab, EPF

Interdisciplinary dialogue on urban futures

Tools from transdisciplinary research 16

Christian Pohl, Transdisciplinarity-Net and ETH Zurich

Working Group: Migrants and the city 18

Working Group: Basic human needs 20

Working Group: Utopian (sustainable) city 22

Working Group: Landscape protection 24



Understanding the Dimensions of Urban Futures Research: Tackling Complex Reality

The Alliance for Global Sustainability (AGS) has highlighted the theme of “Urban Futures” as a focus for collaboration, and this seminar is part of a series of five seminars hosted by the four AGS universities during 2008 and 2009 (www.theags.org).

This seminar aimed to illustrate the dimensions of research that tackles the complex reality of urban futures, in order to achieve a better understanding of how interdisciplinary research must be designed and carried out, using examples from the ETH domain. Cities are habitats, resource sinks, cultural centres, economic hubs, designed spaces, networks, political powers, and ecosystems. All too often, these different aspects are studied in isolation, but to achieve sustainable development we need to integrate these different models. The aims of the seminar were to discuss new research approaches toward understanding urban systems, and to learn from previous projects that have attempted to bridge the disciplines.

The seminar also reported on the results of the AGS workshop “Interdisciplinary Dialogue on Urban Futures”. The workshop was designed to assess and initiate interdisciplinary research within the context of urban sustainability. Experts from various disciplines, such as architecture, economics, social sciences, engineering, and ecology, were invited to participate in an exercise in interdisciplinary problem framing with the focal topic of sustainable urban development. At the workshop, participants brainstormed, mapped, and framed a selection of problem issues. Prepared case studies and questions were used to “catalyse” the discussion. Four working groups came together based on these questions, and deepened their analysis using methods and tools from transdisciplinary research. The workshop was facilitated by Christian Pohl, an expert in transdisciplinary research. The methods they used and the results of their discussions are included in this report.

All the presenters and workshop participants are researching in the universities (ETH, EPFL) and research institutes (WSL, PSI, Empa and Eawag) of the ETH Domain, and they all welcome questions and comments from the other AGS universities. You will find their biographies and contact details in this report.



Dr. Peter Edwards is the professor of plant ecology at the Institute of Integrative Biology, in the Department of Environmental Science at the ETH, and he is the AGS Faculty Coordinator at the ETH. Dr. Edwards' main research focuses include: increasing understanding of biological invasions, conservation of species, and sustainable management of ecosystems.

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Introduction to the AGS Urban Futures initiative

An ecologists view on urban complexity

The population shift facing the world is an epoch-making process. Today, around half of the world's population lives in urban areas. By the year 2050, the proportion in urban regions is expected to grow to 70%, and the total urban population will have doubled. Cities will grow in size and number. Is this level of growth a recipe for chaos or our best hope for achieving global sustainability?

It is clear that no one scientific discipline has all the answers, but that the viewpoints of different disciplines must be combined. I am an ecologist, and ecologists analyse the urban environment as an ecosystem. Two characteristics of ecosystems are nutrient cycling and the influence of infectious diseases, and these examples illustrate how ecological ideas can contribute to understanding and meeting the challenge of urban population growth.

Most natural ecosystems are characterised by a closed nutrient cycle, in which the nutrients that plants and animals need are recycled within the system and only very small amounts are lost into other systems. Natural ecosystems that are dependent on external inputs and lose a lot of nutrients to other ecosystems are generally unstable - and therefore are not sustainable. Cities are characterized by such largely open nutrient cycles—they are dependant on large inputs of food from distant areas and dispose of large quantities of waste into surrounding areas. This huge quantity of nutrients being taken out of agricultural areas, transported to cities, and then rapidly transferred to the sea, is leading to severe environmental problems. For example, off the coasts of urban areas around the world, the oxygen depletion and eutrophication caused by these nutrients lead to marine dead zones¹. Meeting the challenge of how to close the nutrient cycles of cities will require an ecological understanding.

Another important ecological consideration is the threat of infectious diseases. Cities have an enormous impact on the epidemiology of human diseases. Highly contagious diseases require large, dense populations of hosts to continue to exist in their virulent form. In small populations, individuals either die or develop immunity, and eventually the virulent form of the disease disappears. In large, dense, mobile populations, the rates of immigration and births ensure that there are always susceptible people to act as reservoirs. For example, a study of measles in the UK shows how outbreaks of infection spread from cities into rural areas, then disappear². Until the next outbreak, the disease can only persist in cities with populations above 200 to 500 thousand. Without the high population density of cities, some diseases would not exist.

A number of further ecological characteristics make cities places where established diseases can evolve, and new diseases emerge. These include close contact of humans with animals and animal diseases in peri-urban areas, reduced natural control of disease vectors such as mosquitoes or rats in the

¹ Mee, L. (2006) Reviving dead zones. *Scientific American* 295(5): 78-85.

² Grenfell, B.T., Bjørnstad, O.N. and Kappey, J. (2004) Travelling waves and spatial hierarchies in measles epidemics. *Nature* 414: 716-723.

highly simplified ecological communities in the urban environment, and high human mobility that brings together new genetic information to which diseases adapt. As urban populations grow, infectious diseases will continue to provide us with new challenges.

To conclude, if science is to tackle the complexity of cities, we need intensive interdisciplinary and transdisciplinary discussion. The growth of cities presents many problems, none of which is the domain of any one discipline. We will need close cooperation between a wide range of disciplines. The research and discussions presented at the AGS Urban Futures seminar highlight examples of how this has been done.



Adrienne Grêt-Regamey was recently appointed to the chair of spatial planning at the ETH, and is currently building up her research group Planning of Landscape and Urban Systems (PLUS). PLUS concentrates on integrating the goals of sustainable development, economic viability, and good governance in spatial planning. Specific aspects of her research include: inverse model methods in landscape and environmental planning, integration of environmental concerns in spatial planning processes (e.g. the value of ecosystem services), risk-based decision-making for landscape and urban development, and participatory approaches in landscape and environmental planning (including visualization tools).

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New approaches to understanding complexity

Science of Cities = Big Science

The world is facing a doubling of the urban population within the next fifty years, leading to a world where three out of five people live in cities. Today, one in six people live in shanty towns or slums and suffer from disease, unemployment, and poverty. Despite these huge challenges for humanity, the science of cities has not been recognized as a 'big science', unlike for example biological science or physics. However, just as biological science underpins human health, the science of cities underpins the overall well-being of humanity.

The complexity of a city can be grasped by applying four levels of analysis that form a framework for all aspects of urban research: system articulation, theory development, methods, and application in management and planning³. System articulation encompasses the identification of the entities, the spatial representations, and the scales of resolution of urban information. Once these system features have been identified, patterns can be determined and represented as a theory. This theory can then be operationalized using a range of methods and tools. Finally, theory and methods must be validated, and the insights applied to management and planning.

System articulation begins with identifying entities. Cities are made up of infrastructures that are both the product and carrier of the activity of humans, households, and organizations. These physical and social entities can be analyzed by either function or spatial ranges or by both dimensions together. For each defined entity, the maximum level of resolution, both in space and time, is set by the available data. The third step of system articulation is to determine the spatial representation of the entity, for example as a continuous gradient or flow, or as discontinuous nodes, networks, or points. The system articulation responds to a specific research question. For example, housing quality can be analyzed either from the social dimension using networks, or from the ecological dimension in the form of a point pattern. It must be kept in mind that this articulated system is only a selection out of the bigger framework of the whole city system, and will not give an answer to the entire system. Certain phenomena will only be revealed at certain system levels and not at others.

From the system articulation, patterns can be identified and represented in a theory. Once a pattern is identified, its marginal rate of change can be determined, and built into a theory. The theory should be able to model the pattern and predict the change in the pattern over time. A range of tools and methods with different levels of complexity and data requirements can then be used to operationalize the theory. Methods can either describe the system or analyze it statistically in order to produce a mathematical model. Once the system model or description has been developed, it must be validated, so that the results can be integrated into policy (i.e. defining desired goals) and design (i.e. the planning process).

³ Wilson, Alan G. (2000) *Complex Spatial Systems: The Modeling Foundations of Urban and Regional Analysis*. Prentice Hall, New Jersey.

A number of approaches that attempt to develop new forms of system articulation, theory development, and methods in other disciplines can be applied to the analysis of cities. An example of a new system articulation is the net view of agglomeration economies in Switzerland, in which a spatially intelligent development of economic activities reduces transport costs and brings benefits to the networked centres⁴. A new approach to theory is the index for urban permeation developed by Jaeger et al.⁵, which classifies how much of a landscape is interspersed with urban settlement areas. One example of a new method is the use of agent modeling to analyze landscapes⁶, for example modeling the behavior of hikers in a landscape according to their reactions to landscape parameters. This approach can also be applied, for example, to model human reactions to safety measures.

Adrienne Grêt-Regamey is using integrative approaches to system articulation, theory development, and methods in the PLUS approach. The PLUS system articulation integrates ecosystem services, such as nutrient cycling, into planning. For example, the inclusion of avalanche protection, soil infiltration, and biodiversity value into the planning of settlement expansion of a Swiss alpine village resulted in a redefinition of the desired building zones around the village⁷. The PLUS approach also uses inverse modeling techniques taken from atmospheric physics. Scenarios of possible desired futures of cities offer starting points for inverse modeling, with the goal of defining the actual boundary conditions that are necessary to reach these future states.

One obstacle for modeling a complex system such as a city is the continuous integration of new information. Oceanographers have developed data assimilation techniques to continually integrate new information into current models. PLUS is investigating if similar techniques can also be applied to the science of cities.

As an emerging science, the science of cities is faced with numerous research challenges. Methods and approaches currently used in other disciplines offer promising tools to try to understand the complexity of city systems.

⁴ Oswald, F. & Baccini, P. (2003) *Netzstadt: Einführung in das Stadtentwerfen*. Birkhäuser – Verlag für Architektur, Basel.

⁵ Jaeger, J., Schwick, C., Bertiller, R., Kienast, F. (2008) *Landschaftszersiedelung Schweiz – Quantitative Analyse 1935 bis 2002 und Folgerungen für die Raumplanung*. Wissenschaftlicher Abschlussbericht. Schweizerischer Nationalfonds, Nationales Forschungsprogramm NFP 54 “Nachhaltige Siedlungs- und Infrastrukturentwicklung”. Zurich, 344 pp.

⁶ Cavens, D., Lange, E., Schmid, W. (2003) *Virtual Alpine Landscapes and Autonomous Agents*. In: Buhmann, E. and Ervin, S. (eds.) *Trends in Landscape Modelling*. Wichmann Verlag, Heidelberg.

⁷ Gret-Regamey, A., Bebi, P., Bishop, I.D. & Schmid, W. (2008) *Linking GIS-based models to value ecosystem services in an Alpine region*. *Journal of Environmental Management* 89: 197-208.



Christoph Lüthi leads the Strategic Environmental Sanitation Planning Group at the Swiss Federal Institute of Aquatic Science and Technology (Eawag). His research includes validation of the household-centered environmental sanitation approach (HCES), development of the material flux analysis (MFA) tool for waste management systems, and testing a new method for sanitation planning that links MFA and QMRA (quantitative microbiological risk assessment). His specific research interests are urban strategic sanitation planning, servicing unplanned urban and peri-urban areas, and stakeholder involvement in planning and implementation.

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Case studies of interdisciplinary research projects on urban futures: process and lessons learned

Research in Water and Sanitation for Developing Countries

Sandec—the Department of Water and Sanitation in Developing Countries at the Swiss Federal Institute of Aquatic Science & Technology (Eawag)—researches effective implementation of point-of-use water treatment, excreta management, solid waste management, and strategic sanitation planning in the developing world. Sandec’s goals are to design and validate new concepts and technologies in water supply and environmental sanitation, improve existing research and expertise in the field of water supply and environmental sanitation in low and middle-income countries, and increase awareness of and expertise in water supply and environmental sanitation issues that face low and middle-income countries. Sandec’s research is transformational in nature. Most of Sandec’s research is conducted in Asia and Africa and aims to improve knowledge of how to realize transitions to a desired situation by transforming how sanitation practices are planned for and implemented.

Implementing adequate sanitation is a global problem, but is significantly more urgent in developing countries. The urban poverty cycle leaves sanitation to local officials or individual households. Improved sanitation coverage is one of the big laggards in the United Nations Millennium Development Goals.⁸ Approximately 2.6 billion people, about one third of the current world population, do not have access to public water or sewer systems. This lack of proper sanitation is responsible for most infectious disease and child mortality, greatly affecting impoverished populations in developing countries. While there are significant sanitation deficiencies in Asia, African countries are the most vulnerable. The research challenge is how to effectively improve current sanitation practices with the implementation of more cost-effective and sustainable sanitation methods from the household to treatment and disposal.

Countless NGO projects have invested significant amounts in failed sanitation projects throughout the developing world. This highlights the need for alternative approaches to planning and implementation that frame solutions to the sanitation problem within the context of sustainability. A specific project conducted by Sandec in Chang’ombe in Tanzania helps outline important lessons for successfully executing transdisciplinary research. Chang’ombe is the largest shantytown in Dodoma, Tanzania, with about 35,000 people and a population density of 211 person/ha. However, the area is subject to rapid migration from outskirts and rural areas. The initial sanitation situation in Chang’ombe was rudimentary and of very poor quality.

In Chang’ombe, Sandec sought to improve sanitation conditions by installing prototype latrines, and strengthen resilience to urban sanitation problems through involvement of stakeholders in planning, construction, and management.

⁸ United Nations (2008) Millennium Development Goals Report. United Nations, New York.
www.un.org/millenniumgoals/

During the twelve month process, we developed and tested a planning tool to improve sustainability of future sanitation interventions. To achieve its goals, the project integrated interdisciplinary groups, such as social planners, anthropologists, and sanitary engineers. If you do not frame your research and select your research carefully, things can go wrong.

Lesson learned: Choose your research partners carefully!

To guarantee the information flow throughout the project, we ensured there was a clear understanding between the involved organizations and team members as to who was responsible for which portions of research, and who was in charge of the project on the ground.



Lesson learned: Develop the research proposal jointly and agree on a clear communication strategy!

Our method employed a three-part process. Prior to starting construction, we conducted a baseline survey to assess the current sanitation situation and motivations for improving sanitation at household level. This survey was directly followed by construction of the prototype latrines. We selected three options for latrine products, ranging in cost from US\$ 80 to US\$ 300: the Arbor loo, the ventilated improved pit latrine, and the Ecosan toilet.⁹ These products were chosen for their foundation in sustainability: all three satisfy the criteria for human health and affordability, and the Ecosan toilet also recovers the nutrient resources for use in urban agriculture. Individuals were able to select the latrine which best suited their situation, and they were built by local masons and local groups, which kept costs at a minimum. Following construction and use of the latrines, we surveyed the citizens to judge users' motivations and preferences. During the survey confusion in terminology between engineers and social scientists led to a large amount of unusable information and poor statistics.

Surveys were conducted to assess the current sanitation situation and motivations for improving sanitation at the household level.

Lesson learned: Fine-tune the language of engineers and social scientists!

In the final stage of the research project, we devised a participatory planning tool that builds on informed decisions of the community. Sandec has been holding workshops to test the new sanitation planning strategy in other locations around the world. The workshops help improve locals' understanding of the sanitation chain from the toilet to disposal and reuse, while providing information to local authorities and NGOs about improvement and implementation of effective sanitation strategies.

Lesson learned: Allow time for strengthening of partner researchers and research institution capacities!

⁹ Tilley, E., Lüthi, C., Morel, A., Zurbrügg, C., Schertenleib, R. (2008) Compendium of Sanitation Systems and Technologies. Eawag, Dübendorf. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_sesp/downloads_sesp/compendium_high.pdf



Silvia Tobias heads the research focus 'Land Resources Management in Peri-Urban Environments' at the Swiss Federal Institute for Forest, Snow, and Landscape Research (WSL). Dr. Tobias' research examines the bio-physical and socio-economic prerequisites for sustainable land use in peri-urban regions and uses them to provide comprehensive decision support for land use negotiations. She is specifically interested in optimizing land use with respect to ecological, economic, and social values, evaluating consequences of mechanical impact on soils resulting from land use, and identifying the mechanical effect of living plant roots on land slide prevention.

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Case studies of interdisciplinary research projects on urban futures: process and lessons learned

Developing Strategies to Maintain Landscape Qualities with Urban Growth: a Case Study from Switzerland

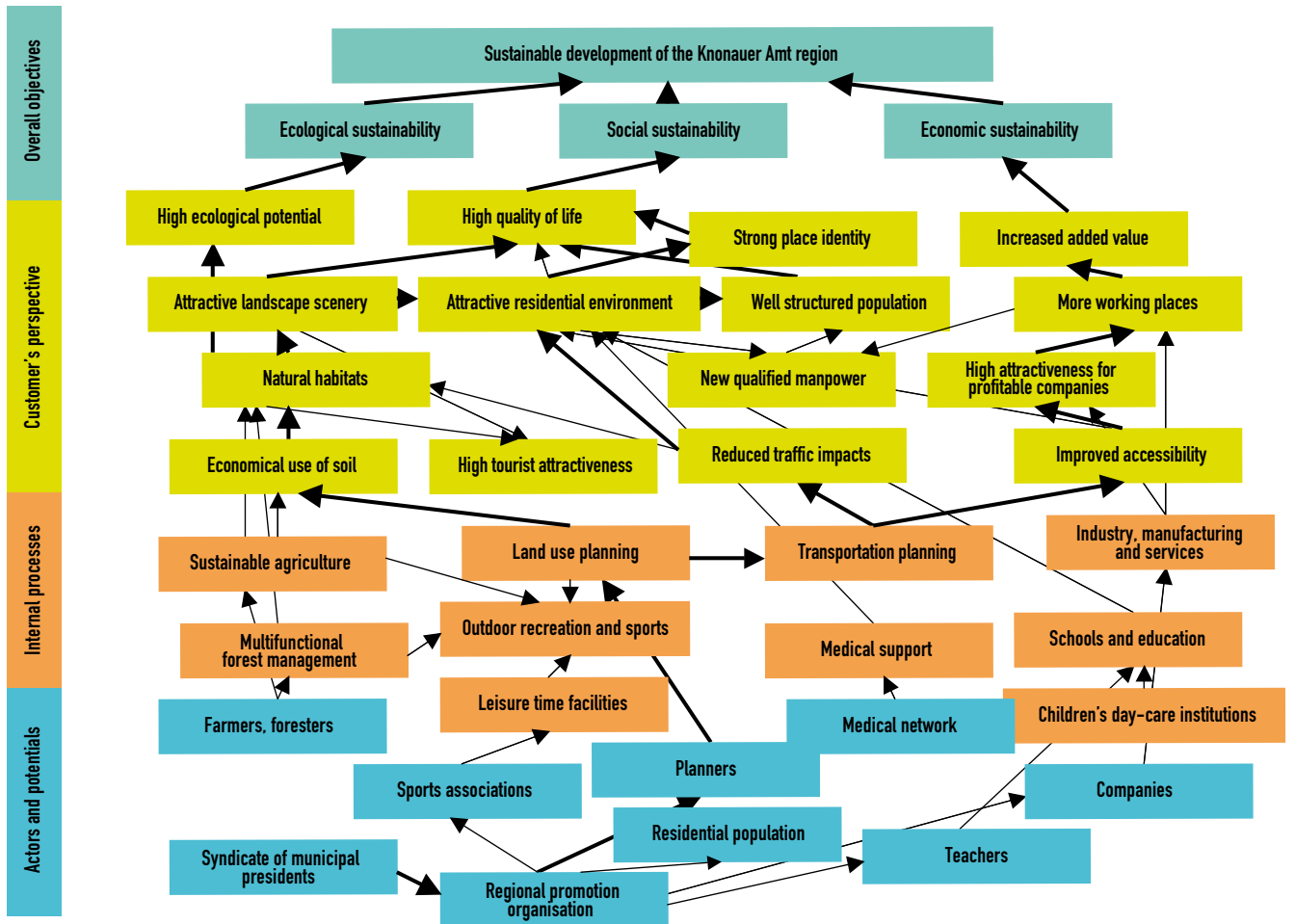
The research program "Land resources management in peri-urban environments" at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) conducts research to develop new strategies, planning instruments, and decision support for sustainable land use in peri-urban regions. Between 2002 and 2007, 23 multi-disciplinary research projects from the WSL, EPFL, and other universities within Switzerland worked in the case study region on the program's four objectives: 1) to determine societal demands on peri-urban landscapes and identify effective negotiation processes; 2) to delineate how to value and steer landscape development; 3) to determine the forces driving landscape change; and 4) to assess the effects of landscape changes on humans, and on wild flora and fauna.

The case study region is the Knonauer Amt, a rural landscape in the southwest of the Canton of Zurich. It lies geographically close to the city of Zurich and is composed of 14 municipalities with 42,200 inhabitants and 12,000 workplaces. Currently, a highway construction project is underway, and the region expects economic profit from the improved accessibility that the highway will bring. However the region also hopes to maintain its balanced population structure, high quality of life, rural landscape, and ecological value, all while promoting the region to visitors. The need for an interdisciplinary solution is inherent in such a complex goal. By involving regional stakeholders, the researchers were able to build a strategy map for the region that integrated the interests of regional players and the research knowledge into a sustainability plan for the region.¹⁰

Strategy maps were originally used in business administration¹¹. They consist of four hierarchical levels: objectives, customer's perspectives, internal processes, and potential players. These are easily adapted to regional planning and sustainable development issues, where the objective is sustainable development, the customer's perspective is the image of the region through the eyes of residents and potential new residents, the internal process is the land use management process, and the potential players are the residents, developers, and users of the region. Because a strategy map is read from bottom to top, it starts with the potential players, and so emphasises stakeholder involvement. The question behind the strategy map is: How should the players in the region organize themselves in order to optimize the land use and planning processes within the region so that

¹⁰ Tobias, S. & Tietje, O. (2008). Eine Strategiekarte für die nachhaltige Entwicklung im Knonauer Amt—Synthese des Forschungsprogramms 'Landschaft im Ballungsraum'. In: Tobias, S. (ed.) (2008) Ballungsräume für Mensch und Natur. Forum für Wissen 2008. Conference proceedings. WSL, Birmensdorf.

¹¹ Kaplan, R.S. & Norton, D.P. (2004) Strategy Maps. Der Weg von immateriellen Werten zum materiellen Erfolg Schäffer-Poeschel, Stuttgart.



Strategy Map of Knonauer Amt. Bold arrows indicate intended effects.

the indicators of the customer’s perspective show high performance in the direction of sustainable development?¹²

The parameters of the strategy map were initially brainstormed by the members of the syndicate of local municipalities. Then in a collaborative workshop with the researchers, the municipality representatives connected the levels of information. The map itself does not model how the current system functions, but highlights the pathways that will reach the intended effects. For example, sustainable agriculture will improve the use of soil, which again has a positive effect on preserving natural habitats, which enhances the attractiveness of the landscape, influencing quality of life. Research findings from the research projects were incorporated into the strategy map and used to derive performance indicators for the parameters. For example, results on the impact of landscape fragmentation on genetic diversity in species showed that natural habitat size was more important than spatial separation for maintaining diversity, so natural habitat size was selected as the indicator. The analysis enabled the identification of synergies between different research findings, reinforcing the power of the performance indicators. Several research projects highlighted that the inclusion of local residents in the planning processes in their region enhances their identity with

¹² Tietje, O. (2008) Strategy Maps—Orientation within the Landscape of Possibilities. SystAim GmbH, www.scrategy.ch

the region, which in turn enhances their quality of life. This linkage had not been considered by the municipal representatives, so was a useful new input into the discussions.

Strategy maps are effective tools for regional development because they help clarify the contributions of all the relevant players, and support communication amongst the stakeholders. In this way they are useful in convincing players to commit themselves to taking action. Strategy maps also have great potential as tools for interdisciplinary research because they create a clear path for communication between science and practice. The map makes scientific findings interpretable and usable for practitioners at the same time as showing stakeholders' requirements and needs to the scientists. Finally, the map is an effective approach to the synthesis of a multi-disciplinary research program because it shows the implementation of each component project in a new context, enables the integration of quantitative and qualitative information, and reveals the synergies between different research projects that may otherwise remain unrecognized. As a visual summary of the program results, it facilitates communication of the research findings among stakeholders and practitioners.

Case studies of interdisciplinary research projects on urban futures: process and lessons learned

Complexity, Sustainability, and the City—Computable?

The mission of the Sustainable Urban Development Group in the Solar Energy and Building Physics Laboratory (LESO) at the EPFL is to improve the optimization of sustainable urban systems through computer simulation of physical processes. While the emphasis is on the environmental factors of a sustainable urban system, social and economic perspectives are also considered. The group's research focuses on the simulation and evaluation of resource flows in urban systems, urban microclimatology, external environmental comfort and social wellbeing, and stochastic modeling of human behavior.

Traditionally viewed as a collection of infrastructure, cities are more usefully viewed from the bottom up as groups of individuals who form families, communities and productive activities, which are accommodated within buildings and districts, driving land use changes¹³. Individuals respond to economic, governance, technological, and education stimuli. These responses to stimuli are largely non-linear and illustrate how cities exhibit a self-organizing, non-linear trend of constant evolution through the interactions and responses of the individuals who live in them.

According to Schrödinger¹⁴, as humans develop, rather than degrade irreversibly to thermodynamic equilibrium [which implies death], we manage to maintain a high level of order, and actually increase our level of order during our early growth phases. We are able to achieve this because our internal entropy is compensated for by exchanges across the boundary of our system, i.e., we take in food and oxygen and expel waste products. While our internal entropy growth must be positive, the exchange in entropy exchange can be positive or negative, such that the total change in entropy is small. This negentropy production [exchanges across our system boundary] is also applicable to a city, which may likewise be regarded as an open non-equilibrium thermodynamic system.

Analogous to human beings, cities may be regarded as undergoing a process of metabolism: cities import, store, transform and export (bio)chemicals; but they do so in a linear way. If this linear flow of resources were found in nature, it would tend to result in a local accumulation of polluting substances and a cyclic overshoot-undershoot of population size [when highly polluted, the population would drop off, to be replenished when pollution levels drop]. But in natural systems, synergetic exchanges between species lead to a balanced cyclic metabolism [a waste product from one species is a resource for another]. Inspired by nature, we can improve the cyclic flow of resources by implementing synergetic exchanges. The primary lessons that should be applied to cities are: minimize applied resource demands (minimizing internal entropy production), maximize



Darren Robinson has been working for the past ten years in urban energy modeling and is currently group leader of sustainable urban development with the Solar Energy and Building Physics Laboratory (LESO) at EPFL. The key focus of the groups work is on the development of CitySim—software to simulate and optimize the metabolism of urban developments, of various scales, and how they may evolve with time.

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¹³ Forrester, J. (1969) *Urban Dynamics*. MIT Press, Cambridge.

¹⁴ Schrödinger, E. (1944) *What is Life?* Cambridge University Press, Cambridge.

the circularity of urban resource flows (also minimizing internal entropy production), and utilize ambient resources (as in negentropy production).

One example of effective cyclic metabolism is an industrial park on the outskirts of Kalundborg, Denmark¹⁵. This “Symbiosis Project” spontaneously developed in response to the economic advantages from encouraging synergetic exchanges between industrial partners. The environmental benefits are a by-product, albeit an important one. That this has proven to be economically viable is highly encouraging and, in principle, equally applicable to cities, whether they accommodate industrial processes or not.

Accurately modeling the complexity of a city and the flows of resources within it is an immense task. A significant step in this direction was the development of the Sustainable Urban Neighborhood modeling tool (SUNtool):¹⁶ an integrated resource flow model designed to provide decision-support for the design of more sustainable neighborhoods. This model simulates energy, water and waste flows in a way that is sensitive to the urban microclimate, human behavior and local synergetic exchanges. After defining the global coordinates, for association with climate data, the user defines a 3D representation of the site of interest. This might relate either to an existing or to a proposed settlement. The type of activity accommodated by the associated buildings (or parts of) is then defined, so that default datasets relating to constructional, occupational, and heating, ventilating and air conditioning systems characteristics can be associated. These default datasets can be adapted by the user, as can the characteristics of specific buildings or building surfaces, and whether these have embedded solar energy conversion systems. Buildings may also be connected to centralized resource management centers, intended predominantly for heating, cooling or electricity supply. Once the project description is complete, it is parsed to a detailed model which can be solved for hourly resource flows. Once the development is well defined, there are various options for simulation. For example, the solver can simulate performance of a selected group of buildings, a certain time of year, or a parametric run of specific variables.

A successor of SUNtool, CitySim, is currently being fine-tuned for preliminary release in 2009¹⁷. It will contain a more general thermal model, more comprehensive modeling of energy conversion systems and energy storage, more complete stochastic behavior modeling, and more robust rendering. Also in development is an urban mesoclimate model that accounts for the urban heat island effect, as well as incorporating evolutionary optimization algorithms with which one can explore the user-defined parameter space to identify the most suitable solution to the problem.

Several projects are currently underway to apply this software at the district level in Switzerland, including studies in Basel and Neuchâtel. A new study will model the entire city of Zurich with the goal of reducing the per capita energy

¹⁵ www.symbiosis.dk

¹⁶ Robinson, D., Campbell, N., Gaiser, W., Kabel, K., Le-Mouele, A., Morel, N., Page, J., Stankovic, S., Stone, A. (2007) SUNtool – a new modelling paradigm for simulating and optimising urban sustainability. *Solar Energy* 81(9): 1196-1211.

¹⁷ Robinson, D., Giller, C., Haldi, F., He, F., Kämpf, J., Kostro, A. (2008) Towards comprehensive simulation and optimisation for more sustainable urban design. Status-Seminar, ETH Zurich, Sept 2008.

consumption by a factor of four. This model will integrate the transport model MATsim with CitySim to enable a more comprehensive simulation of Zurich's resource flows. MATsim (Multi Agent Transport simulation) is able to simulate the movement of individual vehicles at a fine temporal resolution, offering unmatched detail for the design and control of transportation infrastructure¹⁸.

Application of such sophisticated models in sustainable urban design will enable us to examine the potential repercussions of alternative planning endeavors, incorporating foresight into urban development. Potentially, models can offer guidance about manipulating the urban microclimate, buildings designed to minimize resource demand, land use changes, the feasibility of decentralized resource management options, and targeting of programs for synergetic exchanges and renewable energy technologies. However, these models, no matter how complex, are largely spatially fixed.

Integration of spatially dynamic models into urban environmental modeling would enable us to model the temporal evolution of cities and the environmental consequences, so improving their applicability. To this end, Wegener has identified a range of time-scale dependant sub-systems and good progress has been made in the modeling of them¹⁹, but there remains much work to do before we have a fully comprehensive spatially dynamic environmental model. Achieving this will require collaborations among many disciplines, including demographics, economics, planning, physics, sociology, computer science, and politics.

But this isn't all. Ideally, future models should also account for ecosystem diversity and abundance, the interconnectedness of cities, as well less tangible factors such as the overall feel and quality of a city or the process of its governance. Overall, the city is computable. But model developers have many significant challenges ahead of them if they are to achieve this in a comprehensive and efficient way.

¹⁸ www.matsim.org

¹⁹ Wegener, M. (1994) Operational urban models. *Journal of the American Planning Association*, 60(1), p17-29.

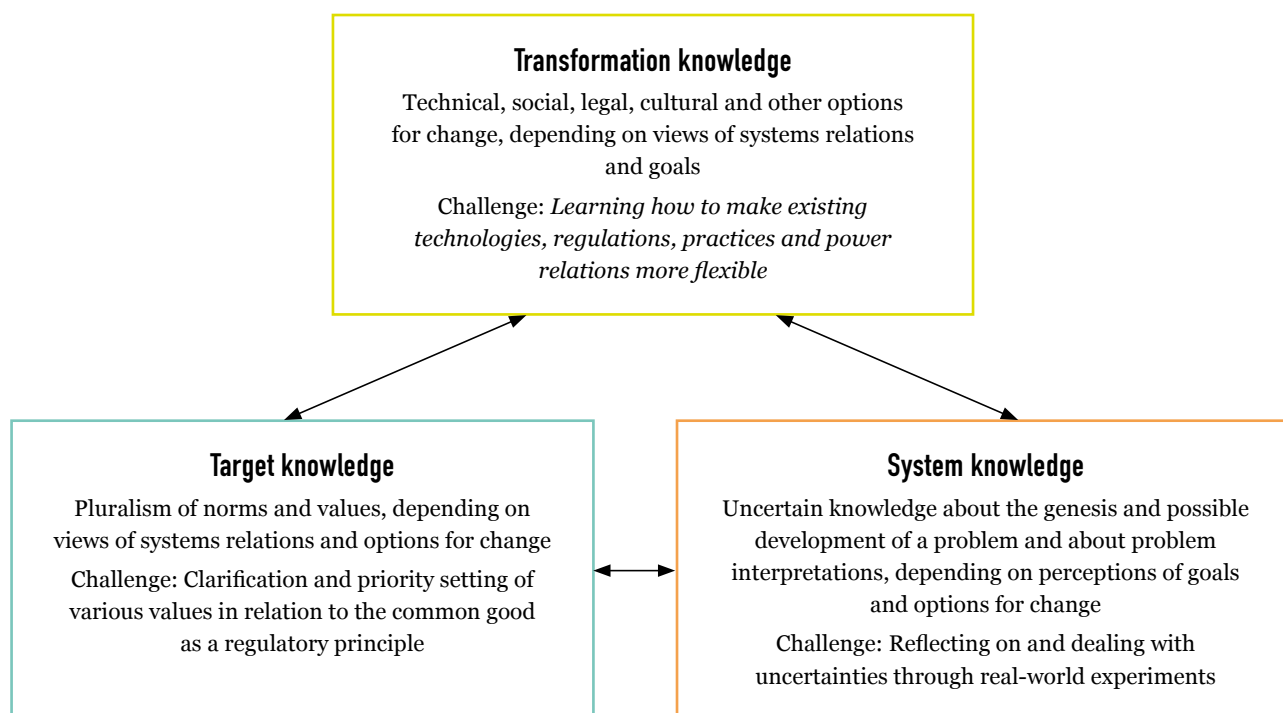


Christian Pohl is lecturer and research fellow in the Environmental Philosophy group at the ETH Zurich. He is also co-director of the Transdisciplinarity Net of the Swiss Academies for Arts and Sciences. His current research focuses on transdisciplinarity, with a particular interest in the collaboration between natural and social sciences and the inter-relationship between science and policy.

Interdisciplinary Dialogue on Urban Futures Tools from Transdisciplinary Research

“The world has problems, but universities have departments²¹”.

Why do we need more interdisciplinary and transdisciplinary research to tackle the challenges posed by urban futures? Many urban problems are complex, multidimensional, socially relevant, and diversely perceived or contested, and we need solutions that increase the common good, the well-being of humanity—a goal that is defined by the values of society. Not only are the solutions beyond the scope of a single discipline or area of research practice, but they need to incorporate non-academic knowledge and practices in order to develop workable solutions. Transdisciplinary research not only integrates information, methods, and concepts from a range of disciplines, but also takes into account empirical and practice-oriented knowledge²². By establishing relationships between different forms of knowledge that are all focused on the same problem, it reduces complexity, and enables those involved to achieve a consensus about solutions to the shared problem. In other words, it is participatory, it transcends disciplinary paradigms, and it is problem-driven.



Interdependencies between the three forms of knowledge in transdisciplinary research.²⁰

²⁰ Brewer, G.D. (1999) The challenges of interdisciplinarity. *Policy Sciences* 32:327-337.

²¹ Pohl, C. and Hirsch Hadorn, G. (2007) *Principles for Designing Transdisciplinary Research*. Oekom Verlag, München.

The research process consists of three main tasks: 1) problem identification and structuring, 2) problem analysis, and 3) integrating the results and bringing them to fruition. The first task is identify the problem in all its complexity, then to reduce complexity by specifying the need for knowledge to solve the problem (separating the “must know” and the “nice to know”), and by identifying those who need to be involved. Starting off with a very broad picture of the problem ensures that social, technical and environmental factors are all considered, including empirical insights, technical options, value orientations and policy options. This wealth of information can then be structured into three forms of knowledge: knowledge of the system, the target, and the transformation.

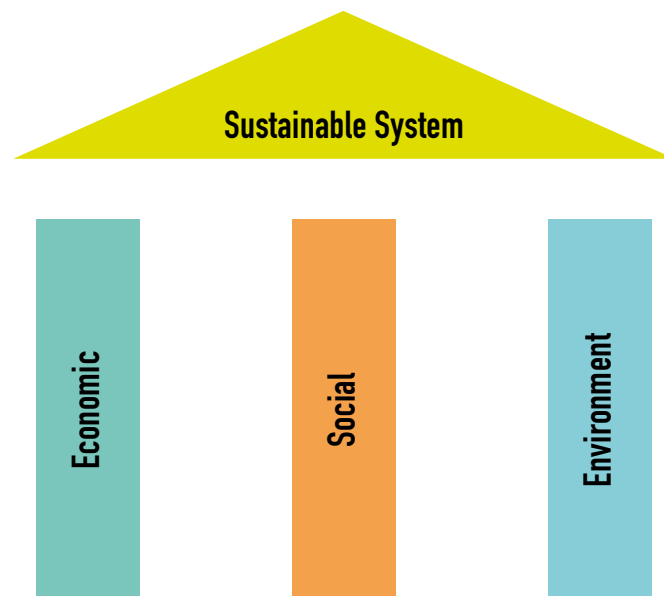
System knowledge is knowledge about the current situation and the origin of a problem, and about its various impacts. It is what the analytical sciences (such as the natural sciences) normally provide. For solution-oriented research on urban futures, transformation and target knowledge also become relevant. Target knowledge is about determining and explaining what more sustainable urban future we wish to achieve, and how it differs from the present state. It includes the evaluation of prognoses and scenarios, questions of critical limits to development, visions, and ethical guidelines. Transformation knowledge is about the options for change or the restrictions on change from the present state of a particular urban situation to the desired target.

It is essential to consider what different kinds of expertise are needed to find solutions, and what different views of stakeholders in society need to be included. This includes thinking about who might have knowledge on the current situation, who might have knowledge on how to create change (e.g. policies, technologies, planning), and who might have tools, concepts or perspectives that can be used to approach the issue (e.g. models, visualisation, views of young or old people or particularly affected groups). Involving different kinds of expertise requires techniques for mutual learning and deliberation.

The AGS workshop took the participants through the steps of problem identification and structuring. The workshop process was catalyzed using previously identified problem questions and images. The initial brainstorming around these questions and images, using the World Café method²², resulted in problem complexes that branched out from these questions in all sorts of directions. The groups were then challenged to map these diverse aspects of the problem to reduce the complexity by classifying the aspects into the three types of knowledge, to frame the problem through identifying the needed expertise and stakeholder involvement, and to formulate research questions.

²² Brown, J. (2002) *The World Café: A resource guide for hosting conversations that matter.* Mill Valley, CA Whole Systems Associates. www.theworldcafe.com

The workshop groups were also asked to consider what their project contributes to economic, social and environmental sustainability. Economic and social sustainability contains the core concepts of meeting needs for human well-being, and good governance, with participatory deliberation and decision making, to ensure equity among the living and in consideration of future generations²³. Environmental sustainability maintains the balance and resilience of ecosystems and the services they provide. Finally they were asked to present their results in a structured way. In the following workshop reports, the groups show how they used the methods to generate both interesting and meaningful research questions, and to critically re-examine how the problem has been tackled in the past.



Three pillars of sustainability

²³ Hirsch Hadorn, G. and Brun, G. (2007) Ethische Probleme nachhaltiger Entwicklung. In: Schweizerische Akademie der Geistes- und Sozialwissenschaften (SAGW) (ed.) Nachhaltige Entwicklung. Nachhaltigkeitsforschung – Perspektiven der Sozial- und Geisteswissenschaften. SAGW, Bern, pp 235-253.

Interdisciplinary Dialogue on Urban Futures

What impact does migration have on the sustainable development of residential areas of rapidly growing cities?

Migration into cities is a dynamic reality that varies in form from city to city but exists on a global level. Despite the undeniable presence of migration into cities, differences remain between migrants' access to basic human needs and requirements of sustainable urban development. From a migrant's perspective there is limited access to adequate shelter and subsistence in a city. Therefore the migrants are vulnerable upon entering the city. When viewed from a city's perspective, migration into the city creates an increased demand on social and environmental services and resources.

The system knowledge necessary for approaching the issue of migrants and cities was addressed with two basic questions:

- What are the existing conditions for migrants in a city?
- What current problems in a city are created by migration?

The workshop group determined numerous migrant needs as compared to requirements of sustainable urban development. Upon entering a city, migrants are most immediately faced with finding a place to live and means of subsistence, but also require a social network, participation, and recognition. Basic requirements of a sustainable city faced with massive migration are proper sanitation, functional infrastructure, security, and economic growth. An example of conflict between migrants' needs and sustainable city requirements is seen throughout the developing world in large shantytowns. While these shantytowns offer housing, a social network, and even subsistence to migrants, they create large sanitation problems for the cities.

The experience of migrants is highly variable depending on the nature of the city they inhabit. In cities with largely formal economies it is challenging for migrants to find basic human needs and become integrated into the city. Conversely, cities with informal economies are easily accessed by migrants, yet have many social and technical problems. Cities with only informal economies do not have the resources to develop sustainably, while cities with only formal economies offer limited opportunity for the vulnerable. The solution for this problem must balance the individual needs of migrants and the common good of a city.

Once the system knowledge was outlined, the target knowledge was identified as:

- How can cities respond to the needs of migrants while also addressing the requirements of a sustainable city?

The philosophy behind research into migration in cities is the need for diversity among and balance between migrants' access and cities' development requirements. From further development of the system and target knowledge, a transformation question was developed:

- How can technical, political, and social solutions be optimized considering the diversity of lifestyles?

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Optimization of a complex solution is not a destination but a continuum. To achieve this, it is necessary to determine a solution which integrates migrants' individual needs and common goods with consideration for diversity.

The group identified a large number of stakeholders who should be involved in developing and implementing necessary changes, ranging from planners, engineers, and economists, to citizens, migrants, and social organizations. Inclusion of various disciplines will allow consideration of diversity and construction of a higher level of common good that also meets household level cultural problems. Interdisciplinary research and cooperation among stakeholders are also critical for developing and implementing effective management tools.

This approach to addressing migration into cities uphold the principles of sustainable urban futures by transforming perspectives to include diversity-friendly technical, social, and political tools and mechanisms. This approach is successful in part because it includes the three pillars of sustainability. It addresses the dynamics of formal and informal economies through considering livelihood and subsistence. It includes consideration of the health and diversity of the environment. And by addressing equity, security, and diversity, it upholds the social pillar.

Interdisciplinary Dialogue on Urban Futures

How can cities provide for the basic needs of their populations: What are the obligations/roles of public (city and local government), private and civil society actors?

There are many ways to define basic human needs. From the perspective of improving living conditions of poor urban populations, the workshop group decided that a rights-based approach, meaning that individuals have an implied right to having their basic needs met, was the most sensible. They focused on the basic needs defined by the United Nations: food, clean water, shelter, health, and education.²⁴

Kibera is a very large shanty town in Nairobi, Kenya. The workshop group to used Kibera as an example of the challenges a city faces in providing basic human needs to its inhabitants. In Kibera, 12% of a family's income is spent on housing, 84% of inhabitants live in one-room dwellings which they share with 4 to 6 others, and 58% of the population in Kibera rely on private water sources, 12% rely on public water, and the remainder rely on water vendors.²⁵ There are no public toilets and approximately 150 people use a single pit latrine. There is no electricity in Kibera.

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Photo courtesy of C. Lüthi, Sandec, Eawag

²⁴ United Nations (1966) International Covenant on Economic, Social and Cultural Rights. http://www.unhchr.ch/html/menu3/b/a_ceschr.htm

²⁵ World Bank (2006) Kenya- Inside Informality: poverty, jobs, housing and services in Nairobi's slums. World Bank publications, Report number 34367-KE.

The system knowledge pertaining to basic human needs is clear: despite attempts to improve circumstances, poor urban populations, like those in Kibera, still live in utterly inadequate conditions. Additionally, available technologies and projects intended to help improve health, education, and sanitation have limited impact, largely because of a lack of interdisciplinary action, effective implementation, and successful diffusion of the technology.

The principle research questions identified by this workshop group focused on target and transition knowledges:

- What are the key dynamics for upscaling and diffusion of successful technologies and process interventions?
- What are the barriers to success?
- What role can information and information management systems play in enhancing the impact of technologies related to meeting basic human needs?

Interdisciplinary action between experts is necessary, specific to the basic need addressed: this needs sociologists, cultural experts, economists, ecologists, and engineers, as well as local communities and authorities, NGOs, donors, and manufacturers. Cooperation and interdisciplinary investigation into specific problems of basic needs will help the research account for the complexity of the problem and ultimately have the greatest impact.

This approach to interdisciplinary research supports sustainable development in many fundamental ways. It addresses basic needs of the poor, reduces negative impacts on the environment, improves the urban poor's access to livelihood resources, and contributes to knowledge about the successful diffusion of new technologies, intervention processes, and information management to improve the livelihoods of the urban poor. Naturally, implementation of such a research project will have positive effects on all three pillars of sustainable development: social, economic, and environmental.

Interdisciplinary Dialogue on Urban Futures

What form might a future utopian sustainable city take and how can we optimize the sustainable resource use of newly-born cities?

This workshop group began with the question “How do cities function? How should they function?” This discussion led to clear outlining of the system knowledge. Metabolically, cities function linearly with inputs including food and water, non-renewable energy, processed goods, and building materials and outputs: sewage, exhaust gases, household and factory wastes, and wanton disposal. This model of metabolism is unlike most natural ecosystems, which process their resources cyclically. This linearity of urban metabolism is also linked to interconnectedness among cities and across the planet. Food, processed goods, and energy are largely not produced for local consumption, but are imported and exported from place to place. Environmentally and economically these elements of a city are extremely relevant. Cities are not only places where resources are exchanged. They are homes, social centers, geographical landmarks, and cultural and business centers.

A utopian city has a cyclic metabolism, is self-reliant, and is not more expensive than other cities. It fits within a geo-cultural context and has minimal transportation needs with maximum social exchanges, to encourage a sense of community. Government in a utopian city would involve monitoring and feedback mechanisms that connect decision-makers and citizens and provide nearly instantaneous results from feedback.

If the target knowledge is how to guide a city towards a utopian model or to create a utopian plan for a newly-born city, implementing a cyclic metabolism is necessary. Important factors in transitioning towards a cyclic metabolism include eating seasonally and locally, maximizing renewable resource use and energy and transport efficiency, recycling waste materials, and maintaining cities as a home for flora and fauna.

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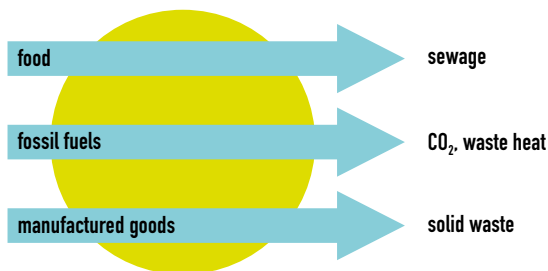
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Linear Metabolism



Circular Metabolism



Transitioning or developing a social utopian plan is also linked to the physical layout of the city. One model of a utopian city is a polycentric city, with a central city surrounded by numerous peripheral satellite cities. Such a model has been widely studied and addresses the more complex social and cultural diversity issues. This design may also be conceived in such a way as to optimize population density while maximizing diversity, leading to an increase in social exchanges. High-speed transportation would connect the satellite cities to the central city. Meanwhile lower-speed transportation would connect the satellite cities to one another. Transportation of resources could also be designed in a similar fashion to human transportation.

A third important element of developing a utopian city is the government. While many options are possible, it should include mechanisms for direct feedback from the population and nearly instantaneous response from the government. There should also be monitoring mechanisms for resources, quality of life and the economy of the city, so that a clear picture of the overall state of the city is always available.

Traditional disciplines involved in city planning and development, i.e., politicians, planners, engineers, and architects, do not satisfy development requirements for a utopian city. In order to achieve sustainable development in utopian city planning, additional stakeholders, such as sociologists, economists, natural scientists, and most importantly city users, must be included.

Interdisciplinary Dialogue on Urban Futures

How can we protect landscape and manage land use change for the needs of people and environment in the face of strong drivers for urbanization?

Landscape management is an interesting aspect of sustainable urban development because it is relevant to all areas of the world and is not limited to developing nations. In Switzerland, as in many industrial nations, a clear distinction is made between city regions and remote rural regions, which determines landscape management for these regions. However, there is a large amount of land between completely urban and completely rural, referred to as open landscape. These areas are susceptible to development for many reasons: proximity to urban regions, mediocre beauty relative to remote regions, and suitability for agricultural, industrial, and infrastructure development. Should this landscape be free for development? These various factors contribute to a complex problem and an unclear process for definitive landscape management. How can unspectacular landscapes be protected from overbuilding?

Currently, so-called valuable areas are protected and so-called unvalued areas are more or less free for development. While this has saved precious landscapes in urban and remote regions, it has led to pressure to develop open landscapes which are not as easily categorized.

An alternative approach to reaching the target of sustainably developing open landscapes is to assess a value for every landscape and region. Assigning a landscape value helps create regional identity and gives greater protection to unspectacular landscapes. Placing a value on a landscape or region includes consideration of the potential capacity of the land, such as agricultural and infrastructure development, as well as user needs. From these values, a common agreement can be reached that optimizes the landscape’s potential.

The workshop group determined future research questions that attempt to define the methods for valuation of a landscape, or a regional identity. Key questions include how to define which characteristics contribute to value, and who determines the regional identity of a particular landscape.

As a complex problem requires, the research and application must involve interdisciplinary cooperation among scientists and experts. Additionally, people attached to the region should play an integral role in developing the value and regional identity. The workshop group emphasized the need for iterative communication between scientists and regional stakeholders for successful implementation of this strategy.

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