Emergy Applications in Urban Planning and Regenerative Systems
Landscape Design

Torbjörn Rydberg, Daniel Bergquist, Per G Berg, Per Hedfors

ABSTRACT

Though the number of urban districts with sustainability ambitions is growing worldwide, it is not clear to what extent such areas achieve environmental and resource efficiency. From a holistic perspective, global rebound and displacement effects are equally likely consequences of urban “sustainable” development. Furthermore, efficiency improvements in construction processes and buildings’ functions impact socio-economic factors on various societal scales. Apart from a range of urban qualities created locally through the built environment, when improvements reduce overall consumption, this may also reduce or move the functions of societies welfare system closer to the environment where people live, as well as other life-sustaining services that are directly and indirectly necessary for the process. Widening the system boundaries of time and space, we therefore identify a need for urban planning that enables the built environment to be assessed not only in terms of its resource use, but also in its ability to feed back and reinforce other input to the system. Hence it becomes important to create multifunctional urban landscapes that maximize empower in the larger system by simultaneously delivering functions not only housing but also recreation, ecosystem services and food production etc, as well as other social and cultural values. Conceptualizing urban districts as nested systems landscapes with direct and indirect linkages to other systems at multiple scales, we identify and discuss some interdependencies of biophysical and socio-economic processes. Drawing on a quality framework consisting of seven important quality aspects of modern sustainable communities derived from the UN Habitat agenda and further developed, and Emergy, we explore possibilities for a theoretical synthesis capable of handling such interactions of urban systems landscapes. The approach is used in order to discuss general consequences of sustainability transitions on different levels in society.

INTRODUCTION

Buildings and the Built Environment

Buildings are a result of a variety of inputs. The inputs can be aggregated as information, buildings material and energy. Inputs are needed for its planning, building manufacturing, maintenance over its operational lifetime and demolition. It has been identified a need to assess the renewable and non-renewable resources used for buildings and the need to progressively replace non-renewable resources with renewables.

High degree of intensification of cities and living housing construct requires an almost 100 percent reliance upon imports of resources for construction and maintenance and as well a total reliance upon surrounding environment and by human constructed services for waste treatment. Less intensive cities allow for more inclusion of green-blue sub-systems, which has the capability to generate essential goods and services for the building as well for the people living in it.
Systems Landscapes

In this work we draw attention to dependencies and embeddedness of urban systems in human and environmental systems at multiple geographic and temporal scales; drawing resources from the systems in which they are embedded, such as a larger region or city, its infrastructure, green structures and people, as well as adjacent landscapes and in extension geographically distant areas. In this view, urban systems represent locally specific and unique geographic entities that interact with other sub-systems and the larger scale systems that contain them. As such, we use the concept of system(s) landscapes (Granvik & Hedfors 2015; Bergquist and Hedfors, forthcoming) to emphasize the inherent complexities of any urban system. Furthermore, to this conceptualization we add the concept regenerative, to underscore the need in urban planning to push strategies beyond sustainability hypocrisy.

Urban Development Trajectories

Widening the system boundaries of time and space, the reasoning above implies there are at least three potential but fundamentally different urban development trajectories, all with very different outcomes. Figure 1 below illustrates these trajectories as changes in resource (emergy) intensity over time.

![Figure 1. Three possible urban development trajectories, expressed as changes in emergy intensity over time. Trajectory A represents conventional urban development, where relatively low initial investments result in short term financial gains through externalization of costs into the future, by establishing urban functions that require high resource throughput indefinitely. Trajectory B represents ecological modernization as a strategy to solve this predicament, however resulting in higher initial investments and throughput, since the built environment is designed more based on popular rhetoric and trends than a deep systemic understanding. Arguably, this trajectory is by the contemporary discourse on sustainable urban development. Trajectory three represents a hypothetical trajectory, based on regenerative systems landscape thinking as proposed in this paper. In this scenario, conscious design of the built environment requires high initial investments, also financially costly, though only in the short term. However, these initial high investments are used to create multifunctional systems landscapes, i.e. an urban system with the long term capacity to regenerate and self-organize in the long run as emergy intensity drops to justifiable levels.](image-url)
In Sweden a majority of the population live in urban areas. 90% of disposable household incomes is spent on travel, food and housing. Together these activities add up to approximately half the nation’s total resource use, part of which translates into significant negative environmental and health impacts (Edman 2005). In urban areas strategic responses to these challenges are pursued under the banner of ‘green growth’, ‘dense and green’, ‘greening the city’, ‘smart cities’ and ‘sustainable cities’ etc. Yet it is not clear to what extent such areas actually achieve environmental and resource efficiency, let alone if they generate real wealth, as understood by Odum (1996). In other words, it remains unclear to what extent “sustainable” urban development actually results in more sustainability, i.e., if aspirations and claims in urban planning and policy translate into real improvements, or rather are just a matter of popular rhetoric. From a holistic perspective, increased resource throughput, oftentimes hidden in global rebound and displacement effects, are equally likely consequences of ‘sustainable’ urban development. This risk appears particularly apparent under the current paradigm of ecological modernization, where many planning initiatives and projects are perhaps best described as mere sustainability hypocrisy (Vogel 2015).

Even if the outcome is indeed more efficient and resource conserving urban systems, planning and construction processes, and resulting buildings’ functions, may simultaneously impact socio-economic factors in reinforcing and limiting ways, and at various societal scales. Apart from a range of urban qualities created locally through the built environment, when efficiency gains reduce overall consumption, this may also reduce the need for certain types of societal services linked to the welfare systems, as well as other life-sustaining services that are directly and indirectly necessary for urban life. Widening the system boundaries of time and space, we therefore identify a need for urban planning that enables the built environment to delivering physical sites of high multiple qualities, i.e. which generate real wealth as opposed to sustainability hypocrisy. We propose that combining Emergy and PEBOSCA (Physical, economical, biological, organizational, social, cultural and aesthetical according to Berg (2004)) analysis may be useful to articulate and evaluate such wicked planning problems.

Aim and Research Question

The aim of this presentation is to introduce an assessment approach to sustainable urban development from a combined perspective of PEBOSCA and emergy. And with that in the forthcoming work explore possibilities for a theoretical synthesis capable of handling interactions of both qualitative inputs and qualitative outputs, all of different kinds, of urban systems. Our research question is: how to value multi-functionality in urban development, i.e. what values are created, what support from environment and society is required, and how can these be valued and weighted against each other, e.g. as trade-offs and synergies at different scales of society and environment.

MATERIALS

Selection of Cases

The following cases are tentative based on principle situations, however mainly grounded on empirical studies over many years (Berg, 2010; Berg et al., 2013). The cases work as examples of specific complex planning and design problems concerning different landscape patterns at various scale levels in landscape management, urban planning, and garden design. These cases and patterns are systemized hierarchically in accordance with a pattern language developed in urban planning (Alexander et al., 1977). Other relevant sustainability frameworks also relate to the Pattern language multi-scale theory (Ecocities projects (Gaffron et al. 2005). Three scale levels are identified here: (1) the comprehensive regional level, (2) the city district level, and (3) the house level.
Selection of cases at the comprehensive regional scale level

Cases that we investigate on the comprehensive regional city/municipal scale level comprise towns with systematically different height regimes (free heights or restricted heights of buildings and constructions), towns with different approaches to waterfronts (the interaction between built structures and water features that are seen as barriers or attractions in the urban fabric), green fronts (the interaction between built structures and green structures that are seen as barriers or attractive public spaces) and towns in different stages of expansion (fast growth, moderate growth, steady-state or decline) (Boverket 2006; Berg et al. 2013).

Selection of cases at the city district scale level

Cases of interest for our research comprise various functional townscape units. The following cases are patterns in urban areas seen as landscape elements with high complexity forming an important part in the understanding of systems landscapes. Abundant material exists from a range of our earlier research projects within community studies, studies on functional density studies of townscapes and studies of green structure as cultural and ecological phenomena.

The principally different case types (townscape types) are listed in Table 1 below: comprising iron grid districts in the city core, small-house areas at close range of the city center, multi-family housing from 1950-ies and 1960-ies respectively, new multi-family housing at a distance from the city core, larger villas areas and small towns, connected with but clearly outside the city.

Selection of cases at the house estate scale level

The following cases are patterns in districts seen as landscape elements with medium complexity forming parts in the understanding of systems landscapes.

- **Green roofs and walls**: Green facades for noise control will not work based on the plants alone. Effective layers of insulation are needed to support the plants.
- **Rooftop greenhouses**: On roofs for creating opportunities for social life – building community and small-scale local food production through organic gardening.
- **Inner courtyards**: Inner courtyards constitute key units for sustainable community living. Their size, housing context, equipment, micro-infrastructure, green structure, sun exposure, compartmentalization, insight protection, soundscapes are some examples of qualities that indirectly determine the potential for social interactions, practical co-operation and sustainable lifestyles in everyday action.

We treat the following as aspects/resources within the cases above:

- Recreational facilities
- Social spaces for recreation through physical exercise, socialization, allotment gardening.
- Integration of green-blue infrastructure
- Creating parks for handling runoff and storm water and creating aesthetically appealing courtyards.
- Reducing noise, heat island effects and creating green social spaces for all generations.
- Prioritizing biking/walking
- Fewer parking spaces – more services for biking. Walkable districts.
- Food production and food processing
- Fuel production (solar panels)
- Ecosystem services (such as temperature regulation, air cleaning, water purification, recreation availability as well as generation of environment for relaxation and aesthetic experience).
Table 1. Principle townscape types at the city district scale level of interest to further investigate in our emergy+PEBOSCA quality synthesis.

<table>
<thead>
<tr>
<th>Townscape type</th>
<th>Explanation</th>
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<tr>
<td>City core districts</td>
<td>Typically at least century old iron-grid districts with historic center containing layers from multiple centuries, close to advanced education, culture and central service-nodes and main transport/travel junctions. About 1 million inhabitants dwell in about 800 000 flats of this townscape area type – in the larger cities a major proportion are one-person households. The city core is one of three hotspots for urban densification.</td>
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<tr>
<td>Small houses areas</td>
<td>Small houses on small 600 m² lots at close range from the city center. These small-house areas were built between 1920-ies to 1950-ies for families with small incomes – typically with a large proportion of self-construction. For villa areas comparatively dense districts. There are more than 1 million such small houses areas in Swedish Cities and towns – home for about 2.4 million inhabitants.</td>
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<tr>
<td>Multi-family housing 1950s</td>
<td>Multi-family housing built in three-story houses around larger lush inner courtyards mostly from mid-1940s and during the 1950s (the peoples homes houses program - folkhem). These housing areas is home for about 800 000 inhabitants in 500 000 apartments. The folkhems areas constitute one of three urban hotspots for on-going densification.</td>
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<tr>
<td>Multi-family housing 1960s</td>
<td>Multi-family housing built between 1960-1975 (the million program) comprise of 900,000 apartments. The million homes program constitutes dwelling for about 2 million people. The million-program area is the third prominent contemporary densification area type.</td>
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<tr>
<td>Large villas areas</td>
<td>Larger villas with large garden plots (around 2000 m²) built continuously at a larger distance from the city centers from the beginning of the 20th Century – typically in green-area-rich locations. Such large villas areas in the urban periphery settings contain about one million homes with about 2.5 million inhabitants.</td>
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<tr>
<td>Newer multi-family housing</td>
<td>Newer dense low-height residential courtyards built from the 1980-ies up to now, built as new enclaves in the urban periphery. The Newer multi-family housing areas contain more than 200 000 dwellings for up to ½ million inhabitants.</td>
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<tr>
<td>Small communities outside cities and towns.</td>
<td>Small communities in the countryside surrounding the city with a predominant commuter relationship to the urban labor market. Small communities contain different dwelling types (see above) but where distances between various housing types and functions (dwelling, work, service) is very low. The number of dwellings is around 1 million (mostly villas) with around 2.7 million people. The number of dwellings and inhabitants are a part of the six housing types above.</td>
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**METHODS**

**Emergy**

Emergy is used to identify potential connections for establishing autocatalytic processes and empower over long time horizons – leads to lower throughput and higher contribution of real wealth to systems at larger scales. Such values of urban system organization and multi-functionality are otherwise overlooked in other conceptions of value. It is important also to note that emergy is a network concept that includes the generative processes in the geo-biosphere.

Emergy describes and evaluate new qualities that emerge from self-organization in open and interacting systems. It is a physical quantity able to describe the increase in qualitative dimensions that goes beyond the classical thermodynamic aspects on energy quality, with full acknowledgement to the
quantitative measure of energy (Odum 1996; Gianantoni 2002). The physical measure Emergy is able to appropriately describe the significant increases in quality and is especially associated with co-generating processes. This is what we refer to as multi-functional systems and the qualities they contain or contribute with. This is of utmost importance for a system’s capacity to sustain and reinforce its own autocatalytic processes as well as its surrounding systems and their processes. It is essential for all systems to be resilient as well. This is done by feedback mechanism of high quality (UEV’s) such as information/knowledge as an example.

The specific emergy algebra shows that co-generative sub-systems constitute the fundamental processes that most obviously contribute to an increase in quality measured in emergy in self-organizing subsystems. Such increase in emergy and organization of the system does not only affect the output from the system but it also contributes to a better self-organization and outcome of the system it is embedded into. A fundamental characteristic of self-organizing systems that needs to be acknowledged and accounted for.

**PEBOSCA**

This research combines emergy analysis of modern settlements with a quality framework of sustainable communities derived from the UN Habitat agenda (UNCHS, 1996). During the UN Habitat II meeting – seven dimensions were discussed as equally important quality aspects of modern sustainable communities. During the past 20 years our research team has operationalized and applied these Habitat dimensions into a now well-established resource model – PEBOSCA (Berg & Nycander, 1997; Berg et al. 2002; Berg, 2004; Berg et al. 2010; Berg et al. 2013; Berg et al. 2015). The acronym’s seven resources (Physical, Economic, Biological, Organizational, Social, Cultural and Aesthetic) are defined and explained in Table 2 below.

**Table 2.** Seven categories of resources necessary for a sustainable function of local townscape areas, developed from the policy texts of the UN Habitat agenda (UNCHS, 1996). The PEBOSCA resources model was first presented in Berg & Nycander (1997); and then applied in community planning research and practice in Sweden in Berg (2004) and internationally in Berg et al. (2010).

<table>
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<tr>
<th>Resource</th>
<th>Examples</th>
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<tr>
<td>Physical Resources</td>
<td>Clean water and air, energy, matter and soil available to the residents of the local community.</td>
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<tr>
<td>Economic Resources</td>
<td>Houses, roads, tools, knowledge and informal economic services of importance to the residents in the community.</td>
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<tr>
<td>Biological Resources</td>
<td>Species, biotopes and ecosystems in natural and cultural landscapes within or closely connected to the community.</td>
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<tr>
<td>Organizational Resources</td>
<td>Plans, orders, laws, infrastructures, services and informal rules connected to the local community.</td>
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<tr>
<td>Social Resources</td>
<td>Relationships and local co-operation within the community. Moving rates within the community. Age structure, demographics and health of inhabitants in the local community.</td>
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<tr>
<td>Cultural Resources</td>
<td>Knowledge of history and cultural patterns of the site. Fine arts, traditions and ceremonies, in or of significance to the local community.</td>
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<tr>
<td>Aesthetic Resources</td>
<td>Sensuous impressions, architectural and spatial qualities (related to visual, auditory, olfactory, kinesthetical and tactile senses) characteristic for the local community.</td>
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RESULTS

No results available yet.

DISCUSSION

With energy theory of value and its specific emergy algebra, we see the possibility to evaluate co-generative processes. Co-generative amplifying self-organizing systems are in fact the base for sustainable system development. We see the potential in application of emergy theory and its synthetic evaluation procedure to evaluate urban planning and construction of multi-functional regenerative systems landscapes. Furthermore, with PEBOSCA it becomes possible to evaluate different qualities of the built environment, as a concrete expression of urban planning and development emphasizing and identifying aspects that should be given priority to reach sustainability goals. In other words, to consciously design for trajectory C. To facilitate such a shift, we propose that the concept of regenerative systems landscapes can be used for strengthening the capacity for long term systems thinking in urban development and planning. This is illustrated in Figure 2 below.

Synthesizing Emergy and PEBOSCA may also provide emergy researchers with a new functional unit for use in emergy evaluations; mathematically expressed as $\text{SeJ/FunkTät}$.

Figure 2. Holistic systems view encapsulating the multiple scales, i.e. rural-urban-cultural subsystems that together shape systems landscapes.
REFERENCES


