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A New Generation of Demo-Projects for Sustainable Sector-Integrated Innovations

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Abstract

The building sector is currently pressured by a global call to review its management of the flows of matter and energy. A radical change is required and at the same time a change is going on. Design processes and construction management are actually inserted in a changed new operational context deeply influenced by the sustainability and globalization debate. The focus has been moved to energy and matter flows as the peculiar base of all building business and this fact introduces ecology as a base knowledge in construction. Ecology is the science of intelligent, self-organizing complex systems.

Large complex systems react to change and innovations are the tools the system creates in order to adapt. The management of innovations in construction has been a complex, theoretically weak and often ill-defined problem partly due to the contingency and heterogeneity of all parts and variables involved. This study highlights the emerging of new practices able to link knowledge innovations and project managing processes when sustainability goals are on stake.

Demonstration projects are the investigated unit assumed as contexts for the co-evolution of research, design and management developing technological change and innovations. The discussion is based on real case-projects studied within a stakeholder participatory approach. Findings reinforce the need of identifying and better understand integrated sector-specific innovations. Still innovations in construction can be inconsistent with concepts of sustainability.

Keywords

Change, Built environment, Ecology of innovation, Matter and energy flows, Demonstration projects

1. Introduction

The entire system of building activities in Sweden has been deeply perturbed by the effect of the climate change and resource management discourses developed within the society as a whole. The building sector reveals its complex characteristic, dynamically adapting to external perturbations.

However, changes in this sector have usually proved difficult to implement due to the claimed fragmentation and one-off characteristics of its activities as well as a lack of integrated theories makes it hard to understand what happens in time of turbulence. More integrated theories are needed which correspond to the multitude of different activities that structure the becoming and transformations of the human built environment. Previous attempts to theories of building and innovation are still linked in old mechanistic approaches, lacking insights about system dynamics and about the nature of change and innovations. Models for industrial production have formerly lead research in construction hindered by the sectors fragmentation and heterogeneity.

Drawing on the international attempts to found a theory of the built environment as a social-ecological system (Moffat and Kohler, 2008; Du Plessis, 2008) this paper tries to develop some of the complex questions the changed approach has opened. The expansive notion of built environment more easily conveys a broader system perspective where dynamic relationships exist between a greater number of built elements and agents. All efforts for reaching a 'theory of the built environment' are challenged by the need to cope with the complexity and mutability of elements and actors over time and space.

The new theoretical approach gives the possibility to interpret different strategies for decision-making at different levels of the system, assuming its characteristic 'nested hierarchy". The unit of decision-making taken into consideration by the investigation is the project-team for a building, taken as the level where answers can be found to the many questions beginning with "How is it possible to any team of professionals within the design process to understand the long-term effects of their design and management decisions?" This paper proposes a series of answers.

2. Background for Praxis and Research

While the Climate is changing also the praxis of construction in Sweden is changing, faster and faster. Nobody is really sure about what or who is driving the change. It is full of technical and organisational innovations, new ideas and concepts, participatory trends. The uncertainties are many. Doubt seems to guide the scientific reason to build up models which may help humans to concentrate upon action, leaving off sight all the uncertainties which in fact arise from doubt.

Projects are focused on new energy efficiency approaches, and sustainability goals are paramount. Projects want to enact strategies for mitigating the climate change and for reducing the environmental impact of construction. Issues of reduction of Green House Gases (mostly CO2 emissions) are intertwined with LCA based choices of building materials, primary energy is finally distinct from heat energy and Total Environmental Control System is assumed by a wide range of companies.

The change seems now to come suddenly, but its evolution can be followed back in time along with the long path of energy efficient and eco-buildings (Femenías *et al*., 2008; Jensen and Gram-Hanssen, 2008). Maybe due to a lack of integrated theories of change in construction, it is very difficult to fully explain what is happening. Very little of previous leading theories of construction management and project design can be used to understand why a sector told to be "fragmented and conservative", inertial and difficult to control, suddenly could show opposite capacities, fast innovation rate and innovative engagement. The speed of the information flow within the heterogeneous agents involved in construction practices has never been so high. The regulating activity of the governmental administration is surpassed by an agreement within the current practice to reach advanced sustainable results as to the flow of energy and materials in building.

2.1 The Need of a Theory of the Built Environment

Somehow, all efforts for reaching a theory of the built environment are basically challenged by the need to cope with the complexity and mutability of elements and actors over time.

If new theory is to help with predicting impacts of decision-making on the Performance of the Built Environment, then this new theory must perceive it to be a system with a multitude of design, construction, operation, maintenance, and disposal processes relating flows of material and energy to decisions made by different actors at different moments and in different places.

This system is the interface between culture and built environment and determines a cushion of ‘initial conditions’ given in time and space which *locally* defines which parts of the material world that are deemed to be artifact, and part of the built environment. “Due to the high complexity factor, any model of the built environment needs a way to describe which of the many subsystems are addressed, and a framework for decomposing the many physical elements. If a consistent framework is adapted, it may help to unify modeling activity. It should be possible to relate the mass and energy flows to the financial and information flows at each stage of design, planning and management. A framework provides the context for development of tools for understanding simplifying such relationships.” (Moffat and Kohler 2008).

2.2 Development of Tools – A New Representation of Buildings and the Life Cycle Assessments

The usual geometrical representation of buildings through plans, sections, elevations, and details is in this context of limited interest. It has become more convenient to base assessments on the textual, process-oriented building descriptions used for cost-calculations and for tendering, i.e. to describe building as it is built. For this purpose the building is decomposed into functional units (or cost elements) such as $1m^2$ of exterior wall. The functional unit of wall is then described as layers of materials, each linked to information on life expectancy, maintenance and cleaning cycles, energy consumption during use, recycling behavior and finally possible downstream paths.

By this way it becomes possible to calculate a multitude of key-performance indicators for the particular wall section or element, including life cycle costs, life cycle impacts, heat flows, vapor diffusion, off-gassing, toxicity, acoustic protection, fire resistance, construction time and deconstruction potentials.

A generalized application of the life cycle costing (LCC) and life cycle assessment (LCA) has been retarded by the lack of a robust and shared building representation.

The search for a multi-purpose information model based on LCA find an initially solution in the development of a common Building Information Model BIM. It is now possible to imagine a scalable object and process description (from urban settings of building types and linear infrastructures, down to the level of construction and operation process) and compile a complete metabolism representation. This metabolism can have ecological, economic as well as social dimensions that evolve over time and as issues change.

Current models for representing the built environment do not provide the performance information needed to generate mass flow analysis (MFA) profiles (if energy is used for lighting how much contributes to space heating? If rain is captured by roof and pathways where does it go?)

It is still difficult to communicate performance in a standard way. What are the total impacts of a built environment on the natural capital? Do these impacts satisfy fixed constrains?

The concept of a human built environment as a social-ecological system opens for two base problems: 1) the impact of spatial relationships at different scales is ignored in physical models. 2) with respect to long-term patterns and consequences, the concepts of time are inadequate.

Spatial scales can be described as nested hierarchy while the experience of time is individually changing rapidly. Time has disciplinary definitions, so as the relationship of built environments to ecosphere is conceptualized in the 21-th century, one of the challenges appears to be how society can adapt or create timing concepts, integrating the recent time concepts resulting from trans-disciplinary approaches.

2.3 The Next Technological Leap

The new developing tools move the building-project and the work of the professional teams towards interfaces with other disciplines and other levels of the system, i.e. towards ecology and the persistency of the built environment. The traditional narrow boundaries of the modern parcel are widened in a controversial interaction with the surroundings. The shape and substance of the single building is going to change making the leap into a more sustainable built environment (Du Plessis, 2003). Pushing the limits of the possible the model which is growing up is a kind of off-grid independent unit self-sufficient as to the many services which are currently allocated on surrounding ecosystems (CH2, 2008).

In a near future each apartment building may have a rain water cistern and septic tank into the foundations, or infiltration trenches next to the street for treating surface run-off. Every parcel functions like a *transformer toy* (Moffat and Kohler, 2008) that at different times of the year or at stages in its lifetime may become a source of surplus water, energy, peak power, organic material, transportation and more.

2.4 The Existing Stock and the Capital Approach

A theoretically weak point in all assumptions is given by the fact that the environmental impacts caused by construction, operation, maintenance and disposal of the human built environment on the ecosystem have only been considering initially for the effects of final operating energy in new constructions. This fact reflected the market-oriented interest in developing new technologies for new building. Innovation theories have also been developed within the same focus. Even building codes and standard were developed following simple regulatory solutions of the new. The recognition worldwide that extended time horizon must recognize that at 2035 over 75% of the building stock worldwide had already been built. Sustainable performance of built environments can only be achieved through better management of the existing stocks. In the industrialized European Countries, with their shrinking populations and long-lived buildings and infrastructures, the situation was even more pronounced"

Guidelines for environmental friendly construction practice (on a local level as much as on an international level) are still discussed only for new buildings. This happens though the wide awareness of the need of retrofit and regeneration of the "modern" building stock from the 1960s and '70s.

It must be possible to develop a scalable perspective that includes the net effects for stocks and urban systems. The first flow-oriented approaches (LCC, LCA and MFA) were based upon system-ecological and thermodynamic modeling, and proved to be very efficient. They made it possible to superpose mass-flows, energy flows, financial flows and information flows.

The more recent flow-based approaches mostly used to simulate the economic framework of investments in time, have further been combined with the existing *capital-based approach* used in environmental economics. Human capital is determinant for the preservation of housing estate. At the same time the building and infrastructure stock constitute a cultural capital. It allows society to develop a shared world view and develop a sense of time, place and identity which are key ingredients for social capital. This cultural capital constitutes the persistency on which all change operates. The balance between persistency and change is anyhow important in the analyses of a social-ecological system. All transformations and adaptations of the human built environment must be verified by their linked *social-ecological performance* which by no way can be divided anymore.

3. The Ecology of Innovation

The named focus on new technology and new buildings produced a one way theoretical focus on innovations. Since World War II the overwhelming existing stock (new buildings constitute only 5% of the built environment every year) has been considered a burden for an 'industry' which was allowed only to develop sporadically and fragmented. What the war was not able to destroy was demolished by men. In ecological terms the catastrophic social ecological effects of that period turned the human ecosystems back to type I system (Benyus, 1997) where the enormous need of matter and energy threaten the stability of surrounding systems.

Even the British "Hidden Innovation Report" (Abbott *et al*., 2008) applies the very interesting results on new buildings. Still the approach focuses on the fact that innovations take place at a micro-level in the context of individual projects. "The inherent problem-solving nature of construction" they claim "and the specific challenges of individual projects means that there are frequently high levels of innovations within project-teams Since this happens on a local scale, it normally goes unmeasured by normal indicators" (NESTA Report, 2008).

When the new goal is described as to the linked social-ecological performance, then the environmental game must be played at micro- and the macro-scales at the same time. The micro-scale is regulated by self-organization. Moffat and Kohler (2008) refer to this when developing issues of social relationships to spatial interactions. They see two different types of effects, first those moving from local scale outwards and then those occurring in the opposite direction, for example from the regional back to the parcel. These are referred to as 'localization' and 'synergyzation'.

"Localization means that the search for creative design solutions ideally begins at the most local scale – building or parcel, with primary responsibility on the local actors and decision makers. It is they who first explore design options, and thus have the greatest freedom to innovate" (Moffat and Kohler, 2008). What they pass on to the scale above are those concerns about services and performance requirements which they cannot satisfy locally (due to technical reasons, economic constraints or practical conditions). The responsibility for these services moves outwards, into the hierarchy of that nest (to neighbourhoods, to the city, to some communal partnering organisation). The responsibility load becomes lighter and lighter, until, at the regional scale, there may be little or no reason for policy or investments. In this way the built environment seems to emulate the self-organising and self-reliant properties of studied natural ecologies.

Synergyzation refers to a spatial interaction driven in the opposite direction where for example the region takes the responsibility at a macro-scale, deriving the definition of constraints and targets from the big picture. From this same big picture coordinated solutions may be enabled that are seen as possible in order to achieve positive synergy. This enabling function develops at each scale and can include information transfer to more local scales (a kind of centralised diffusion as in Rogers, 1995) including training, certifications, requests, recommendations, fee structures, incentives, pricing signals, and feedback systems (see the activity of the Swedish Energy Council or of the IVL or of the new Passive House Centre). The same enabling functions may also involve design and operation of larger systems for connecting more local scales – i.e. surplus resources at local scales can be transferred, shared and stored (this can be the case of solid waste used as combustible for district heating services or biogas production, or composted organic waste designated to cropland use).

The very picture for the future begins to clarify the possible connections between ongoing isolated efforts. The increased collaboration and interaction and link between the different actors and projects acting on different levels of the system emerge as the key-factor for all sustainable development. In theory the combination of 'localization' and 'synergyzation' with a conception of the 'building' as a "transformer parcel" can produce an efficient, different or diverse built environment where the whole system is really much greater than the sum of the parts.

3.1 Sector-Integrated Innovations Interacting with Research and Demo-Projects

The overall technological effort going on in Sweden is centred on energy concepts and seems to enter the sector of construction through approaching different types of innovations found within the different building activities. From the production of components to the systemic nature of the whole of the building, through the combined activities of designers, builders, construction firms, regulatory activity and construction-related research, an eco-technological change seems to be taking form.

Table 1: Four Levels of Interacting Innovations, Research and Demo-Projects

Integrated sector-specific innovations	Research	Demos
1. Product innovations **R&D by material and component producers** (e.g. new low U-value windows, solar technologies, heat pumps and exchangers, insulating materials…..)	**Innovative research** **Inventions** Indifferent of the context	**1. Demos of new materials,** components and products
2. Process innovations Improvement of design and construction on the part of → **designers and builders** (e.g. Lindås, passive-house, solar housing)	**Adaptative research** **Tends to order**. Practical applications of 1. for a better built environment	**2. Demos of experience** and resilience
3. Configurational innovations Addresses the way in which existing components and processes are combined in new ways to provide improved performance characteristics → **best current practice** (e.g. Hamnhuset, Alingsås, Chabo)	**Management research** (**Tends to resistance** towards innovations). Looks at the economic and industrial consequences of implementing 1. and 2.	**3. Demos internal to firms and organizations.** Individual and organizational learning
4. Systemic innovation Affects the design and construction of building and environments. The whole is integrated and works together → **architectural practice** (e.g. Gårdsten, Siedlung, backcasting/visions)	**Architectural research** **Tends to disorder.** The results of 1., 2. and 3. are applied to whole systems and vitality.	**4. Demos of the new possible shapes** of whole environments

For ten years ago *Gann et al.*, (1998), while addressing the impact of regulations on innovations, presented an analysis of the many factors which are influencing innovations which, they noticed, became more and more performance-based so that regulations increasingly depended on what current practice was able to perform. Four integrated types of innovations were found in building activities: 1) *product 2) process 3) configurational and 4) system* innovations. It can be of importance to keep these aspects in mind when trying to understand the kind of change specifically going on in Sweden (Rubino, 2008). Each type of innovation is developed by a specific group of agents focused on different goals and results, using very different kind of research expecting different outcomes often proved in a specific demo-project practice, aimed at proving the validity of solution, of decision made or the consequences of the implementation of change. They work on different levels of the system and often at different scales. Feedback mechanisms link all these levels, still shared interfaces make the links stronger.

4. This Study

4.1 A stakeholder Approach

This study proceeded from the assumption that social and technological phenomena can be explained as the outcome of interactions among actors. Governing the built environment towards sustainability improvements is here seen as a collaborative process which involves all stakeholders. “A stakeholder is any group or individual, who can affect or is affected by the achievements of the organization’s objectives” (Kuhndt *et al*., 2004).

Within the framework of a research study in western Sweden, the social and technical settings from the design process of a group of evolving project-cases of buildings, with advanced sustainable environmental goals, were gathered in late 2004 in an arena. The agents involved in the projects were interviewed and invited to participate in focus groups, workshops, seminars and public conferences to share questions, problems and solutions. Some of the projects have been followed-up all throughout the design stage. The purpose of the study was initially to monitor, compare and verify the prior ‘environmental friendly intentions’ of the projects in relation to their final outcomes, and cultural as well as social obstacles were expected to emerge. Following a linear model of diffusion of innovations (Rogers, 1995), a general lack of information as well as of diffusion of codified knowledge among the actors of the sector had previously been pointed out as the main barriers for an induced change towards sustainable goals.

The approach has been participatory and had its start from the observed need of a meeting stage, an *arena* where academic research and different stakeholders could meet and start a dialogue upon the possibility existing in the local situation to implement sustainable building assumptions in current practice. Theories are there to backup observations and make understanding more general. Traditional theories are deterministic and reductionist and tend to separate elements more than see how they condition each other and interact. Tend to point out a “we and them” way of thinking always lamenting the lack of responsibility by others. The producers of components and the state, the builders and the designers, the engineers, the administrators and the academic researchers, the solar power panel’s deliverer and the end users, all are we the building sector. The model of a local multi actor arena answers on this point and gives an idea of the intensity of the information flow in a phase of transition.

4.2 A New Generation of Projects

Five demonstration projects are linked to a local multi actor arena. They present a wide range of the requisites that projects must perform in contemporary Sweden as to the environmental, energy efficiency and social transformation new codes. What is not codified is the way to reach the environmental, energy and social goals. This means that it is easier to find the rhetoric about what should be done than to clarify the way to do it.

Working in a time of change these projects are embedded in a multitude of discourses sounding between two extremes: the one is coming from the many so called *change agents*, with the eco of many natural scientists, declaiming that the time for a change is in, now it is only a question of building in *harmony with nature* and the “passive houses” are the model and just adapt human buildings to the “natural environment” and of course the architects will collaborate to make them aesthetically attractive. Simple substitution of one model with another model.

The other discourse is that of those building companies still making resistance and telling about the impossibility of accepting the constraints of natural systems. Their message is “Not now, technology is not ready!” In the middle are lots of local efforts, sometimes from individuals or users, sometimes from clients collaborating in smaller communal administrations, saying “We can do better than that!” “We want a better future now!”

Table 2: Requisites of the Five Demo-Projects Linked to the Arena

One. The project was started by a **developer** as a demo for the future performance of the whole area. High-energy efficiency building in the centre of town with apartments for rental. Passive-house standard, no traditional heating system, central mechanical ventilation with heat recovery units, LCA and LCC for the choice of material and of technical device, solar panel for 50% of all hot water and district heating for 50% hot water and for excess space heating in very cold seasons, individual measurement of energy “consumption”, 116 apartments with heated garage for 90 cars.
Two. The project has been started by a **public manager** as a demo for partnering solutions and energy standards for the whole communal area. Retrofit of a social housing unit built during the 1960s. Passive house, new façade, no balconies, passive house glazing, heat pump in each apartment, mechanical ventilation, solar panels for 50% hot water and district heating for the rest. Existing inhabitants are moved to provisory apartments and at least 50 % of them are staying though the much higher hire. 20 apartments as a first stage of a total of 400
Three. The project was started as a demonstration of the responsible environmental policy by **the office manager** of the University of Technology being owner and developer of a wide campus area. Low energy building for student apartments as infill in the central part of the university campus. Energy goal of 80 kWh/ m2 year (lower than the national norm), investment related to the monthly rental (low), heat pumps for heating of water to the radiators, district heating for DHW, prefab concrete elements, total environmental control system for the choice of materials and technical solutions with LCA. 500 apartments.
Four. The project was started by **the City Council** in order to add new companies in the development of buildings in town, and successively to prove the possibility to stipulate guidelines for environmentally friendly and energy efficient buildings for all future developments done by the commune. A **competition**, for low energy and environmentally controlled housing, where builders and architects together should find solutions they could be able to guarantee in a ten years period. The winning project is still in the design process
Five. Started by **a public developer**, a low-energy terrace housing has been built, mainstreaming the model of the first project for a passive house built in the region. Cheaper than the first project, changed architect, new materials in the structure, less expensive glazing and less optimized energy performance. Good enough quite traditional solution, easy to sell to individual buyers with the guarantee of small future energy costs.

5. Results

It is possible to introduce ecological perspectives in the management of the built environment and this may happen through the co-production of innovative design solutions in project teams.

Built environments are no longer isolated on a global scale. For urban systems today the energy inputs are no longer local. They are mostly imported as food, fossil fuels and manufactured products.

Beyond the many passive houses of today we find many challenging problems. The first is the isolation of the parcel: new boundaries for building management and design are shaped in order to close the cycles of water and waste. The second challenge is to assume the possibilities of renewable energy sources and totally reject any compromise with still existing technical systems. All buildings can be regenerated into transformers of water and waste and into power plants. The timing of change is long-termed but the timing of novel technology is ‘now’ and it is already happening. There is nothing to be implemented, only a lot of design to be evolved.

These are possibilities to the near future. The role of synergyzation is fundamental in this succession. From localisation, the innovative capacity of local realities, now the actors of other scales, the administrators or the decision-makers will assume the scenarios given to them by stakeholders and, enhance synergies for the social-ecological performance of the built environment, satisfying the urgent social needs in function of the urgent environmental needs.

Adaptive management and adaptable design increase flexibility, durability and shock resistance of built environments. The goals for the eco-technical performance are adjusted during the project, the interactions between the actors evolve and the possible synergies between the parts of the designed building emerge and show potentialities to be optimized. The system's efficiency is incremental: it develops during the iterative loops of the design process (Rubino, 2007). The project team, more than the firm, carries the potential for the concretization of novelty. Local efforts need backup from societal external stakeholders able to see what is new in projects and draw the lines of future developments, not of models, but of potentials.

The innovative local solutions for sustainable buildings give a less diffuse picture of what can be done and of the future possible transformations of the built environment. Hence, when the boundaries are looser and the project for one building becomes a link, an interface between different levels and scales, each single construction becomes a possibility to facilitate the succession from a young ecosystem to a mature one. In the transition the focus changes to system maintenance and quality, cycles become closed, the role of waste material as a nutrient source becomes more important, food webs or resource exchange networks becomes complex, diversity increases and so does specialisation of function and efficiency of resource use. Information flows play an increasingly important role in this progression, helping the mature system to become more cybernetic and adaptive.

The *innovations* may be hidden in what a project did *not* assume. The potentialities are often embedded in the solutions which were not chosen but make all professionals finish a project saying 'next time I know much better what I am going to do'. C*ompromises* in projects are of different kinds, but what here is important is that the real innovative solution is often hidden in the process and will be materialized in near future projects. The project-knowledge evolving in project-teams for buildings is redundant and spreads innovations within a multitude of possible decisions, of which the final decision made is only the top of an iceberg. Goals are optimised during the process. *Creating capacity in excess of need* must be the very specific translation (in terms of human learning) of what in ecological terms have been described as redundancy and capacity building. No action is ever isolated or ever happening in a vacuum of initial conditions.

The Arena model represents one form of 'localization' which inspires regional authorities to more centralized models of 'synergyzation' focusing on new strategies to generate and integrate a diversity of ideas, viewpoints and solutions.

The lesson learnt is: 1. Communicate and engage with key individuals in different sectors: 2. Move across levels of governance and politics / span scales; 3. Promote and start experimentation at smaller scales; 4. Recognize or create windows of opportunities; 5. Promote novelty by combining different networks, experiences and memories and 6. Consider the cultural capital along with the natural and human capital.

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