BRP building resource performance – development of an operational material flow management system for construction project development

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ABSTRACT: Resource performance of buildings (BRP) is an instrument aiming to improve resource efficiency in real estate economy. By the aim of steering the development process, the resource performance indicator integrates reduction of consumption as key point in planning, documentation, and development calculation processes. Besides the demanding challenge to minimize energy consumption in buildings operational phase, future life time by developed durability measures, environmental sound production and end-of-life are essential phases in life cycle thinking of buildings. Meeting these demands, BRP process streamlines information achievement of materials´ origin, quantity and quality and value chain and integration into engineering and management processes. Resource efficiency due to informed reuse and recycling is being steered. Case studies of real estate companies practice support the scientific process for implementation and facilitation of scientific knowledge.

1. INTRODUCTION

1.1 Resource efficiency and real estate decisions

Real estate economy develops and operates a substantial share of the built environment and has direct and indirect access on the material stock and flows in our urban areas. A sustainable use of these materials requires a) efficiency in use by b) recovering, c) innovative methods (design for recycling, material accounting, and more) as well as d) hazardous free construction materials. These are linked components of resource performance of buildings. Efficient consumption, use and recovery of resources, often shortly called as resource efficiency, is an essential part of sustainable development and has to be brought into decision making of real estate developers. Resources are defined in this context as raw material input in new construction or as secondary material embodied in existing buildings. In today's construction management processes, the feasibility to incorporate environmental information and demands of sustainable development into decision making and to make it applicable is missing. This creates a distorted view of sustainable development without scientific basis; current assumptions merge into the treatment in daily business. The concept of ”ecological construction“ is emerging, although the environmental scientific definition of ”ecology“ no longer corresponds to what is intended by the construction industry now.

That is why it is necessary to clarify the environmental scientific component for construction processes. Applicability in everyday business in developing, designing, building design and construction realization is required. Construction processes, materials availability, customer habits and needs all influence each other. In order to offer the possibility for a resource efficient construction process through an extended range of information available for product development, a good preparation is necessary. This requires applicable information. Resource as a normative definition is well known in environmental science especially in the area of waste economy also for the construction waste. The material resource concept described by (Kneese et al. 1970) exceeding energy resource as an environmental impact is rather new to building design and planning and even more to real estate development. the notion of life cycle thinking as described by Clift (1993)often expresses the embodied effort in energy units and forget about the stocks and sinks of materials and processes taking place in between. Both concepts should be considered parallel to economic added value. Three priorities are to be used here: product and value chain focus, systems design focus as well as the go-to-market focus. Strategic company goals (developers and contractors), supply chain, use phase and end of life phase have to be explored. The development of the resource performance indicator of BRP is used as basic concept for data collection and application of technical data to material flow management and

documentation of building materials. During this process, content and structures are identified, which support sustainable development; using BRP as a process, compared to energy performance certification of buildings (European Commission 2002). It offers the information, which can be attached in documents like rental or purchase contract, for tenants or buyers. BRP has a multiplier effect through the transferability after the pilot phase to other buildings within a market segment and through the pressure of competition in the market.

BRP basis needs the identification of environmentally relevant scientific data and guide of the tools used for the data base. The protection of natural resources – water, air, and land, abiotic and biotic resources – is a necessary part of product responsibility in the real estate economy. Also stand the demands of sustainable development. A claim has to be associated with resource-related environmental properties of a product. This means new products have to show better environmental performance than forerunners. Even retrofitting of existing buildings and the final product are required to commit to such a goal. The goals for reduction of resource consumption are economy, efficiency, sufficiency and consistency in order to protect the environment effectively. Sufficiency is not the focus of our work although it is the most important yet the bumpiest road to sustainable development because it requires rethinking of societal values. The scarcity of natural resources needs a responsible use and a radical new orientation on material recovery. Shift of paradigm commits all stakeholders to act passively in the planning of future urban mining and actively in the reuse of recovered secondary material. The reuse requires new rules for a successful licensing and use of secondary material, in order to assure quality and warranty for proprietors.

Through resource efficiency in the building sector, high reduction potential is revealed. By structured planning and reuse of material, in various life cycles it can be metered alongside with economic figures and visioned in key performance indicators.

1.2 Management of material flows in real estate

For construction activity materials are extracted, processed and incorporated, which are removed from the ecosphere. This does not happen without environmental impact. The interference with the material and energy accounting of the biotic and abiotic environment for establishing a construction may affect the environment as little as possible to ensure living conditions of people within an intact environment (principle of sustainable development). Whilst construction is first built and then operated, maybe refurbished several times and finally dismantled all based on substances contained in construction material in life cycle aspects. Resources for the production of a construction product or service must be documented over the entire life cycle, so that it can be controlled. Here, the resource life or material flow is built on the existing life cycle concept from building LCA, how it is considered within current standards (EN 15978, EN 15804). Further, legal provisions at EU level of eco-design directive and waste directive by European Parliament (2009 & 2008) and at the national level can be found mainly in the public environmental law. Environmental concerns also intervene in other areas of the law. Multi-tiered arrangements are required, which must follow a principle of resource protection. Management of material flow is used as a method to reduce and get control of environmental impacts in built environment. Different theoretical concepts have already been developed by Obernosterer and Weber-Blaschke. (Obernosterer et al. 2001, Weber-Blaschke et al. 2005). Both studies investigate the built environment of existing buildings and their material output at the end of life and therefore analyze it retrospectively based on material flow accounting and life cycle indicators. Additionally, they began to investigate the environmental impacts of buildings bottom-up with a system border beyond the building, starting from the local ecologic system. Obernosterer developed further the already existing concept of a low energy consuming Passive House, to a low-material-house. He sets several objectives for such a kind of material efficient house. Namely, those are avoidance of local sinks of harmful substances around settlements, of hazardous substances in construction material, components and materials designed for recycling, opening of secondary material potentials, material flow accounting.

In EU, there are various resource efficiency indicators existing. No common agreement exists yet how to define it clearly without ambiguity and calculate it neither on European level nor in Germany (BIO Intelligence Service 2012). The material input per service unit (MIPS) concept developed by Hinterberger et al. (1999) measures all material input and energy flows for a product or service unit, to get data on the intensity of input for product alternatives. Schmidt-Bleek (1994) had the initial idea, to reduce the energy demand and environmental impact by applying MIPS whilst reducing the overall amount of material needed for a product. This concept cannot really accomplish the requirements of calculation of direct environmental burden as it accumulates various inputs and indicators and was not applied in the broad. However, it provides quick insight in product properties when secondary materials are used and the diversity of substances in e.g. a construction element is quite low for better separability and recycling. The theory proposes that really resource efficient buildings involve strategic planning at concept stage of buildings (Weber-Blaschke et al. 2005).

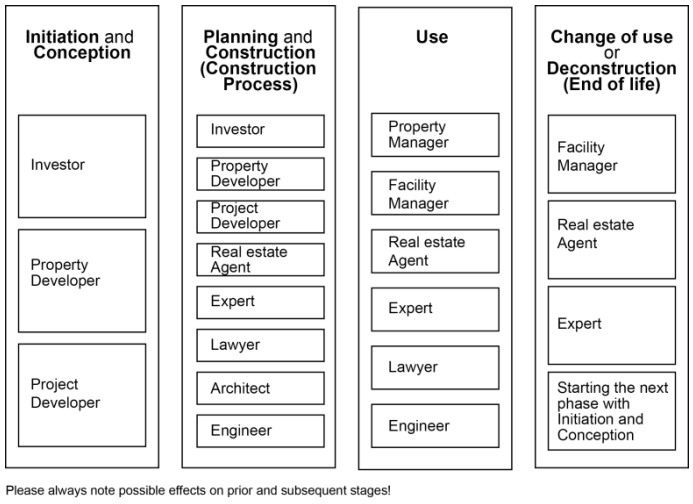

Figure 1. Institutional systematization of real estate economy, source: Schwarz, 2013.

As illustrated in Figure 1, the conceptual phase of real estate is determined by different stakeholder and institutions. Economic and technical oriented structure of real estate economy results from specialization of professions and has economic reasons. Within this structure resources are bought and used almost exclusively under economic conditions. A subsequent recovery, in particular efficient recycling, is not considered. Although on a technical level efforts for recycling are discussed and various technical trials are untertaken, a holistic approach has not yet been set as proposed by Beal & Haseler (1972). Was the recycling process so far always concerned with preventive measures, in order to save landfill costs, avoidance of pollution of the biosphere with waste and especially to save energy; Thormark (2001) describes building recycling scenarios, which originate from the reduction of environmental impacts through energy savings by reuse, recycling or thermal down cycling. Other environmental impacts from flows and the protection of resources by lowering sinks or stocks are not discussed. The work shows also one indicator is not enough to describe comprehensively the efficient use of resources as intended by Obernosterer, or alternatives can be compared without metrics for a functional unit. Additionally, it is known from exemplary mass calculations of existing buildings that beside the volume and mass of the material fractions for end-of life status and recycling the content of hazardous substances in material is crucial for further reuse of material (Hafner et al. 2014). For future planning, the reuse and recycling of buildings has to be integrated quite early in the real estate development and planning process to be able to reuse the materials in the best way. Detailed information on included building materials help to identify embodied critical substances. Small scale drawings also show how components are built in and how jointing is done. This information is useful for dismantling. Today's constructions are created from the resources out of a background system which is the local or even global environment. It gradually comes to mind that quite valuable raw materials are stored in the everyday life products but also in very large quantities in the built environment, which should be considered more carefully and exploited more intensively. When resources are stored in the foreground system, in our context also known as building, they need to be used to relieve the background system or the ecosphere. The cost for extraction of resources might decrease and the burden on the background system will decrease. In practice it shifts economic and other burden to the foreground system (like hazardous substances).

1.3 Research and development gap

Different strategies for safeguarding resource flows and fulfilling the demands of sustainable development exist. Four main routes have to be considered which are derived from the three big R rules namely Reduce, Reuse, Recycle, and the additional category Rethink for the change of human behaviour (UNEP 2006). A rationalisation of material flows helps to reduce the overall input of primary resources. Consistency gives rules for replacement by renewables or reuse of limited resources. Efficiency together with consistency of material input aims at the best result for the minimal investment. Efficiency will also take place on a regulatory level with supporting legislation, adapted standards, and in management which should decide on a basis of full information without the risk of uncertainty. Rationalisation and consistency are on the technical level where optimized constructions, new materials, and deepened knowledge of feedback loops as shown in Figure 2 are necessary results. The framework for better environmental performance by resource protection is largely unknown in the construction industry, as well as in other sectors. But in construction sector it is important because of its massive amount of material demand. Still, there is inconsistency in the feasibility of long-term resource protection goals by non-customized valid conditions (e.g. warranty, safety). The optimization is performed for construction scenarios for construction jointing strategies, taking into account the choice of materials and technical features for certain functional properties, for example, a certain strain sets sizing and materiality of the load-bearing structure. Linking environmental data and the retention in the life cycle and the recovery options at the end of life of the building, as a whole and its individual parts, allows the determination of the environmental effects. These substance-specific issues will be examined in relation to production, maintenance and dismantling capability. Further, IT

is getting more and more capable to implement qualitative information and to connect different processes from development and production. But still, research is needed to get the red line from qualitative information, information weighting to production processes. BRP indicator development and certification as consequential step wants to deliver a part in that, regarding of further life cycle effects and fulfillment of demands of sustainable development needed in an early conceptual stage of real estate development. Real estate development has to be involved in research directly, because real estate economy is strongly linked with economics and engineering sciences, and legal disciplines. Real estate development can be systematized according to functions in the life cycle, by institutions, and according to objectives of property owners (Schwarz 2013). Life-cycle of property, as it is defined in real estate development consists of following steps: project initiation, project design, and project realization, property use, refurbishment, dismantling and recycling (Alda & Hirschner 2007).

2. OBJECTIVES OF BUILDING RESOURCE PERFORMANCE

2.1 Objectives

Crucial in quality determination of construction works and property is the owner or developer (Hafner 2012). Material quality and characteristics is determined by the early decision in real estate development and by the client. The production phase and the contractor are further determining quality and taking responsibility for material quality and resource origin by providing certificates and ensuring construction quality. In Figure 2 the feedback loop real estate development−contractor−client is structured by construction management and planning processes. In order to reach a technical optimum and information quality by management and planning, BRP is an essential basis for information to meet. It creates the base for the development of an instrument that improves the resource efficiency in real estate industry. Involved stages are interfaces of processes, controlling and information management, which have to meet in development, planning, manufacturing and production.

Systematization and analysis of information instruments and tools is necessary for identification of key points for further development. Various criteria for resource protection and use are derived from Obernosterer's postulate: reduction of import flows in building construction and renewal, use the stocks from their export flows, avoiding hazardous substances, and integration of renewable materials. Other criteria from the formal procedures must rise significantly the controlling; examples are the efficiency measurement and determination of the scarcity of a resource or a substance. The aim is to make an effective resource protection possible by influencing construction material flows.

Goal of the research study is formulation of an implementation strategy and course of action for further development on technical level. On the one hand: construction on technical level describes the quality and durability from materials to whole constructions up to the disposal of elements and buildings. Both requirements have to be realized as efficient as possible throughout life cycle. On the other hand, decisions have to be made applicable for implementation of lifecycle and resource efficient information implementation. Developing projects this way empowers demands of sustainable development to be met.

2.2 Research questions of the first step

There are several questions in course of the development of building resource performance indicators which follow the order of analysis, evaluation and design of a resource protection system. Therefore one of the basic questions is how to overcome information imbalance? More specifically, what kind of data can be drawn from early project development stages? How trustful is environmental information in the entire development and are not resource and material information highly volatile in early development as well as project stages? How can use of resources be affected in these phases and also have implications on economic side?

On strategic level there are questions about the final result and the implications of decisions. Is it possible to reach sustainable development by real estate development through a clever resource management? Can sustainability goals help in maximizing the efficiency in achieving defined project quality objectives by a minimal amount of all resources?

Finally there are questions remaining for practical implementation on the operative level. How can the project development set and reach resource protection goals? What is needed on the organizational, technical and economic level?

Beyond the conceptual design for greater resource efficiency, the risk factors from assuming service life, manufacturing quality, to decommissioning and their characteristic variables in construction processes need investigation.

A) Which are the demands of sustainable development that have to be met by decision making in real estate and construction? What is the state of the art?

B) Tools used in construction within the feedback loop development−contractor−client – which of them are capable to build up the basis for implementing requirements of sustainable development?
C) Indicator development: what further steps are needed?

2.3 Methods

At this point, it is the task for new construction and refurbishment to develop a method for the awareness of the scarcity of resources. It is necessary to use resources most efficiently and to keep regional occurrence in mind. The research project wants to make the use of resources transparent to the developers of projects by giving them the ability to better control material flows. This based on a practical approach to implement circle loop economy, a certain notion of industrial ecology, and Integrated Product Policy (IPP) by European Commission (1999) into project development by a material content certificate for buildings. Such certificate opens up planned treatment of construction materials at end of life and helps to access valuable resources from urban mines to minimize environmental degradation.

The methodology for that includes the following steps:

- Advancement of a systemized description of constructions, their functions, included substances and exposures and their environmental and material properties
- Complemented with a description of the spatial construction of the system to get a formalized representative of the building by means of building information models and databases.
- Description of the dynamics of a buildings resource flow system along the life cycle model which is complemented with organisational process flow charts.
- Description of the feedback loop from concept stage of real estate to meet sustainable consumerism by investigating the interrelation development−contractor−client

Main data source is case study research within the real estate company and project partner Bayerische Hausbau GmbH & Co. KG. Further, the resource and environmental databases from German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, namely *WECOBIS* (a web-based information tool with producer neutral material data) and *ökobaudat* (LCA and resource use data) are used as data source. Other databases used are *WINGIS* (hazardous materials database of employers insurance association), *REACH* (European regulation and framework on chemical risk and safety), product technical datasheets and safety information datasheets form the industry, available for almost each construction material and provided by German Federal Ministry of Environment on their sustainability portal (BMUB 2014). Supplementary information is used from well-known eco labelling schemes like *FSC* or *EU ecolabel*. Lots of the information is already needed to fulfil the European Construction Products Regulation (CPR) in its newest version (EPC 2011).

3. RESULTS

The coupling of economic information with resource information is crucial to the objectives of the project and resource performance indicator BRP. Strategic implementation can be done on a qualitative basis. For a quantitative approach an operative application will follow in the second step. The operative implementation requires a structured framework consisting of analytics by key figures to enable prognosis based on alternative scenarios. Both results are used for assessment and decision based on prioritisation, cost accounting and investment statement.

The BRP is a decision-support and management tool in the phase of project development. The BRP is a proof and documentation of the implementation of the objectives of sustainable development at the end of a project development and can thus be used for communication to the customer. The BRP should cover two technical areas. In project development it should be an instrument to affect the structural and material relevant decision making. For this reason, a few basic indicators are chosen. These could be: proportion of renewable raw materials per square meter of gross floor area; proportion of recycled material; regional value creation. In the planning phase itself, the BRP would allow a structured documentation of built-in materials. This contains building services components and construction elements by walls, ceilings, floors, and roof. Each construction elements is described and split in individual layers, whose material consumption (kg and m^3), ecological footprint (e.g. global warming potential, primary energy demand), as well as for supporting materials. Origin, hazardous substances, in addition to technical data sheets are provided as supplementary information.

Besides the ways of the separability described in a BRP documentation, varietal purity and recoverability for every construction is a kind of recycling concept at the end of the life cycle. The requirement of recycling concepts is already enshrined in the sustainability certification and can therefore be transferred. For the detection and documentation of material flows of the import and export; flows are accounted and differentiated for building model. The model shows general quantities and in addition single figures according to resource protection criteria.

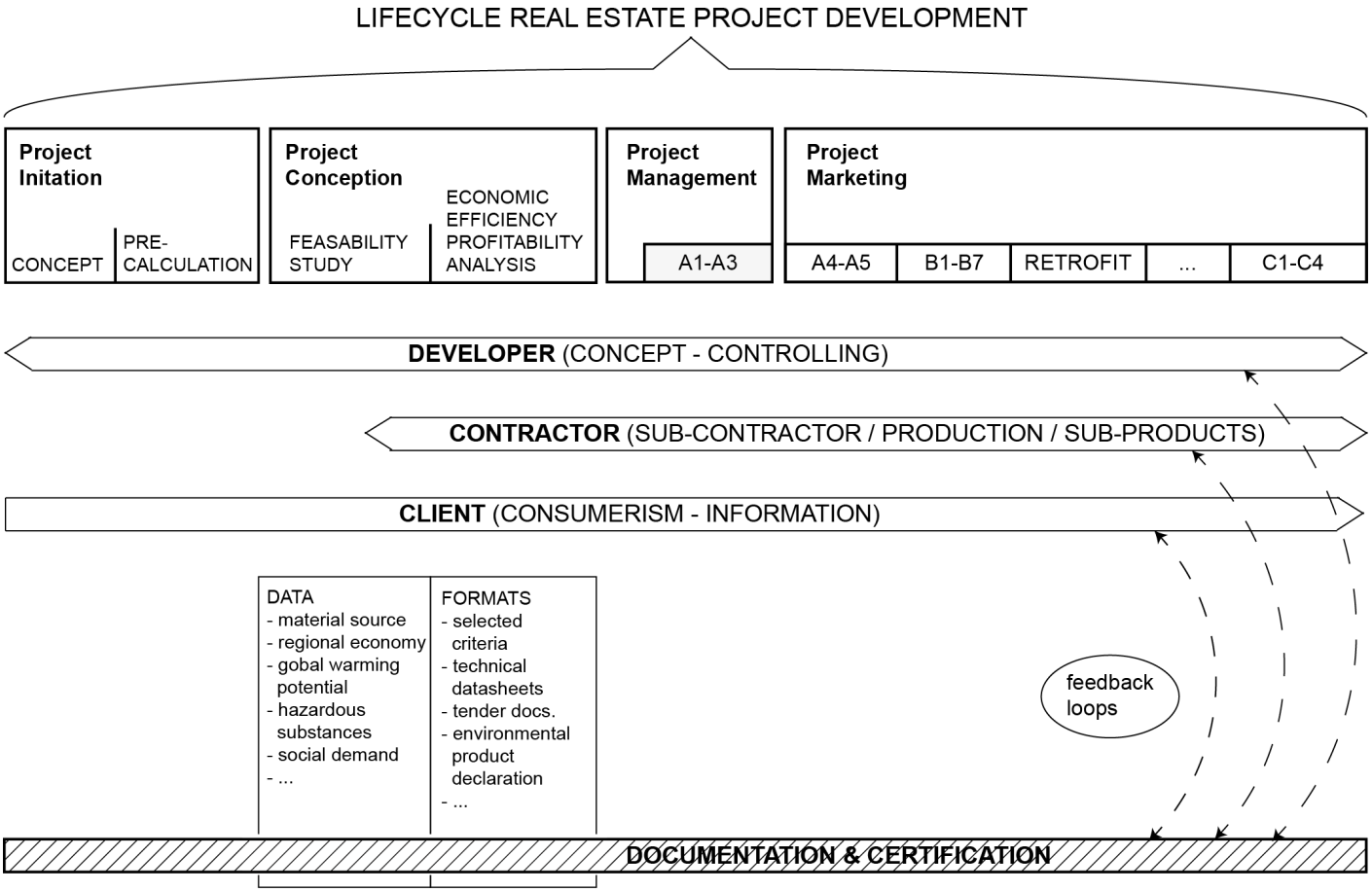

Figure 2. Life cycle and steps of project development with different levels of influence and control.

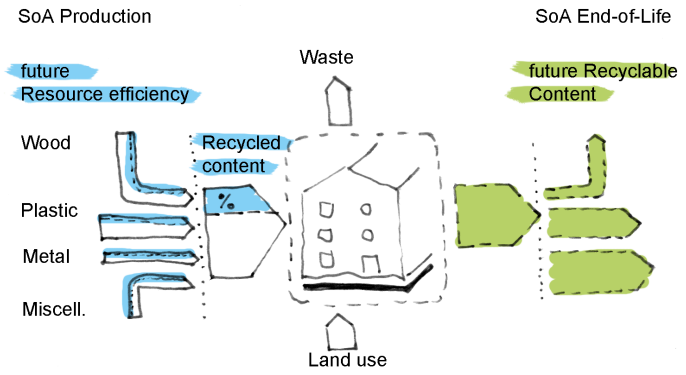

Figure 3. Material flow on building level with the inputs and outputs throughout different stages of the life cycle.

The construction material flow model is shown in Figure 3, which describes measurable material flow from several groups of substances entering or leaving the storage system building. This is the case whilst erection and renewal phase of the building as well as a possible consumption of land and the emergence of residual or waste materials. A renewal or decommissioning of the building cause an outgoing flow from the stock and materials will be documented. Material from the storage can be recovered and recycled or separated into its substances. Further measurable numbers are the recycled content of inputs and the share of renewable materials. Output is classified fictitious or real substance groups with its shares of recoverable material.

4. CONCLUSION

The building resource performance (BRP)

A) Has to be implemented as management tool in real estate project development. Therefore, the ability working with cumulative numbers and benchmarks should be investigated, as it seems to be a practical approach. By assessing the feedback loop development-contractor-client, it preserves deep scientific input and aims at profound information quality.

B) Is documentation full of comprehensive and detailed information on the material resources used in projects. It is the result and documentation of the product specification when the building is finished and handed over. It can be used during operation as well as before end of life when the building has to go to secondary use in an environmental sound manner.

C) Is an instrument for client information. This goes beyond a construction management tool and builds the bridge to corporate sustainability. This supports sustainable consumption.

Building resource performance indicators supplement existing real estate development and planning tools with a clear focus on resource efficiency aiming at the same standard and market implementation as energy performance certificates. They follow the idea of a summarized visual label to show components of building and their ecological footprint. Indicators accomplish two key objectives: on one hand to give measures in real estate development stage about use of material resources and sustainable development and on the other hand to document the used materials whilst the construction process for further information purposes and preparation of future demands.

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