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Resource Efficiency of Settlement Structures: Terms, Conceptual Implications and Connecting Factors to the Resilience Debate

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Abstract Sustainable development, the great challenge of the twentyfirst century, requires a long-term economic use of valuable, increasingly scarce resources: land, materials, and energy. In Germany, a large share of resources is used for buildings and the related infrastructure; therefore the development of settlements is of crucial relevance in this context. Despite this utilization of resources, questions concerning resource efficiency have predominantly focused on consumer goods. Due to the specific nature of the topic "built environment", we have to consider that the concepts used and the results gained so far are not directly applicable for an analysis of settlement structures. From the perspective of spatial sciences, foundational orientation becomes necessary against this backdrop. This paper systematically introduces basic concepts for resource efficiency, starting with the separate concepts of "resources", "efficiency", and "built environment". Building on these, an integrated concept, "resource efficiency of the built environment", is outlined before some limitations of an efficiency perspective are brought forth. Among several challenges, the criticism of the static nature of classical efficiency concepts stands out. In contrast to efficiency considerations for short-term consumer goods with a defined benefit, in the case of the "built environment" efficiency analyses have to deal with a considerable degree of uncertainty, due to the longer life span of the "product". This especially refers to possibly changing users' expectations and demand preferences. Reflecting on these conceptual restrictions, initial considerations are presented for discussion, outlining to what extent the concept of "resilience" might be suitable for the extension and improvement of an efficiency-driven analysis of the built environment.

Keywords Efficiency · Built environment · Resilience · Resources · Settlement development

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Ressourceneffizienz von Siedlungsstrukturen: Begriffe, konzeptionelle Implikationen und Anknüpfungspunkte zur Resilienzdiskussion

Zusammenfassung Die große gesellschaftliche Herausforderung des 21. Jahrhunderts, eine dauerhaft umweltverträgliche Entwicklung zu gewährleisten, bedingt einen sparsamen Umgang mit den immer knapper werdenden Ressourcen Fläche, Rohstoffe und Energie. Ein großer Teil der Ressourcen wird in Deutschland durch den Gebäudebestand und die umgebende Infrastruktur beansprucht, so dass den Fragen der Siedlungsentwicklung eine zentrale Bedeutung zukommt. Trotz dieser grundsätzlichen Bedeutsamkeit werden Fragen der Ressourceneffizienz bislang überwiegend für Konsumgüter diskutiert. Dabei ist festzustellen, dass die dort verwendeten Konzepte und erzielten Ergebnisse aufgrund der Spezifik des Gegenstandes „gebaute Umwelt" keineswegs unmittelbar auf Siedlungsstrukturen übertragbar sind. Vor diesem Hintergrund ist aus raumwissenschaftlicher Perspektive grundlegendes Orientierungswissen erforderlich. Der Beitrag führt systematisch in die Grundgedanken gängiger Ressourceneffizienzkonzepte ein. Es werden die drei Teilkonzepte „Ressourcen", „Effizienz" und „gebaute Umwelt" vorgestellt. Darauf aufbauend werden ein Konzept der „Ressourceneffizienz der gebauten Umwelt“ entworfen sowie Grenzen einer Effizienzargumentation herausgearbeitet. Unter anderem ergibt sich eine besondere Herausforderung aus der Kritik am statischen Charakter von klassischen Effizienzkonzepten. Im Gegensatz zu Effizienzbetrachtungen für kurzlebige Produkte mit definiertem Nutzen stellt sich hier die Frage, wie das Verhältnis zwischen der vergleichsweise langen Lebensdauer des „Produktes“ „Gebaute Umwelt“ und den sich entlang des Lebensweges gegebenenfalls ändernden Nutzungsanforderungen bzw. Nachfragepräferenzen berücksichtigt werden kann. Die Skizze eines Konzepts zur Ressourceneffizienz der gebauten Umwelt dient als Grundlage, um erste Überlegungen zur Diskussion zu stellen, inwiefern sich das Konzept der Resilienz als Erweiterung eignen könnte, neue Perspektiven für die Weiterentwicklung einer effizienzorientierten Betrachtung der gebauten Umwelt zu eröffnen.

Schlüsselwörter Effizienz · Gebaute Umwelt · Resilienz · Ressourcen · Siedlungsentwicklung

1 Background

The economic use of resources serving for the satisfaction of human needs—resource efficiency—is a crucial topic on the way towards a sustainable development. According to the World Wide Fund for Nature’s (WWF) “Living Planet Report”, we may assume that “mankind’s demand for the resources of our planet, its ecologic footprint, exceeds the latter’s regenrative cpacaities … by about 30 %” (WWF 2008: 4), whereas at the same time the worldwide consumption of resources continues to rise. Thus, in the context of scientific and political debates, the necessity of “dematerialization” (Schmidt-Bleek 2007: 34), in the case of which more desired output will be produced than resources are put in for consumption or, in case of the same output, less input of resources is needed, is again and again made a topic of discussion. In depth insights at the international level are provided on this matter by the current report of the “International Resource Panel”: “Decoupling natural resource use and environmental impacts from economic growth“ (UNEP 2011). Accordingly, resource efficiency is indeed also the topic of several sustainability strategies at different political levels. For example, the stragety for a sustainable development of the German Federal Government emphasizes, among others, resource saving (including waste avoidance), energy consumption and land use (Bundesregierung 2002: 92 ff.) as aspects which in the stricter sense may be grasped by a concept of resource efficiency. At the European level, the efficient use of resources was initially taken up by the “Thematic Strategy on the Sustainable Use of Natural Resources” (Commission of the European Communities 2005a). Most recently, this orientation has been further supported by the flagship initiative “Resource Efficient Europe” (European Commission 2011a) as well as the then following “Roadmap for a Resource Efficient Europe” (European Commission 2011b).

In this context, also questions of settlement development and the thus connected use of land, energy and material are of crucial significance. The sustainability strategy of the German Federal Government identifies the support of a sustainable settlement development—under the headline “Reducing Land Use”—as a focal point for a sustainable development (Bundesregierung 2002: 287). Additionally, Einig and Siedentop (1999) pointed out to the cumulative effects of—individually seen—less significant measures of landuse for construction purposes on the resources intensity of the urbanization of the environment. The current four-years-average of new land use for settlement and traffic purposes is 87 ha/day (Statistisches Bundesamt 2012: 14). With about 20–30% of all direct and indirect material flows, also the construction sector in almost all European countries contributes vastly to the consumption of resources at the respective national levels (Wallbaum/Kummer 2006: 19 f.). In this context, Schiller (2007) points out to the often underestimated significance of resources needed for urban infrastructures. In the European “Thematic Strategy on the Urban Environment” it says: “Better urban management can reduce the impacts of day to day use of resources such as energy and water. Avoiding urban sprawl through high density and mixed-use settlement patterns offers environmental advantages regarding land use, transport and heating contributing to less resource use per capita”. (Commission of the European Communities 2005b: 12). Reutter (2007: 9) considers “resource efficiency a strategic principle for a sustainable urban development” and an opportunity “for a sustainable management in city and region”.

Despite their fundamental significance, for the time being questions of resource efficiency are most of all discussed concerning consumer goods, the achieved results not all being immediately transferable, due to the specifics of the topic of “built environment”. Against this background, from a spatial sciences’ point of view at first fundamental orientational knowledge is required: Before the status quo or the various possible options for action and development scenarios can be analysed, the core concepts of “resources” (Chap. 2.1), “efficiency” (Chap. 2.2), resource efficiency (Chap. 2.3) and “built environment” (Chap. 2.4) need to be reflected. To take care that the built environment will be developed in a resource-efficient way, goals and technical framework conditions must be determined, priorities of interventions must be defined, and efforts at the preservation of the various kinds of capital and resources must be adjusted to each other. Concerning this, however, still today there is already a lack of numerical data concerning the built environment as well as scientific basic knowledge which, in the context of resource efficiency, would allow both for a deeper analyses of life cycles and for impact assessments concerning ways of proceeding, technologies and possible scenarios.

The following explanations are thus meant to provide conceptual orientation on the way towards an understanding of resource efficiency in a spatial-scientific context—here: specifically for the topic of the built environment (Chap. 2.5). The starting point in this context is a spatial-physical model view on the built environment, guided by a primarily engineering interest which is first of all oriented at the goal of quantifying material supplies and material flows. Typical fields of application are e. g. material flow analyses and life cycle assessments[1] (see e. g. Buchert/Fritsche/Jenseit et al. 2004; Bergsdal/Brattebo/Bohne et al. 2007; Schiller 2007).

Based on a criticism of existing classical efficiency concepts and their weaknesses regarding the particularities which must be considered for a discussion of the topic of "built environment", there will be a concluding discussion of the question of in how far the resilience concept might be suitable for opening up new views at a further development of an efficiency-oriented view at the built environment, to be able to reflect particularly on the change of related social demands.

2 Concepts

2.1 Resources

In the broad sense, the term "resource" refers to a "means which is or may be used for a process. A resource may be of material or immaterial nature" (Umweltbundesamt 2012: 21, own translation). In somewhat more detail, the "Sustainability Dictionary" defines "resource" as "any form of capital available for use" and explains further: "In terms of manufacturing capital, any material or energy available for use in manufacturing, including industrial nutrients that used and recovered from manufacturing processes. In terms of natural capital, natural materials (including sunlight, air, and water) used in an organization or society's operation or production. Humans also provide … resources, in terms of intellectual capital".[2] Thus, socioeconomic, technological and cultural conditions also influence the definition of an object, a subject or a phenomenon as a resource.

Natural resources form a section of this. Both scientific literature and political strategy papers offer very different concretizations (see Siebert 1983: 3; Schütz/Bringezu 2008: 5 ff.).

Based on an analysis of different ways of using the term at the national and the intenational levels, Schütz and Bringezu (2008) suggest a two-levelled definition of natural resources, which is as follows: "In the wider sense, natural resources include all functions of the ecologic system of the Earth as well as of our solar system which are directly or indirectly used by man or may be used or which provide the basis of man's life and survival as well as man's economic management and man's co-existence with nature. Among this there count e. g. functions such as climate stability, protection from hazardous radiation by the ozone layer, the capacity of absorbing harmful substances, the stability and regeneration capacity of natural, species-rich habitats and solar radiation. In the stricter sense, by natural resources we mean on the one hand biotic and abiotic raw materials (biomass and minerals) and water which, due to their material or energetic qualities or technical conditions, are taken from the natural environment for various socio-industrial purposes (food production, building materials and other materials, energy), and on the other hand the land used for this as well as for various purposes and in different ways and different intensity (for settlements and traffic, agriculture and forestry, excavations, recreation space and protection of nature)" (Schütz/Bringezu 2008: 45, own translation).

This basic understanding of the term "natural resources" provides a suitable starting point for spatial-scientifc work, in so far as the effect of settlement activities on the use of natural resources in the stricter sense—and in this context particularly land, materials and energy—is at the core of discussing questions of a resource-efficient settlement development.

However, a focus on natural resources does not rule out that also indirect references may be made. One particularly significant aspect in this respect concerns the question of substitution. For example, in case of closed loop management building materials incorporated in the building stock may serve as subsitutes for natural resources. Physical products, such as building materials, building parts or complete buildings, may be considered (potential) resources for a future development (Lichtensteiger 2006: 1). Thus, in this context, we also speak of "secondary raw materials" and their production in the context of "urban mining" (Brunner 2011)—a term which so to speak transfers the image of the quarry onto our way of dealing with the urban built environment.

Often also monetary figures, such as costs, show a close reference to the use of natural resources. Whereas sheer

[1] Life cycle assessment refers to a "roundup of and judgement on the input and output flows as well as the potential environmental impact of a system of products throughout its lifecycle" (Umweltbundesamt 2012: 15). A material flow analysis is a "systematic procedure for the recording of material flows resulting from a certain reference system" (Umweltbundesamt 2012: 35) (own translations).

[2] http://www.sustainabilitydictionary.com/resource/ (accessed 14.03.2012).

information on the extent to which natural resources are used often has comparably little effect on the behaviour of actors in the context of settlement development, monetary figures are important criteria for the planning practice (Schiller/Gutsche/Siedentop et al. 2009: 359). Thus, apart from natural resources, substitutes and physical building products, monetary figures are further essential analysis criteria for the discussion of the use of resources in the development context.

2.2 Efficiency

2.2.1 Efficiency as a Political-Strategic Concept

Together with sufficiency and consistency, efficiency as a fundamental normative concept is in the focus of the discourse on strategies for a sustainable development (Rogall 2009: 175).

Sufficiency strategies aim at contentment and count on an absolute quantitative reduction of the consumption of resources (Reutter 2007: 9). Linz (2006: 7, own translation) discusses "sufficiency as the question of the appropriate balance"; Huber (2000: 113) points out to the relation to basic values and way of life. According to Rogall (2009: 176, own translation), to this there belongs "to [voluntarily] restrict the use of natural resources for the sake of other humans and future generations". Often also the significance of sufficiency strategies as an important complement of efficiency strategies is emphasized, which, taken for themselves, bear the risk of "rebound" effects, i. e. "that efficiency gains are (over)compensated by growth effects" (Allen 2002: 7, own translation).

Consistency strategies "aim at a qualitatively different, nature-friendly way of production and consumption, while including nature-adjusted technologies and behaviour patterns" (Reutter 2007: 9, own translation). Typical principles are "self-organization, retrievability, recycling, entropy-friendly way of using energy" (Linz 2006: 6, own translation), the idea of "entropy-friendly way of using energy" referring to the necessity to minimize losses of usable energy.

The basic idea behind *efficiency strategies* is the decoupling of the development of wealth and consumption of resources (Reutter 2007: 9), after all "increasing output while reducing input" (Linz 2006: 6, own translation). The idea of win-win situations which is regularly connected to this, that "the realization of an appropriate level of wealth while at the same time preserving the natural resources" (Scholl/Clausen 1999: 10, own translation) is possible, is probably the main reason why the efficiency concept is very prominently and positively represented in the discourse on a sustainable development, even more as the political concept is directly equivalent to the colloquial, typically positively connotated concept of efficiency. Usually, the latter refers to an appropriate and desirable cost-benefit ratio, while the specific implications of using the term are seldom reflected on. "In many cases the adjective 'efficient' serves … only as a synonym for the adjective 'good'" (Kleine 2002: 1, own translation). Against this background, the concept of "efficiency"—similar to the overarching concept of "sustainability"—must be understood to be most of all a "boundary object" (Star/Griesemer 1989) for great parts of the public discourse. Precisely because of being vague or malleable, boundary objects have the discursive potential to provide orientation for different groups of actors while at the same time mediating between them in the form of a common point of reference.

In contrast to this discursive function, which is particularly due to the factual conceptual vagueness of the political-strategic concept of efficiency, it is indispensable for the scientific debate to make the use of the term more explicit for the respective context. This will be the topic of the following explanations.

2.2.2 Efficiency as a Basic Category of Economy

The general efficiency concept, aiming at an economic use of means, is called the "economic principle", meaning "a constant balancing of input and output" (Streit 1991: 3, own translation). According to the economic principle, a unit is efficient if by way of a given input a maximum output is achieved (maximum principle) or if a given output is achieved by way of minimum input (minimum principle) (Wöhe 2002: 344; Kositzki 2004: 38; Schlander 2009: 119). Economics literature distinguishes in particular technical efficiency and allocative efficiency.

2.2.3 Technical Efficiency

Technical efficiency is an essential concept of economic production theory (Wöhe 2002: 342 ff.) and refers to the quantitative relation of input and output, that is to physical entities. Quite generally, techical efficiency as the relation of input and output is also called productivity (Cantner/Hanusch/Krüger 2007: 1). Technically inefficient processes or units result in a waste of production factors. In the English speaking countries, technical efficiency is also discussed under the term "engineering efficiency" (Cooper/Seiford/Tone 2006: XX).

From an economic point of view, the concept of technical or engineering efficiency is often criticized as being purely descriptive: "Technical efficiency combines the amount of input with key performance indicators calculated on the basis of quantity units … and does not take key economic indicators into account, such as prices" (Kletzan 2003: 117, own translation).

As usually different technically efficient variants of production processes are possible for a product, further criteria are needed to decide which of the existing technically efficient variants must be favoured. For example, one may ask which of the technically efficient variants can be realized while producing the same output given the lowest possible investment (minimization of estimated budget). This is the subject of micro economic costs theory (Wöhe 2002: 357 ff.) which looks for that technically efficient variant which is most *cost-efficient*. Apart from costs-orientation, priorization may also be done according to other criteria, such as the minimization of unwanted ecological effects, which are operationalized by using appropriate indicators. Often the term "eco-efficiency" is used for such a perspective (see Chapter 2.3).

2.2.4 Allocative Efficiency

The concept of allocative efficiency is in the fore most of all with welfare theory, and it is used in the context of distribution questions raised by national economy. It deals with the problem of the best possible distribution of goods (or resources respectively), with the goal of maximizing a defined overall benefit. As the essential premise of welfare economy in this context one must mention the *Pareto* principle. "To have it simply, [it] states that a reallocation of resources is 'efficient' if the benefit of at least one member of society is increased without at the same time the benefit for other members being reduced" (Schlander 2009: 120, own translation).

2.3 Resource Efficiency

From an economic point of view, the term "resource efficiency" may be criticized as being a tautology, as—such as with Günther's definition of eco-efficiency[3]—the term "resource" may be considered as an equivalent of the term "input". This corresponds to the above quoted comprehensive meaning of resources as "any form of capital for use".

Thus, the term "resource efficiency" gains its specific significance only from an—in the widest sense—environmental-scientific point of view which restricts the concept of the resource to natural resources: "Resource efficiency expresses the relation of output to the use of natural resources … In this context, also pollutant releases are considered a consumption of natural resources" (Rogall 2008: 26, own translation). The latter refers to the function of the natural environment as a "sink", that is the latter's (restricted) capacity of absorbing emissions (in Günther (2005: 17, own translation): "unwanted output" or "conducts") (see also Umweltbundesamt 2012: 22). If one considers the normative aspect of the concept of resource efficiency, it means looking for ways to provide and use desired outputs while using less resources (minimum principle).

It is also that here the term "resource efficiency" converges with the above mentioned term "eco-efficiency". However, the definitions and ways of understanding "eco-efficiency" or "ecologic efficiency" as used for practical work show a considerable range and variety, which is why the term is also qualified as "opalescent" (Allen 2002: 9; Scholl/Clausen 1999: 10, own translation; for an overview see Günther 2005). Schaltegger (1999) is often quoted, who denotes the ratio of added value and added damage "economic-ecologic efficiency" or, in short, "eco-efficiency". In this context the term "added damage" is defined as "the sum total of all environmental impact caused by business operations and weighed according to their relative ecologic harmfulness" (Schaltegger 1999: 13, own translation). As a variant, in this context "ecologic efficiency" is also said to be interpretable "in a purely ecologic sense", according to which the added value is exclusively contrasted to the added damage in the sense of exploiting the environment, but not to other costs (Schaltegger 1999: 13). This example makes also obvious that any way of understanding "ecology" and "ecologic" itself would have to be reflected on in the context of this debate. Against this background, the term "resource efficiency" is favoured because it is considered to be scientifically easier to handle and, in tendency, to be definable more clearly than "eco-efficiency".

2.4 Built Environment

2.4.1 Elements and Structure

According to a very simple definition from "Science Dictionary", "built environment" refers to "the buildings, roads and other structures made by people and in which they live, work or travel".[4] A comprehensive definition is found in Coyle (2011: 1) who, beyond the invidiual elements of the built environment, also takes its structure into consideration: "physical structures and organization patterns of buildings, blocks, neighbourhoods, villages, towns, cities and regions". Bartuska (2007: 3 ff.) structures "built environment" according to several "components": "Products (e.g. materials like bricks, wood, concrete), interiors (e.g. living room, workrooms), structures (e.g. housing, schools, office buildings and highways), landscapes (e.g. courtyards, parks), cities (groupings of structures and landscapes), regions (groupings of cities and landscapes) and earth (includes

[3] "Eco-efficiency is the ratio of input (resources) and/or unwanted output (conducts) and desired output (product)" (Günther 2005: 21, own translation).

[4] http://www.science-dictionary.com/definition/built-environment.html (accessed 15.03.2012).

all the above and may be, as human power expands, the ultimate artifact)".

We may state that scientific approaches at the built environment, according to the respective discipline, vary considerably. For example, from a social-scientific point of view the analysis of interest groups, networks, institutions and questions of governance are very important (see Healey 2002; Selle 2010; Herrmann/Keller/Neef et al. 2011). On the other hand, engineering disciplines often approach the topic at first from a physical point of view, via constructions (buildings and infrastructure) and open spaces as well as their spatial structure (see Schiller 2007; Schiller/Siedentop 2010). According to this understanding, the built environment can also be grapsed by terms such as "urban form" (Jabareen 2006), "city form" (Lynch 2001) or "settlement structure" (Arlt/Blum/Gruhler et al. 2010: 29 ff., own translation).

2.4.2 Settlement Structure and Scale Level

Settlement structures may be analyzed at different scale levels. According to Gibson/Ostrom/Ahn (2000: 217 ff.), appropriate scales can be defined by a spatial, a chronological, a quantitive or an analytical dimension. According to Schulze (2000), the predominant processes which are relevant for an explanation of the phenomenon may change at the various scale levels. Accordingly, in the context of discussing the topic of the resource efficiency of the built environment, it seems to be necessary to develop an idea both of a suitable spatial scale and of relevant physical elements of settlement structure and its functional references. Micro-, meso- and macro-level refer to spatial sections which may be used for a description of small-scale, medium-scale and large-scale phenomena.

At the micro-level, settlement structure is commonly defined along the settlement area components of infrastructures ("line"), open spaces ("area") and buildings ("bodies") (Arlt/Blum/Gruhler et al. 2010: 29 ff., own translation). With the scale level rising, these objects retreat to the back, in favour of superior structural units. This way it is possible at the level of the overall city (meso-level) to grasp different types of settlement structures as elements (see Schiller/Siedentop 2010). According the understanding of spatial planning (macro-level), spatial and settlement structure refers e. g. to the distribution of cities, places and the location of institutions in the space, their networking to each other as well as to their inclusion into surrounding useable and open spaces (Sinz 2005: 863). At the same time, by describing the built environment as settlement structures, the characteristics of thus developing structures are added to the characteristics of the elements of settlement structures. Essential structural features are locational relations and density, functional dependencies as well as features determined by the land use pattern.

2.4.3 Scale Level and Hierarchy

To be able to depict complex interactions at different scale levels, systems theory (see e. g. Bossel 2004) offers the concept of so called hierarchies (Mesarovic/Macko/Takahara 1970). In contrast to a scale as a measurable, absolute entity, the depicted object—here: the built environment—is considered a system whose limits may be freely defined. For this, the term "loose coupling" (Wu 1999: 372) plays an important role. On the one hand it refers to the basic quality of the object under consideration of being segmentable into components, in the context of which coupling on the other hand at the same time emphasizes the resistance against being completely sub-divided. The number of components in a hierarchy level is called "span", the number of hierarchy levels is called "depth". Different sub-systems can be defined, which show functional links and can be hierarchically organized. Furthermore, the attribution of processes or sub-systems to appropriate spatial and chronological scale levels becomes possible.

Topically, the hierarchy allows for a standardized structuring of natural, technological and economic as well as of social or political systems. In our context, this way also spatial and social subjects can be understood by their relation to each other. Commonly, an understanding of the process of hierarchical systems requires at least three hierarchy levels ("Triadic Structure"; O'Neill 1989: 144).

- Level [+1] allows for an extended classification of the phenomena under analysis (macroscopic view).
- Level [0] defines the abstraction level (focal level/analysis level) at which a sub-aspect as well as the connected phenomena are analyzed.
- Level [−1] makes the basic mechanisms of the phenomena visible (microscopic view).

The purpose of such a theoretical model—a graphical implementation is found in Wu (1999: 371)—is to structure the connections between the individual components which are located at the various hierarchy levels. In this context, the hierarchy levels may also be understood as a sequence of entities which are related to each other, in the context of which emergent qualities become visible, as a result of overlapping or integration. Towards lower levels, the effects of hierarchical relations between the individual levels become more immediately obvious than the other way round (asymmetry). In the sense of the hierarchy theory, this means that each level affects (at least) the next lower level (e. g. in the sense of setting boundary conditions), thus showing an additional emergence quality, that is each totality is more than the sum of the elements of the previous level. At the same time, a change of the horizontal structure, when a turning point is reached (critical threshold value), may also result in changes of the vertical structure.

Any change of scale of the theoretical concepts may result in changed views of the structures. If the scale is understood as referring to the spatial or chronological dimension of an object of study, the characteristics of the theoretical construct depend both on grain and on extent. Determining boundaries and surfaces means drawing a picture which must be understood as defining the "totality" (e. g. the housing scheme as the basic geometry, or the building as a 'footprint' or solid body). Accordingly, moving up the hierarchy means thinking by larger units and/or longer chronological periods. In this context, each process runs with a different specific speed, that is each level has a spatial-chronological range.

For spatial science, the orientation at hierarchy theories provides an approach to structure its complex topic, to identify components of a possible hierarchy and to develop a model of how these components might be structured and how they might influence each other. It must be noticed in this context that after all such spatial-scientific structurings do not lead to 'truths' about the object under analysis but can at first only be the result of the observer's interaction with the objects of study. The advantage is that complex situations are not simplified at the expense of neglected criteria or, vice versa, look confusing as a result of producing amounts of data. Rather, the purposeful handling of objects of study provides an opportunity to act more adequately to the problem, in the sense of structuring data and information as well as of making it easier to formulate hypotheses and questions about system contexts.

2.5 Resource Efficiency of the Built Environment

Based on the discussion of the various sub-concepts ("resources", "efficiency", and "built environment"), now a concept of the resource efficiency of the built environment can be outlined, which is suitable for an analysis of questions regarding a sustainable development of the built environment.

Connected to the concept of the "built environment" is a spatial-physical view at the topic, which is represented by different settlement-structural characteristics and, at different scale levels, by different degrees of concreteness. In this context, settlement structure is defined at the micro-level, usually by referring to infrastructures, open spaces and buildings as elements of the settlement space. However, at the meso- and macro-levels it may just the same be about a system of urban neighborhoods or even urban settlements as a whole. These different levels must not be viewed at as being isolated from each other, neither in respect of the spatial nor in respect of the chronological dimension of the levels. A reasonable discussion of questions of the resource efficiency of the built environment always also requires a reflection on the interaction of scale effects and hierarchical relationships existing between these levels, as they become immediately obvious by the example of infrastructure networks, also due to the latter's durability.

Against this background of a physical-spatial perspective, it becomes immediately comprehensible that basically the resource concept refers to natural resources in the stricter sense—in particular to land, materials and energy. While referring to the sink-function of the natural environment, this comprises also the release of pollutants as a consumption of natural resources. This does not rule out the possibility and necessity also of indirect references, as for example to building materials stored in the building stock as potential substitutes for natural resources. Monetary entities—particularly in the context of implementation—are further essential and thus completing issues of analysis.

Regarding the debate on the sub-concept of "efficiency", at first it must be generally stated that the latter, due to its market and balance orientation, can only with reservations be related to products of settlement development. Settlement development must be considered a field where different aspects of market failure occur and where furthermore the demands on the "product" of settlement structures—along the life cycle of the product—may be subject to non-linear dynamics. This way, particularly an assessment by way of reaching back to classical efficiency concepts becomes difficult. Particularly concepts of allocative efficiency developed by welfare theory assume as essential premises either functioning markets or controlling institutions being provided with complete information (Pindyck/Rubinfeld 2005: 758 ff.) and are not helpful in our context, where both is not the case. Thus, for an analysis of the built environment under the perspective of resource efficiency, according to the here chosen focus on the physical dimensions of the resource input, it is at first considered reasonable to put technical efficiency to the fore. However, in this context it must also be taken into consideration that the concept of technical efficiency (just as that of allocative efficiency), coming from production theory, is somewhat static and oriented at assessing the state of a product whose purpose/usefulness is clearly defined. Accordingly, a thus developed concept of the resource efficiency of the built environment requires appropriate methodical extensions.

For example, the development dynamics of settlements can be descriptively taken into account by way of a series of point of time related comparative analyses along the course of the development. The problem of defining the benefit provided by the built environment can methodically be dealt with by referring to the classical economic concept of the willingness to pay (see Donaldson 1990). Just as there one concludes on the benefit provided by a good from the willingness to pay of the demand side, the benefit provided by the built environment might be derived from the readiness for political and, after all, fiscal commitment. This way, it is possible to assume that with the political decision for providing the spatial-physical conditions for meeting basic existential needs a benefit and usefulness of the outcomes—the built environment—can generally be taken as given.

The comparability of the usefulness of different settlement units can be stated by reaching back to the concept of functional equivalence, which has been introduced as an element of the Life Cycle Assessment methodology (DIN EN ISO 14040 2009). For this, according to the scope of analysis to a different degree, one must abstract from the qualitative difference of the products under comparison and establish the comparibility regarding defined, relevant (main) functional goals or demands (in more detail see Gruhler/Deilmann 1999: 42 ff.) Additionally, analyses and models of the trends of demand can contribute to a more differentiated assessment of the benefits provide by possible development paths of the built environment. This way, apart from a differentiated description of required resource-inputs, relative as well as a chronoligically and spatially comparative assessments of the resource efficiency of the built environment become possible.

3 The Resource Efficiency of Settlement Structures—Connecting Factors to the Resilience Debate

Although there is no doubt about how important and instructive the taking into consideration of efficiency concepts is, given the necessity of an economic use of resources for the development of the built environment—a close look reveals also the limitations of the efficiency argument, even if economic and ecologic perspectives are brought together (see Stephan/Ahlheim 1996: 85).

Here, particularly criticism of the static nature of classical efficiency concepts is justified, which is why in the following some more light shall be shed on it. Essential in this context is the question of how the relation between the life span of the "product" of "built environment" and the usage requirements or demand preferences, which might change in the course of its existence, could be taken into account. After all, it is about the question of how much the system of built environment could be adjusted to changed context conditions whose occurrence is uncertain, to make matters worse. Here it seems to be reasonable to discuss a few connecting factors to the debate on the resiliency of urban structures.

At first it must be stated that for the time being the resilience debate has been focussing strongly on questions of climate change and the thus connected risks for the built environment (e. g. Otto-Zimmermann 2011). Thus, our suggestion for the here discussed context is to rather terminologically connect to Cumming/Barnes/Perz et al. (2005: 976) who—less exclusively hazard-oriented—define resilience as: "The ability of the system to maintain its identity in the face of internal change and external shocks and disturbances". This way, resilience can meaningfully be discussed below the dimension of threat. Dependently of how the system of the built environment is grasped topically, the usage requirements changing in the course of time might then either be interpreted as "internal change" (built environment and users and their requirements as an urban (sub)system), or as "external disturbance" (built environment as a technical system to support basic existential needs and to meet the usage requirements of an urban society). It is important with this concept of resiliency that basically it is not oriented at a balancing idea ("engineering resilience"; Holling 1996: 33) but at the system's identity. This allows for a certain degree of change, as long as the purpose and the structure of the system as well as the regime remain basically unchanged.

However, efficiency and resilience are definitely not independent of each other. In this context Löhr (2009), while referring to Müller-Reißmann/Bohmann/Schaffner (1988), speaks of "guideline values" "any 'self-organizing' system … [must] be oriented at" (Löhr 2009: 394, own translation) and whose "relationship is latently tensed" (Löhr 2009: 403, own translation). On the relation of resilience and efficiency he explains: "Generally, efficiency at the system level can unfold best within a secure, structured environment requiring comparatively little freedom of action, ability to transform and adaptability. However, the more insecure the environment within which the system exists, the more importance—at the expense of efficiency—will be assigned to any precautions against thus resulting threats and for exploiting thus resulting opportunities. According to an economic interpretation, the best strategy against ubiquitous uncertainties is to create options…. However: Any establishment of options as a strategy against ubiquitous uncertainties … is expensive; such a 'strategy' ties up resources. Thus, the system's inefficiency increases most of all with the achieved variety" (Löhr 2009: 401, own translation).

Transferred to the resource efficiency of the built environment, this relation can be grasped in such a way, that the efficiency criterion in tendency aims at a "slimline", at a decoupling of the development of welfare and the consumption of resources (see Reutter 2007: 9; UNEP 2011), whereas an orientation at the concept of resilience—regardless of a higher input of resources—would have to aim at the creation of degrees of freedom ("options") to adjust the built environment—such as by way of functional redundancies or an overdimensioning of statics.

4 Conclusion

As a summary we may state that the concept of technical efficiency at first provides an important point of reference for an engineering definition and quantification of resource-consumption and is particularly suitable for providing short-term orientation for the development of the built environment. For a medium- and long-term orientation it will be necessary to develop dynamic efficiency concepts which will be suitable for reflecting social dynamics. For the latter, the concept of resilience might provide a suitable connecting factor, for example by taking a surplus of options—as a basic condition for a higher degree of the resilience of the system of the built environment—into consideration, as a positive criterion for the assessment of development variants, even if this way—compared to classical, static efficiency concepts—(at least) short-term inefficiencies must be accepted.

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