THINKING IN A HOLISTIC WAY: A CRITICAL LOOK AT CURRENT SUSTAINABILITY STRATEGIES

GANZHEITLICH DENKEN: EIN KRITISCHER BLICK AUF AKTUELLE NACHHALTIGKEITSSTRATEGIEN

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SUMMARY

Socially, economically and ecologically comprehensive, sustainable development requires that more unconventional paths be taken in science and research. Specialisation on the smallest subsystems, for which statements can be derived that are as precise as possible in quantitative terms, is not expedient when it comes to sustainable development. The impact of the subsystems - the ecological, social and economic effects and thus their sustainable potential - depends on their functional role in the overall system. This requires a consideration in the whole. The representation of such complex systems is accompanied by uncertainties, for which alternative mathematical approaches such as interval arithmetic are required, with which quantitative evaluations can be carried out taking into account the existing uncertainty.

ZUSAMMENFASSUNG

Eine sozial, ökonomisch und ökologisch umfassende, nachhaltige Entwicklung erfordert, dass in der Wissenschaft und Forschung unkonventionellere Wege eingeschlagen werden müssen. Eine Spezialisierung auf kleinste Subsysteme, für die quantitativ ziemlich genaue Aussagen abgeleitet werden können, ist im Rahmen der nachhaltigen Entwicklung immer nur ein Zwischenschritt. Die Wirkung der Subsysteme – die ökologischen, sozialen und wirtschaftlichen Auswirkungen und damit deren nachhaltiges Potential – ist von ihrer funktionalen Rolle im Ganzen abhängig. Hier bedarf es einer Betrachtung des komplexen Gesamtsystems. Die Abbildung von derlei komplexen Systemen geht mit Unsicherheiten einher, für welche es alternative mathematische Ansätze wie der Intervallarithmetik bedarf,

mit denen quantitative Bewertungen unter Einbezug der existenten Unsicherheit erfolgen können.

1. SUSTAINABLE DEVELOPMENT AND STRATEGIES

The quest for sustainable development is based on the concern that humans are irreversibly changing their habitat, the earth, to such an extent that it becomes uninhabitable for humans in extreme cases. This concern is based on findings from scientific studies: the records of anthropogenically enhanced and accelerated climate change due to increased greenhouse gas emissions in the course of industrialisation are an example of this. Sustainable development is an attempt to manage resources and deal with the earth in such a way that it is a livable and fair, dignified life for human beings for a long time to come. Sustainable development has become a guiding political principle in many nations.

1.1 Sustainability and sustainable development

Sustainability is often described with the three dimensions of sociology, ecology and economy. These three dimensions interact with each other. Sustainable development therefore means a development that satisfies the social, economic and ecological needs of the present without limiting the possibilities of future generations [1]. It is often discussed whether a ranking of the areas is justifiable: without the environment there is no social life and without social life economic activity is also not possible. These questions are of an ethical nature and are not part of this article - however, it is assumed that all three areas are important and must be taken into account when striving for sustainable development.

Fig. 1: Dimensions of sustainability

In Fig. 1, the three dimensions of sustainability are shown as intersecting circles. Sustainable development is illustrated in this figure as their common intersection: The goal is to strive for development that is fair, livable and worth living for people - and the solution to this is to be found where social, ecological and economic aspects can coexist equally. The consequence of this view is that a focus on, for example, the most ecological development possible does not mean that this is also socially and economically advantageous - and thus cannot be described as sustainable under certain circumstances. The result of this development may then be outside the intersection area (cf. Fig. 1, white cross in the area of ecology). In the quantitative sustainability assessment, therefore, one of the dimensions must not be prioritised on the supposedly safe side.

1.2 Sustainability Strategies

A strategy can be described as a plan for realising long-term goals [2]. This behaviour can consist of a combination of different measures, which should be examined in advance with regard to risky factors and possible interactions. The sustainability strategies serve the pursuit of sustainability: a distinction is essentially made between the strategies sufficiency, efficiency and consistency. Sufficiency aims to reduce consumption, while efficiency focuses on maximising utilisation. Consistency, on the other hand, is based on the use of alternative, sustainable(er) systems and aims to transform current systems into sustainable systems.

Fig. 2 shows sustainable developments in the course of sufficiency, consistency and efficiency as a function of resource consumption, the ratio of benefits to costs and the supply of resources as well as the degree of pollution of the earth. The figure is intended to show that the strategies have different guiding principles. Sufficient development should, for example, reduce the global consumption of available resources. Currently, the global population is growing. The absolute consumption of resources must therefore not only be reduced, but also distributed among more and more people. Consistent development should ensure that no more resources are taken from the earth than can grow back in the foreseeable future and that the earth is not polluted more than it can regenerate in the foreseeable future. Here, it is not only necessary to measure the consumption of resources and the potential environmental impact of our anthropogenic actions, but also to consider this in relation to the replenishment of resources or the regeneration of the environment. Efficiency aims at the degree of utilisation. The resources should, for example, be utilised in the best possible way with regard to their purpose, and environmental impacts that are accepted can be compared to a maximised benefit.

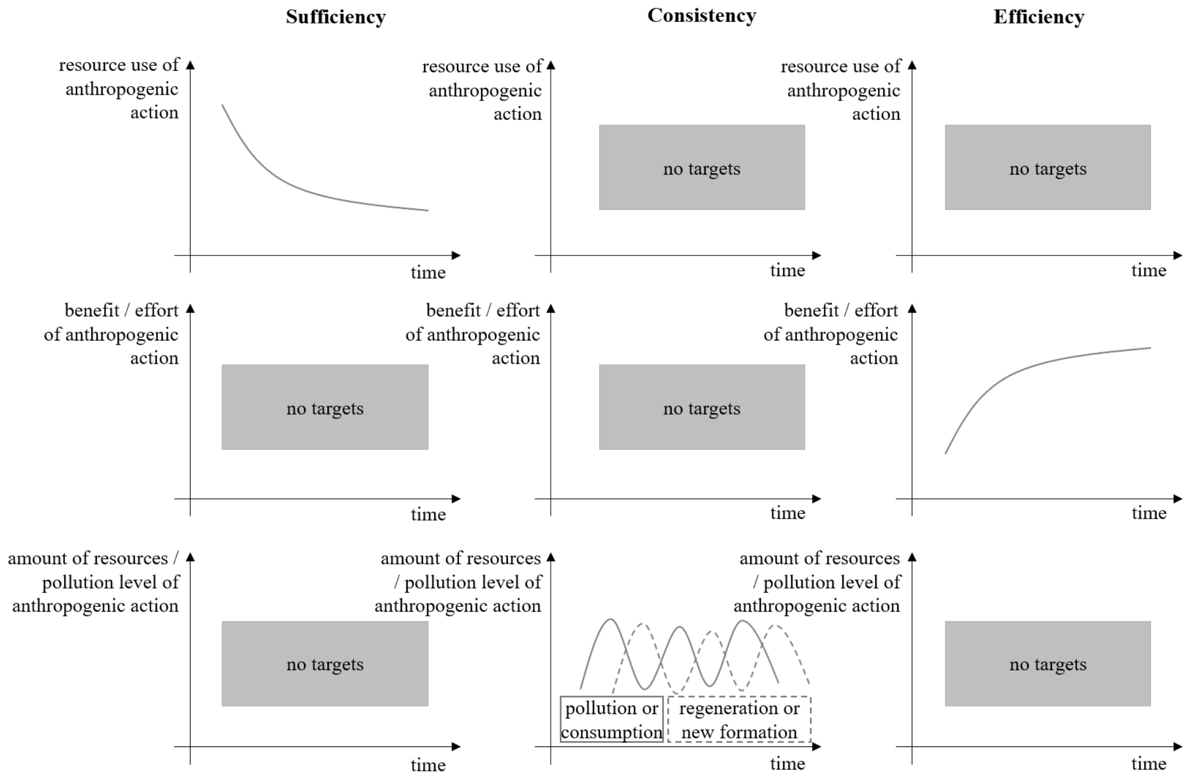

Fig. 2: Sustainable development according to sufficiency, consistency and efficiency as a function of resource use, ratio of benefits to costs and resource supply as well as pollution level

It is often one of the three strategies that is considered particularly desirable in the course of sustainable development. In science, however, a holistic approach should be aimed at here as well, which analyzes, evaluates and, if necessary, compares all three strategies or the measures that can be derived from them.

2. SUSTAINABLE DEVELOPMENT AND RESEARCH

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2.1 System theory

Systems theory is increasingly being found in a wide variety of scientific disciplines. In each field of science, the relevant objects are understood as systems. In ecology, it is ecosystems with habitats and the living beings that exist in them that are analysed as systems, in sociology, for example, it is society, and in economics it is economic systems instead. In the engineering sciences, it is technical systems that are the object of study.

A system is an ordered structure of the real world, which consists of components and their relationships [3]. Systems theory presupposes that there is a reality or, more generally formulated, an environment in which the systems exist [4]. In order to define systems, the demarcation between the system and its environment is necessary. Subsystems can be delimited from a system; subsystems are thus part of a superordinate overall system [5]. For the formal description of systems, methods of mathematics and computer science are used. Systems can be described quantitatively using various approaches. Fixed, growing or time-dependent processes can be described, for example, with (differential) equations; stochastic processes with probability distributions, transitions from states to actions with automata theory and network-like structures with graph theory [6].

If, on the other hand, a system cannot be described quantitatively, then a more abstract approach with concepts is required. For this purpose, formal conceptual analysis can be used in mathematics, while in computer science it is ontology that makes it possible to describe systems formally with concepts.

2.2 Holism

In holism, systems and their properties are considered as a whole and not only as a composition of their parts. Following holism, the interaction of these subsystems cannot be fully understood, but the system as a whole and its overarching functional role must be considered. Rather, the effect of the individual parts depends on their functional role in the whole [7]. Thus, it is assumed in this article that the benefit of the overall system n_F can be the interface between the benefits of the subsystems. It is assumed that the purpose of the individual subsystems differs (cf. Fig. 3).

Sustainable benefit n_F of a holistic system:
Thesis: $n_F = n_1 \cap n_2 \cap n_3$?
with:
$n_1 \neq n_{2,}$
$n_1 \neq n_{3,}$
$n_2 \neq n_3$

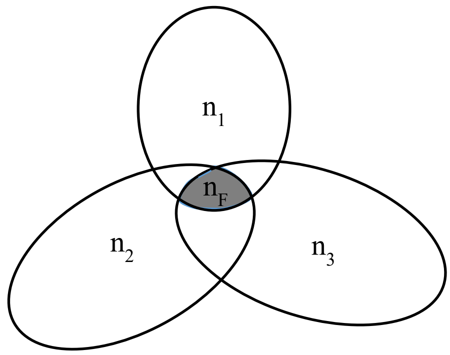

Fig. 3: Sustainable benefit n_F of a holistic system

The contrast to this holistic approach is called the separative approach [8]. In ecological research, ecosystems were increasingly studied in a separative way from about 1930 onwards [9]. In the meantime, it has been increasingly recognised that this specialisation does not allow the interrelation of these complex systems to be adequately analysed. Therefore, a holistic view of the ecological system as a whole is required. This also applies to anthropogenic systems, which can be regarded as sub-systems of the ecosystem and are part of and connected to our world. Inevitably, this holistic approach must also be considered in the assessment of sustainability or sustainable development. It is important to develop procedures that integrate ecological, economic and ethical aspects.

2.3 Research: specialisation and specification

For a long time, the sciences have been increasingly specialising in smaller and smaller subsystems. Increasingly, voices are also being raised outside of ecological research that have recognised the limits of the separate approach and thus of increasing specialisation in subsystems. For example, there are an increasing number of medical specialists who are attempting to regain an understanding of the wholeness of patients with body, soul and spirit and to treat them on the basis of their special field [10]. Thus, a development can be seen in research that is striving away from the highly specialised bottom-up principle towards a holistic top-down approach, away from the separative approach towards the holistic approach, and from specialisation on the smallest subsystems towards a superordinate specialisation of the entire system.

In this context, the understanding of precise science must also be questioned. The "exact" sciences, such as natural and engineering sciences, often use methods with which very precise, quantitative statements can be made. In these "exact" sciences, the development and application of such methods, with which exact and precise values can be calculated, are often equated with exact and precise research - although in the analysis of real systems most quantities are uncertain [11]. Exact decimal numbers suggest precision - but the results have uncertainty. Thus, analyses are necessary to classify their deviations and to consider possible effects on statements about the system as a whole. This can be an acceptable solution if results are increased upwards to be on the safe side (e.g. increased load assumptions to ensure the load-bearing capacity of a building in the structural design) or corrected downwards to be on the safe side (e.g. a reduction of resistances to take account of actual distributions in the structural design that cannot be determined exactly). In sustainable development, however, there is a balancing of many different social, economic and ecological aspects with far-reaching consequences. More on the environmental side is not sustainable on the safe side.

Uncertainty is heightened when the mapped systems are complex and can therefore only be defined imprecisely. In the course of sustainability assessment, however, it is precisely such complex systems that need to be mapped. A suitable approach for this is to take this uncertainty into account from the outset in sustainability assessments - and instead of using exact values, to calculate with interval values that include the relevant and possible uncertainty through upper and lower limits. This enables robust results.

3. STATUS QUO IN CONSTRUCTION

The construction industry is currently responsible for approx. 50 % to 60 % of the world's global material consumption; approx. 80 % of this can be attributed to the consumption of mineral raw materials. In addition, about 50 % of global emissions are attributed to the construction industry [12].

Concrete is considered an essential building material in the construction industry, for which the raw materials limestone, claystone, sands and gravel are required. Even if these raw materials are sufficiently available on earth in the long term, there are local differences in distribution, quality and usability for concrete production as well as limits to degradability. In Germany, for example, about 85 % of the sand and gravel reserves are located in built-up areas and protected areas. Sand and gravel for the construction sector are largely extracted from river deposits and produced by breaking up sandstones and gravel. Annual global consumption is estimated at 40 to 50 billion tonnes. The natural formation of sand is estimated at about 20 billion tonnes per year and is thus significantly below the annual consumption. Approximately 3.5 billion t/a of limestone are precipitated annually in the oceans. With a global consumption of over 4 billion t of limestone per year, anthropogenic consumption is higher than the current annual global formation [13].

Currently, more raw materials are being extracted than are being produced at the same time. It is assumed that the demand for essential raw materials such as gravel, sand and limestone will almost double by 2060, starting from 2017. This circumstance can be considered unsustainable in terms of sufficiency and consistency [13].

4. RESEARCH IN CONSTRUCTION

In the construction industry, research takes place primarily in the areas of building materials and components. The focus here is on applied research. However, there is a lack of in-depth basic research in civil engineering that includes all phases of a building [14]. Focusing on small subsystems in the building industry in order to research building materials and components is therefore not sufficient if sustainable development is also the goal here. Rather, the sustainability of these materials and their interactions in the overall system must be researched. This leads to the need to conduct research at the level of the building as a whole system.

In civil engineering, too, system-theoretical considerations based on a holistic approach are imperative if sustainable development is actually to be pursued.

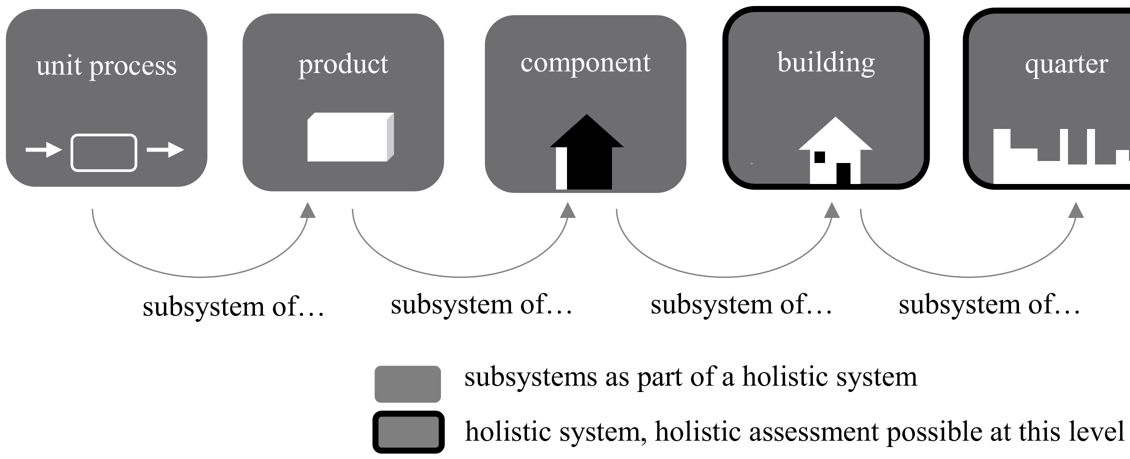

Fig. 4: Levels of consideration in the construction industry and associated subsystems: Manufacturing processes, products, components, and buildings and quarters

Subsystems are on the one hand individual processes to produce products or components, the building products, and components themselves or components resulting from them, which represent a part of the superordinate system of a building or a neighbourhood (cf. Fig. 4). At the level of buildings or neighbourhoods, further subsystems of a different kind result from the time frame of observation: thus, an individual life cycle phase of the building or neighbourhood represents only one subsystem of the entire life cycle (cf. Fig. 5).

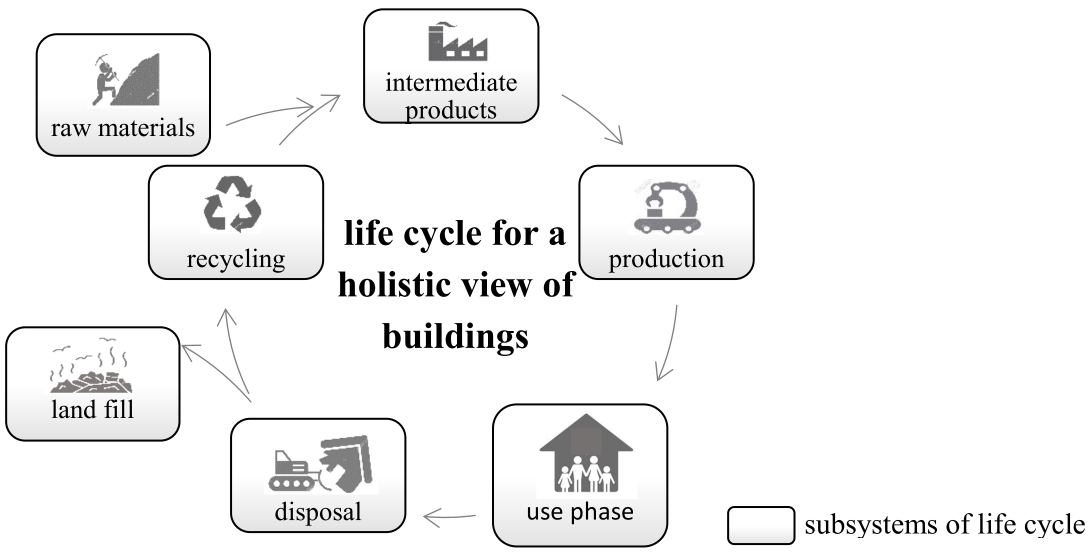

Fig. 5: Life cycle of buildings for holistic consideration

A sometimes very precise analysis to solve (sustainability) problems of the smallest subsystems is not sufficient - the partial solutions cannot be added together to then determine a (sustainable) solution of the overall system. For example, an efficient, highly effective insulating material that requires only a few raw materials in production is not sustainable if it does not lead to significant energy savings in the overall system or has only a short service life. At the same time, a precise and exact calculation of the overall system is hardly possible - these systems are too complex, not to say too real, to be determinable with unambiguous solutions of systems of equations. What is needed, therefore, are methods that make it possible to take recognised uncertainty into account and also have procedures with which the results determined in this way can be analysed. A possible method for this is, for example, interval-based life cycle assessment, which makes it possible to estimate environmental impacts while taking uncertainty into account.

5. CONCLUSION

Optimizing small subsystems based on processes, products or components in the building industry with regard to sustainable aspects is not sufficient to drive sustainable development. Instead, it is necessary to research these subsystems and their benefits in the holistic overall system at the level of buildings and neighborhoods or - even better - in the overall context of social life. Currently, there are a large number of highly specialized research fields that analyze and optimize the smallest units of systems. The manufacturing processes of building materials are optimized in terms of saving materials, increasing efficiency or using environmentally friendly raw materials. However, a building consisting of such building materials and components cannot be judged as material-saving, efficient or environmentally friendly on the basis of these findings. This is because it is only in the building that it becomes clear whether raw materials are saved overall, whether efficient building operation is made possible, and whether the building can actually be consistently constructed, used, and deconstructed.

It is therefore necessary, in the interests of sustainable development, to shift the focus increasingly to the complex overall system, even in basic research, whereby the entire life cycle must also be considered. As a consequence, uncertainties have to be dealt with when modeling these complex systems, for which alternative mathematical approaches such as interval arithmetic become necessary. In this way, uncertain data can be captured as intervals and comprehensively considered. Thus, methods are necessary for the sustainability assessment, with which social, economic and ecological aspects can be evaluated with regard to efficient, sufficient and consistent development, whereby the building or neighborhood should be recorded as a whole - taking into account the associated uncertainties.

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