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# Concept for Planning Sustainable Factories

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***Abstract*****—**In the current economic climate, for many businesses it is generally no longer sufficient to pursue exclusively economic interests. Instead, integrating ecological and social goals into the corporate targets is becoming ever more important. However, the holistic integration of these new goals is missing from current factory planning approaches. This article describes the conceptual framework for a planning methodology for sustainable factories. To this end, the description of the key areas for action is followed by a description of the principal components for the systematization of sustainability for factories and their stakeholders. Finally, a conceptual framework is presented which integrates the components formulated into an established factory planning procedure.

***Keywords*****—**Factory Planning, Stakeholder, Systematization, Sustainability.

## I. Introduction

IT was in 1992 that the Brundtland Commission drew up a notion of sustainability that is still valid and recognized today [1]. Based on the Brundtland definition, a select committee of the German parliament developed the three-pillars model of sustainability, which consists of ecological, economic, and social dimensions [2]. All three dimensions interact with each other and, in the ideal case, need a balanced relationship with each other [3].

In today's economic climate, many companies mostly pursue just one of these dimensions and neglect the other two and the corresponding interactions. As a rule, the economic dimension is given priority, because most businesses operate in an environment characterized by considerable turmoil [4], [5]. Therefore, to safeguard their competitiveness, they frequently initially focus on economic objectives. For example, again and again, companies find themselves having to face the challenges of growing globalization, the individual requests of customers, and shorter planning cycles for products or factories [6]. However, an additional, growing trend regarding the efficient use of resources in factories has been observed in recent years [7], [8]. This development is driven by a range of very diverse factors. It has been ascertained, for example, that customer demands for sustainably produced products are growing constantly [9]. At the same time, the ever faster rise in the cost of raw materials and energy makes it necessary to use resources more efficiently [7]. Furthermore, politics, e.g. in the form of more stringent environmental stipulations or political targets such as the turnaround in German energy policy, is constantly raising the importance of the ecological dimension in sustainability [10], [11]. Parallel with this, the social dimension is becoming more and more influential. This aspect includes, for example, taking into account the interests of employees; and where factories are located in urban areas, which is often the case, then listening to the opinions of local residents is also becoming increasingly relevant [12].

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## II. The Fundamental Areas for Action

The scientific literature contains a multitude of approaches for methodical procedures in factory planning. However, these approaches do not integrate sustainability adequately and so there is need for appropriate action here. This action is outlined below.

### *A. The Dimensions of Sustainability and Their Interactions*

It has been shown that businesses should attach fundamental importance to the simultaneous consideration of all three dimensions of sustainability [13], [14]. No company can afford to omit these dimensions from its corporate goals. In order to guarantee the integration of all three dimensions of sustainability, they must be considered early on, in the planning phase of a factory's life cycle. Factory planning has the biggest influence when shaping sustainability because it essentially defines the operating conditions of a factory (e.g. location, manufacturing resources) [15], [16]. However, current factory planning approaches generally focus on cost, quality, and time targets [17]. These approaches frequently exhibit shortcomings when it comes to considering ecological and social aspects and their interactions, with just a few issues being addressed in isolated cases [5], [18], [19]. Consequently, an existing factory planning procedure must be expanded to take into account all the dimensions of sustainability and their interactions.

### *B. The Interests of the Relevant Stakeholders*

Besides deficiencies in the consideration of all the dimensions of sustainability, the factory planning process also fails to achieve full integration of the interests of the stakeholders relevant to a factory (e.g. local residents, suppliers) [20], [21]. Only by taking into account all interests is it possible to plan a factory that is sustainable for all the relevant stakeholders. In the future, the question of whether a factory's success is sustainable should not be based on a purely economic assessment of its performance – integrating the effects on the individual stakeholders must be included in the assessment as well. A factory can therefore be regarded as sustainable only when the interests of the relevant stakeholders are incorporated in the planning and assessment process. However, it is not generally possible to avoid conflicts of interest between the stakeholders or between the stakeholders and the factory. There are deficits in the identification and solution of these potentially conflicting goals. It is therefore necessary to expand an existing factory planning procedure in such a way that the interests of the relevant stakeholders can be weighed up and taken into account adequately.

### *C. The Chronological Treatment of Sustainability*

Current factory planning approaches do not pay enough attention to the dimensions of sustainability over the various life cycle phases [22], [23]. Plotting sustainability against time is a crucial component in the planning of a sustainable factory. On the one hand, the interests of the stakeholders include a time component. For example, some stakeholders tend to pursue short-term targets (e.g. investors wishing to achieve maximum returns as quickly as possible [24]), whereas others usually have long-term aims (e.g. the employees expect long-term job security [25]). On the other hand, it is necessary to integrate the time component into the consideration of sustainability in order to support the decision-making process. For example, including the entire life cycle is absolutely essential when assessing the economic, ecological, and social sustainability of planning alternatives.

### *D. Summary of Areas for Action*

It has been shown that current factory planning approaches still exhibit many weaknesses when it comes to the holistic integration of sustainability and, correspondingly, there is need for action, see Fig. 1.

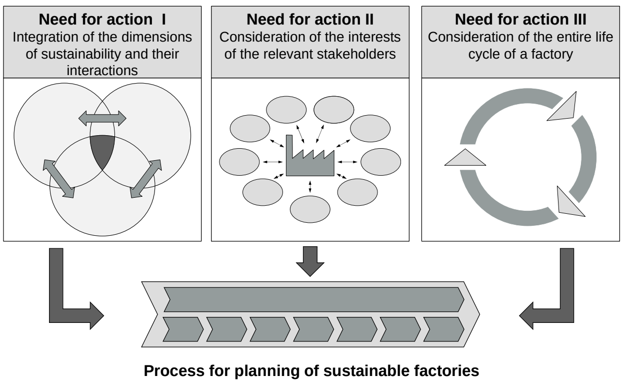


Fig. 1 Areas for action when planning sustainable factories

The deficiencies include the simultaneous consideration of all the dimensions of sustainability and their interactions, the interests of the relevant stakeholders, and the time component in the form of the factory’s life cycle. To rectify the shortcomings identified, appropriate aspects should be added to a factory planning procedure established in science and practice (e.g. the planning methodology according to VDI 5200 [26]). This article presents the conceptual framework for a methodology that will enable the planning of sustainable factories.

## III. The Systematization of Sustainability

In order to solve the areas for action shown above, however, the first step is to systematize the range of sustainability topics for the factory and its stakeholders. This systematization creates the consistent organizing framework required for drawing up a planning and assessment methodology for sustainable factories. The systematization consists of many components, and the main ones will be briefly introduced below.

### *A. System Boundaries*

A system consists of its elements, the system boundaries, and the relations between its elements. A system can also be one element in a higher system [27]. To limit the scope of the investigation, the system elements must be given clear definitions and clear boundaries. The system considered in this approach consists of the stakeholders outside the company, the factory objects within the company, and their relations with each other, see Fig. 2. Describing the system and its boundaries represents the first component in the systematization of sustainability.

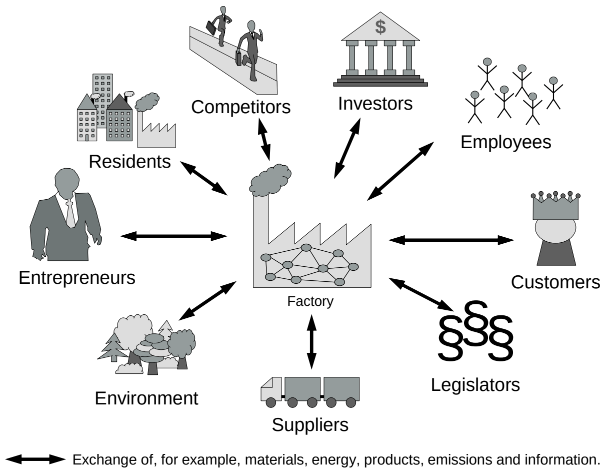


Fig. 2 The system with the factory and its stakeholders

The factory itself is the core element in the system. It has a number of subelements, which are called factory objects in the scientific literature. Existing clusters will be used to create a widely accepted understanding of the system [28]. There is a series of relations between the subelements of a factory, which include the exchange of materials and information.

According to the relevant literature [29]-[32], there are nine relevant stakeholder groups that can be identified as further system elements in addition to the factory. Those groups are: competitors, investors, employees, customers, legislators, suppliers, entrepreneurs, residents, and the environment. It is necessary here to consider the employees as stakeholders, and not as factory objects as is customary in the literature. Regarding the employees purely as factory objects would not do sufficient justice to the interests the employees represent, and the danger of that would be that the employees would not be taken into account properly in the planning process. Stakeholders have an interest in the factory and represent the system elements outside the company. However, every stakeholder has an individual interest in the factory. The result is a number of conflicting aims that occur during the life cycle of a factory which must be taken into account early on in the factory planning process if possible. These conflicting aims define conflicting priorities for factory planning. The fundamental challenge in the planning process is to take up a suitable position within the conflicting priorities so that the interests of the relevant stakeholders are adequately served. The stakeholders have a relationship with each other but primarily a relationship with the factory. Those relationships are due to, for example, raw materials, finished products, flows of energy or information, and emissions.

### *B. Operationalization of Sustainability*

The second component in the systematization of sustainability is its operationalization, i.e. the description of a concept in the form of qualitative and quantitative criteria and parameters. The trio of ecology, economy, and social aspects is used in countless scientific articles and can be regarded as generally acknowledged. However, a detailed operationalization of sustainability for the factory and its stakeholders is lacking. Up until now, sustainability has only been partly operationalized (e.g. regarding emissions). Fig. 3 shows part of a concept for the holistic operationalization of sustainability from the viewpoint of the factory and its stakeholders.

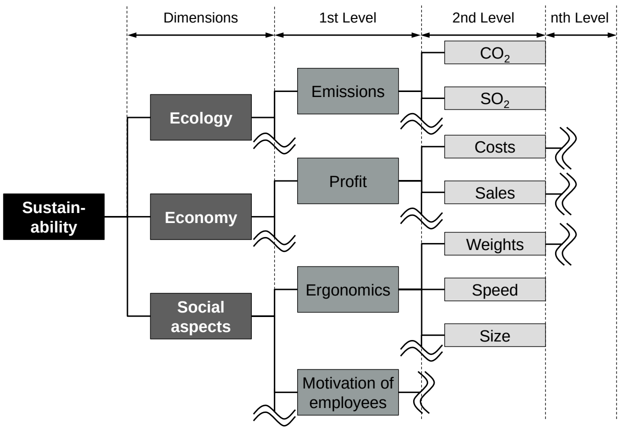


Fig. 3 The concept of the operationalization of sustainability

The concept presented here contains a number of criteria and parameters for each dimension of sustainability. Criteria are generally understood to be qualitative and can be described by a capability maturity model, for instance. A capability maturity model is given a certain number of attributes for one criterion. Every attribute is described by a defined text [33]. Parameters have a quantitative character and are described, for example, by means of a nominal scale (e.g. the presence of a heat recovery system) or ordinal scale (e.g. a system of grades to assess customer satisfaction). However, parameters are normally provided in the form of a cardinal scale (e.g. the measured emissions of a factory). It must be guaranteed that all the criteria and parameters used in the operationalization of sustainability can be determined in the planning methodology. Methods for ascertaining the figures include, for example, surveys, interviews with experts, the use of legacy data or measurements of physical variables. One of the functions of the operationalization concept presented here is to serve as the foundation for assessing sustainability. However, owing to the multitude of criteria and parameters, it is generally necessary to select the most important criteria and parameters for each planning situation in order to minimize the work involved.

### *C. Relations between Sustainability, Stakeholders, and Factory Objects*

The third component contains the description of the relations between the stakeholders and the factory objects and their relations with the criteria and parameters of sustainability. This component is shown graphically in Fig. 4.

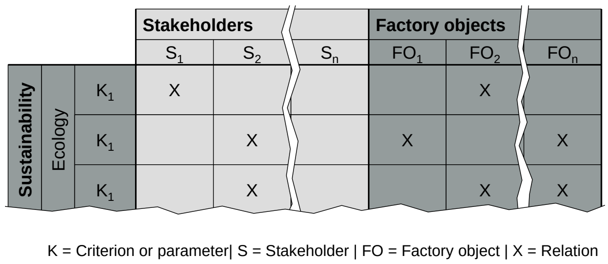


Fig. 4 Relations between sustainability, stakeholders, and factory objects

The matrix shown is a directional matrix. The left-hand part describes the relation between sustainability and the stakeholders. On one hand (reading columns first, then rows), the matrix contains the influence of sustainability on the individual stakeholders. If, for example, a parameter has a particularly conspicuous nature, then the matrix allows drawing conclusions about the stakeholders especially affected by that parameter. On the other hand (reading columns first, then rows), the matrix reveals the effects of the individual stakeholders on the criteria and parameters of sustainability. If, for example, a criterion has to be optimized within the planning process, then the effects described can be used to identify those stakeholders with an influence on this criterion.

A similar procedure applies to the relations between factory objects and the criteria and parameters of sustainability described in the bottom part of the matrix. In its complete form, the matrix contains the relations in the shape of mathematical equations or qualitative descriptions. For clarity, these detailed relations have been suitably substituted in the figure.

## IV. The Planning Methodology Concept for Sustainable Factories

The planning methodology for sustainable factories as presented in this article is based on the factory planning procedure according to VDI 5200, which is established in practice. The procedure consists of seven consecutive planning phases, which include setting of objectives, establishment of the project basis, concept planning, detailed planning, preparation for realization, monitoring realization, and ramp-up support. These phases must be accompanied by continuous project management. The conceptual framework for the methodology presented here encompasses the whole life cycle of a factory. The approach primarily focuses on the phases for setting of objectives, establishment of the project basis, concept planning, detailed planning, and the project management because it is within these phases that the actual planning takes place. The subsequent phases generally only serve to implement the results of the planning work, which are in the form of a detailed schedule for a sustainable factory. The concept of this methodology is shown graphically in Fig. 5.

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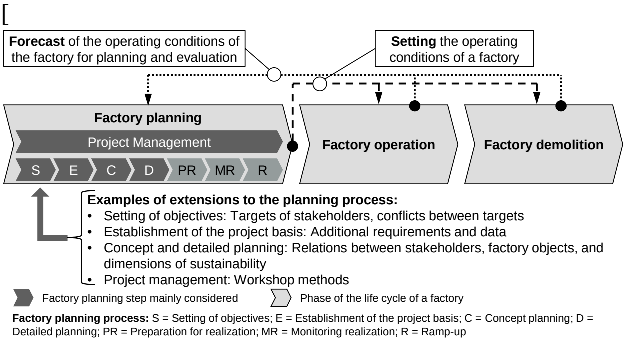


Fig. 5 Concept for planning sustainable factories

The components for the systematization of sustainability are among those components that must be integrated into the factory planning process in order to design a sustainable factory. Therefore, setting of objectives is expanded by including the interests and aims of the relevant stakeholders and a procedure for identifying and solving potential conflicts. The additional data requirement is included in the establishment of the project basis (e.g. explicit consideration of emissions from manufacturing resources). The relations described between stakeholders and factory objects and with respect to sustainability can help to achieve a sustainable planning outcome in the concept and detailed planning stages. The overriding project management phase is expanded by including workshop methods or by adapting project management methods, etc. During the phases mentioned, appropriate preprinted forms are provided for the user of the methodology in order to promote a systematic approach.

Forecasts of the factory operating conditions for the factory operation and factory demolition phases of its life cycle are required in order to integrate the time component of sustainability into the planning process. The forecasts are provided in the form of qualitative and quantitative criteria and parameters. This enables an assessment of potential planning alternatives with respect to the benefits to be expected and the expenditure necessary. Following realization and ramp-up in the factory, the forecast figures can be compared with the actual ones, which allow potential miscalculations to be identified and analyzed. Such experience can be input into an appropriate knowledge database in the form of best practices or lessons learned to help in subsequent factory planning situations.

## V. SUMMARY

This article has presented the conceptual framework for expanding a factory planning process so that the ecological, social, and economic dimensions can be considered in the planning work. Highlighting the areas for action was followed by a presentation of the key components for the systematization of the sustainability concept for the factory and its stakeholders. Those components include a description of the system, the operationalization of sustainability, and consider the relations between the criteria and parameters of sustainability with respect to the stakeholders and the factory objects. That was followed by a conceptual integration of the components into the planning process. Consequently, the user of the methodology is able to plan a factory that is sustainable for all stakeholders.

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