Journal of Production Systems and Logistics
Volume 1 | Article 8
Published: July 2021

Investment Feasibility Study For Factory Planning Projects

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Abstract

Companies and their factories are in a state of permanent change. Factory planning is interested in anticipating the changes that will occur and thinking ahead structural adjustments by dimensioning the operating resources, personnel and space. Often incremental adjustments over the space are no longer sufficient, so that further investments become necessary. Large factory planning projects, such as a greenfield or expansion planning, usually require extensive capital, which has a huge impact on a company's liquidity. The correct evaluation of the economic efficiency of a factory planning project, i.e. the comparison of costs and revenues, is therefore essential. Investment feasibility studies can help companies choosing a proper project. In such an early phase, investments have to be planned and initiated under increasing uncertainty. However, with common methods and tools, a precise evaluation of the investments costs in an early planning phase is only possible to a limited extent. Consequently, the risk of misinvestment increases. Factory planning experts are therefore dependent on tools and methods that minimise this risk through a precise calculation of investment costs under uncertainties. This article addresses the related challenges, shows the need for an improved decision support, and give a first framework to face these challenges.

Keywords

investment costs, dimensioning under uncertainty, factory scenarios

1. Introduction

In today's complex economy, factories are facing permanent change drivers [1–4]. This so-called turbulent environment generates a pressure on companies, which can result in short- or long-term modifications for the production including changes for example in demand, technologies or in the entire supply chain [4]. Referring to this, permanent adaptation of the factory is required by continuous factory planning activities [1,5,3]. Processes and area requirements of a factory must ideally be matched to the physical construction conditions in order to realise a sustainable factory concept [4]. Depending on the initial situation, a greenfield planning in form of a new factory or a brownfield planning in form of a reorganization or an expansion of the existing plant needs to be initiated. Planning a new factory or reconstructions are a significant strategic decision hence the facilities must be set up for several years [4]. Factory planning is conducted in the form of projects, as the associated tasks are predominantly characterised by project characteristics (e.g. uniqueness and complexity of the task cf. [6,7]) [1,3,8]. Due to their importance, these types of projects are characterized by a large project volume, which can have a significant impact on a company's liquidity [9]. Such important projects must be prepared in a profound way in order to generate the best possible outcome for retaining or increasing the company’s competitiveness. Feasibility studies can play an important role by setting the course for projects, as they can guide by the selection of the right project scope or recommend a cancellation.

This Paper has been reviewed by the Certified Reviewer Community of publish-Ing. – 2 reviews – single blind

DOI: https://doi.org/10.15488/11143
ISSN: 2702-2587

As part of the feasibility study, reliable statements on feasibility, risks and benefits need be elaborated [10], so that the company's existence can be ensured by choosing the right project. Apart from the benefit, valid predictions concerning the expected investment costs have to be provided for a better decision process. In order to evaluate the investment in an early factory planning phase the operating resources, the necessary personnel and the required area and their specifications needs to be estimated [11]. As companies make their investment decisions dependent upon the expected costs-benefit ratio such considerations need to be involved in factory planning. If not the risk for a misinvestment increases, which can lead to the collapse of a company (especially small and medium-sized enterprises) [12].

There are numerous approaches for factory planning in the literature, which are characterized by different types of process models and different key aspects (a comprehensive listing is shown in [13]). Ironically, despite the described importance of the feasibility study the concrete execution of such a study is only picked up rudimentarily in a few relevant factory planning procedures (a.o. [1,9,3]). The need for action is further intensified by the fact that the VDI Guideline 5200, a process model for factory planning acknowledged in practice and science, does not address this issue (cf. [8]). In addition to the lack of a standardized procedure for executing a feasibility study, approaches for that purpose need to deal with uncertainty in data, as they need to be set up for an early stage of a factory planning process. The challenge lies in the fact that feasibility studies usually need to deal with a high degree of uncertainty and still need to give a valid advice [10].

Considering the given issues, the hypothesis of this paper is that factory planning projects with strategic construction activities need to be released by a feasibility study that is based on a coherent holistic approach, which is equipped with a toolset that can meet all the challenges by determining investment costs of a factory in an early phase. Referring to this, in this article we first examine the fundamental requirements for a feasibility study in the factory planning under the influence of uncertainty. Based on that we subsequently review current approaches, which are related to the issue at hand, in order to point out the research gap. Following that, we describe first results to support companies in their project selection activities and give a quick conclusion.

2. Derivation of requirements for a holistic feasibility study in factory planning

The research objective to meet the hypothesis is to develop a procedure and evaluation method to conduct a feasibility study in factory planning in order to determine investment costs under missing and uncertain data. The given objective must be reached from two sides. First, we extract requirements for a feasibility study. Then, we are going to link these needs to the requirements of a factory planning project and the intended results.

According to DIN 69905, a feasibility study is defined as an “investigation for possible solutions and their feasibility to achieve the project objectives” [14]. First and foremost, it is necessary to clarify the boundary conditions of a project and whether there are any contradictions between the project objective and the developed results (**requirement – project conditions)** [15]. In addition, this phase essentially has to verify in advance (ex ante) the realistic chance for a project implementation based on their economic, technical and operational feasibility (**requirement – feasibility)** [16,10,15]. The economic feasibility of the project depends very much on the investment cost calculation, while the technical feasibility essentially focuses on the required expertise for the realization of the project and the operational feasibility evaluates whether the project meets the company's requirements in the planned scope. So all in all, the benefits of the respective project need to be highlighted so that an advice for further activity can be given (**requirement – advice)** [17]. Moreover the study should be able to precisely identify the project scope [18], to discuss basic solution directions and to plan further activities (**requirement – planning task**) [19,10]. Generally, the input is characterized by incomplete and fuzzy information, which means that a feasibility study should be able to deal with uncertainties and take them into account (**requirement – uncertainty**) [20]. At least, the effort needs to be kept to a reasonable size. Therefore, it useful to provide a toolbox for factory planning tasks like for dimensioning the resources of a factory or for an investment evaluation (**requirement – reasonable effort**).

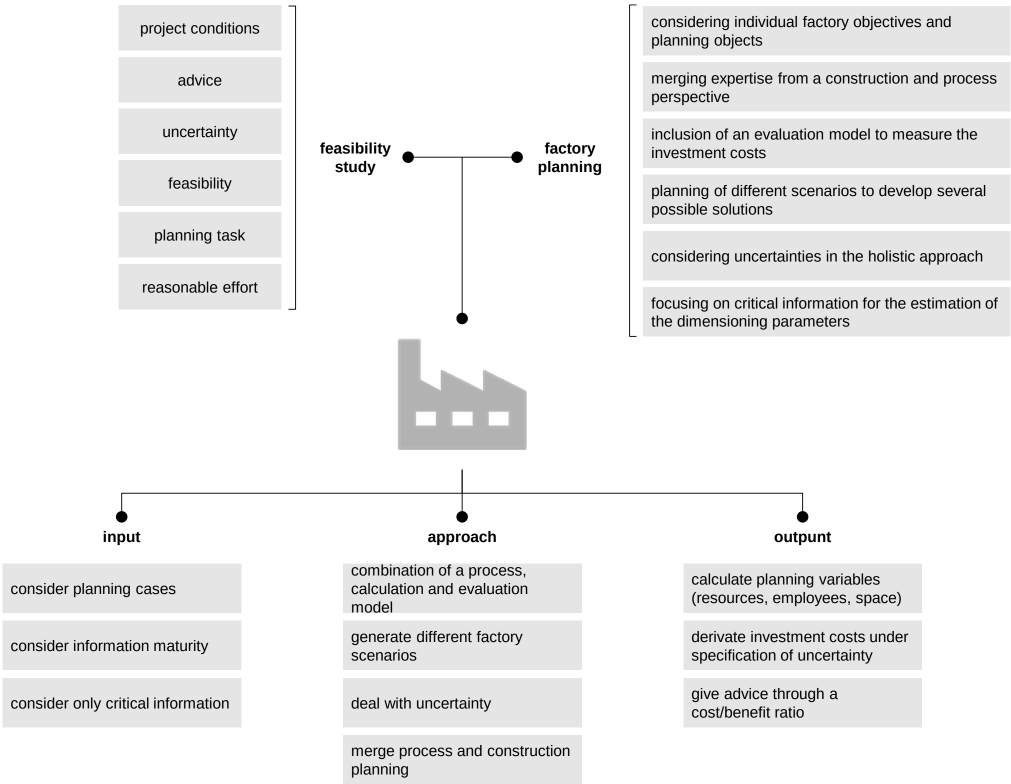

Figure 1 - Adaptation of the generic character of a feasibility study to factory planning

If these requirements are attached to factory planning, design criteria for a suitable feasibility study arise which have an influence on the input parameters, the approach itself and the output parameters (see Figure 1). In the following, we describe the relevant requirements for these three components (input, approach, output), in order to determine an appropriate study design.

Looking at the input parameters it becomes obvious that a feasibility study need to include individual factory planning project conditions. For instance, if the project concerns a greenfield or brownfield planning, the scope will differ, as site-related factors influence the planning results. The construction status as an input parameter has a significant influence on the potential investments if a building needs to be refurbished. Furthermore, the dedicated factory objectives affect the configuration of the factory in different dimensions and scales. If the management declares a certain factory type, e.g. „high-tech factory“, the choice for operating resources can be influenced, which can also change the required space. The increased degree of automation e.g. in the warehouse might result in less operating and/or transport space [21], which in consequence would lead to different investment cost structures. Furthermore, it is also necessary to include other company-specific influencing variables such as growth rates or production data in order to be able to make an accurate prediction for the company regarding the dimensioning variables of operating resources, personnel and space. In addition to the individualisation of the input, the data needs to be evaluated in terms of its maturity so that the results are linked to an uncertainty factor. For instance, if the input parameters are not of a deterministic but of a probabilistic nature, the related results have to be expressed with an expected value and a variance. Finally, the effort of a feasibility study for factory planning should be reduced to a reasonable level. This can be achieved by only focusing on the critical information for the evaluation of investment costs. Furthermore, a given toolbox can reduce the effort for the whole process. Other output parameters, such as operating costs, can only be estimated by using detailed input on all production factors, since precise information on e.g. the operating resources (e.g. electricity consumption, waste rate) is required for this. This limits the needed data to a certain level.

Regarding the approach, it becomes apparent that, in addition to a generic process model, a calculation model as well as an evaluation model is required. Only in combination individual factory planning projects can be dimensioned and evaluated. The process model needs to bring all important activities into a logical order so that the user can be given an individually adapted and comprehensible recommendation. With the help of the calculation model, initial rough but accurate dimensioning parameters (operating resources, personnel, space) must be provided in order to estimate investment costs at an early stage. Furthermore, an evaluation model is needed to check the preconceived solution options with regard to the required objectives of a factory. Here, the investment costs in particular play an enormously important role, as these combined with the opportunities and risks can provide a recommendation for an investment. In the context of factory planning, it is important to evaluate how adaptable the concept is. This consideration leads to the next requirement that several scenarios need to be developed during the process. The feasibility study is not intended to interfere with the actual planning task by creating detailed concepts, but it should enable a fundamental decision and by giving a recommendation for the further procedure. In addition to possible basic concepts (draft solutions), the result also needs to contain a defined catalogue of requirements for the solution [16]. The early stage in particular is responsible for the fact that some planning information is uncertain. This makes it even more important to successfully deal with fuzzy or incomplete data, otherwise the results of the feasibility study may lose their significance. Only by issuing an uncertainty factor the value of the generated results is highlighted, whereby individual planning variants can be compared with each other in terms of their scope. As a final requirement, the approach needs to include an integrated planning from a process and construction point of view, as this synergy is an essential part of factory planning activities [22,4]. From a process perspective (more precisely, production logistics), the focus is on the classic demands for high productivity, quality, short throughput times and the ability to change [7,22]. From a construction perspective (architecture, building services, systems engineering, etc.), factors such as building technology, energy consumption or the identity-creating internal and external corporate design need to be addressed [22,4].

As a result, companies need to be aided by the feasibility study to roughly dimension the factory in terms of operating resources, personnel and space. Once these dimensions and corresponding factory configuration are predesigned, investment costs for a factory planning project can be estimated. These should then be given out with an uncertainty factor, as already mentioned. In the course of preparing a decision, the expected advantages and disadvantages of individual planning variants should be taken into account. Finally, a recommendation can be made with a cost-benefit ratio.

3. Feasibility study for factory planning in the literature

After having identified all the requirements to solve the problem described above, this chapter covers selected approaches for carrying out a feasibility study in factory planning projects. Subsequently, an evaluation of these approaches based on the requirements will be presented, in order to derive the need for research. The approaches are divided into two classes. First, approaches for investment feasibility studies in classic factory planning procedures are explored. In a next step, central approaches with regard to the consideration of handling uncertainty in factory planning are examined. Within these clusters, the approaches were sorted according to the year of the latest edition. The results are shown in Figure 2.

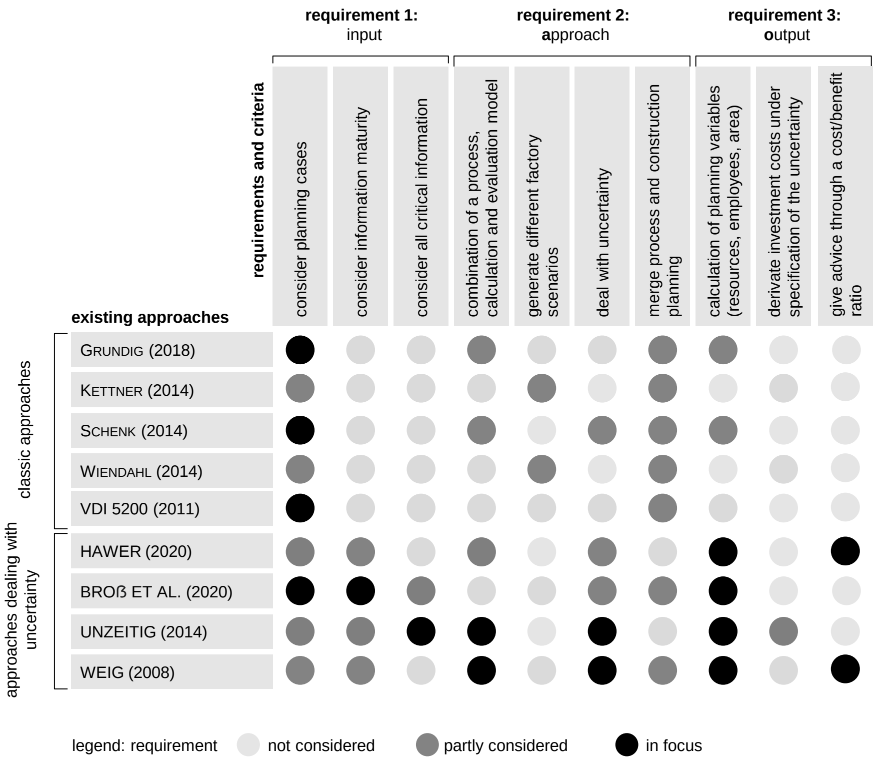

Figure 2 - Assessment of factory planning approaches concerning feasibility study characteristics

The factory planning system according to GRUNDIG [1] does not include a feasibility study in the narrower sense. However, the pre-planning step, which is carried out directly after the target planning, includes a so-called pre-feasibility study as a basis for decision-making. Particularly site selection, building design and resource investments, it is further noted that the planning process involves working with uncertain data and thus decisions have to be made under uncertainty. Specific support services for these issues are not provided.

The planning process according to KETTNER [9] does not explicitly include a feasibility study. Up to the so-called point of no return (end of the rough planning), however, it can turn out that the planned project cannot be realised and therefore the objectives may have to be adjusted. Concerns about the handling of uncertainty, also with regard to investments, are expressed, but an explicit procedure for dealing with this uncertainty is not discussed.

In the phases of factory planning according to SCHENK [3], the first stage is pre-planning. In addition to the problem definition, a situation analysis, site determination and basic solution principles, which contains the first rough economic considerations, is described. The objectives of this pre-planning include the early identification of unsuccessful projects and a general feasibility study. Uncertainties are only insufficiently included in these considerations. Thus, as in all other approaches so far, there is a lack of a concrete toolbox in order to support the complexity under such uncertain conditions.

In the process model of synergetic factory planning according to WIENDAHL [4], a so-called strategic feasibility study can take place, which then provides input information for the following phases of setting of objectives and establishment of the product basis. This strategic feasibility study, however, only includes strategic site planning. Uncertainties are not subject of consideration in this phase.

The VDI 5200 guideline [8] represents a factory planning procedure that is recognised in science and practice. This planning methodology divides the planning process of a factory into seven different planning phases. However, beginning with the setting of objectives and ending with ramp-up support, a feasibility study is not provided. Furthermore, the consideration of uncertainty is not explicitly taken into account.

Consequently, the realisation of a feasibility study is only described in attempts in the classic factory planning literature. Often an explicit pre planning phase prior to the actual factory planning phases is not or only insufficiently considered. As a result, a differentiated consideration of uncertainty in an early planning phase is predominantly missing. Especially this last point could be better taken into account by factory planning approaches that work under uncertainty. Therefore, it is worth taking a closer look at these approaches.

HAWER [23] shows an approach on how to deal with uncertainties in a factory planning project. It aims to develop a methodology to transfer uncertainties into a risk assessment in the course of an early factory planning phase. The developed methodology enables the user to aggregate risks. It should be emphasised that this methodology includes a profitability and utility analysis of the developed factory structure variants. However, this methodology excludes individual site factors so that some external project boundaries are not included. Additionally, the author does not specify optional and critical data for the evaluation of investment costs.

The aim of BROß [24] is to enable the factory planner to recognize the complex interdependencies within the dimensioning of indirect areas. The approach determines, by using fuzzy logic, the three main variables of operating resources, personnel and space sufficiently precisely for an early factory planning phase. However, the primary factory areas (e.g. production and assembly) are eliminated. Moreover, there is no method apparent to evaluate the cost-benefit ratio of the given result. In addition, the approach uses almost exclusively fuzzy logic. This means that the issue of uncertainty is limited to the fuzziness in data.

UNZEITIG [11] designed an approach to consider uncertainties at an early stage of factory planning, aggregating risks and calculating costs for the quotation preparation of products. Substantial analyses to identify important key factors in order to determine the input parameters for estimating investment costs are not carried out. The practicability of the approach can also be criticised, as the user does not have access to a comprehensive toolbox.

WEIG [25] developed an integrated approach to risk management for process and structure design in factory planning projects. The aim is to increase the efficiency of the planning project and ensure its success. The developed approach supports to identify the biggest risks at an early stage, to map them as uncertainties and to consider them in the factory concept. However, in addition to greenfield planning, this approach will only consider major conversion or expansion planning. Furthermore, it is not discussed in detail whether a subdivision into critical and non-critical data is made. Moreover, the dimensioning of the factory as well as the investment calculation is not assisted by a separate logic. In both cases, the output parameters are approximated through expert guesses.

Especially the requirements "generate different factory scenarios“, "merge process and construction planning" and "derivate investment costs under specification of uncertainty" are mostly not or not sufficiently fulfilled by any of the described approaches As shown, some approaches address several requirements, but predominantly requirements are missing in the literature. Even if individual strengths of particular approaches can serve as a template, there is still a clear need for research.

4. Towards an investment feasibility study for factory planning projects

Against this background, the conceptual framework for a feasibility study for factory planning projects has been developed (see Figure 3). The model precedes any factory planning procedure with a construction project and offers the user support according to the requirements (cf. chapter 2) for selecting the right factory planning project. This first draft involves four phases, each with two sub-phases. The phases "Establishing project basis", "Development of planning parameters" and "Feasibility study" are run through using checklists and specially developed tools, while the "Concept design" represents a creative process in which planning variants for the whole site or a specific factory building are developed. In contrast to existing approaches, suitable concepts from a construction and process perspective have to be created at a rough detail level with enough information so that they can be evaluated in the final phase. Below, we like to explain the model illustrated in Figure 3.

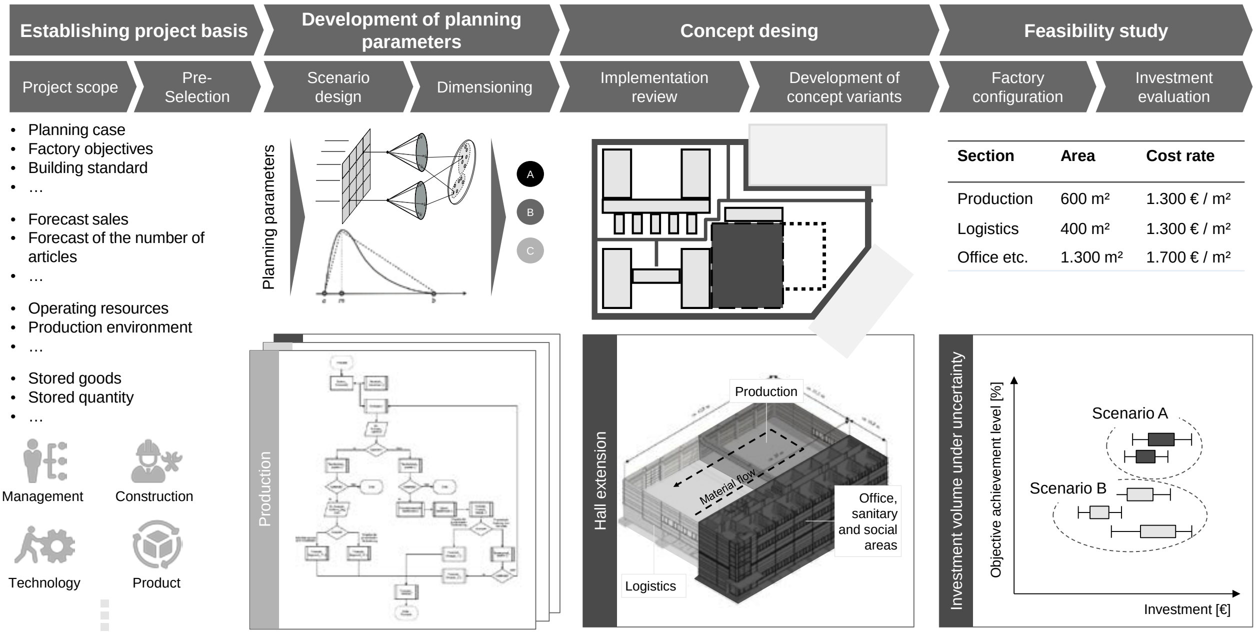

Figure 3 – Process Modell with integrated tools for a requirement based feasibility study in factory planning

In the phase "Establishing project basis", all project-specific conditions are collected in order to provide a holistic picture about the proposed project scope. In addition to all project-specific conditions about the factory (e.g. production volume, product variants) or the site (e.g. location, cost rates for construction projects), more detailed information on the desired strategic factory objectives (e.g. changeability, logistics performance) must be obtained. Essential is the expected production programme as well as the representative bill of material and routing , backed up by data about the desired technologies (e.g. production times, failure rate, personnel requirements, requirements for space and further equipment or spatial requirements). Another substantial component is the logistical quantity structure in the warehouse (e.g. stored goods, ranges), in order to provide information about the needed space in relation to different configuration options (floor storage, shelf storage, automated storage) at this rough level for the different warehouse levels (raw material, intermediate, finished parts warehouse). Depending on the project scope, the second step is to pre-select the corresponding experts and technical planners to gather information. The disciplines and interfaces involved in the planning process need to be determined. The interfaces occur during the preparation of individual planning steps in the form of input and output information. These interfaces have to be coordinated to provide information and data for the model.

In the next phase, “Development of planning parameters”, coherent scenarios and related planning parameters for the future of the factory are generated. First, the required key factors for the investment cost estimation are mapped through a scenario development. For each planning parameter, it must be determined whether it is a deterministic or probabilistic variable. In the case of uncertainties, the initial parameters need to be specified under the provision of a probability distribution. In practice, a density function can be approximated, e.g. by a beta distribution, by defining an uncertainty corridor in the sense of a best/worst/most likely consideration, or the three values can be mapped as a discrete distribution function [25]. The available data is guided through a calculation logic in order to validate the required dimensioning variables (operating resources, personnel, space) as part of a capacity assessment. The model has to deal with the different probability distributions of the input parameters. By combining the possible trends into consistent future scenarios including probabilities and the underlying statistical variances, the various planning scenarios can be evaluated in terms of quality. Separate calculation logics are defined for the primary areas (e.g. warehouse, production) and secondary areas (e.g. office, social areas). These are based on the needs and required degree of detail with regard to the areas under consideration. While the production can be broadly dimensioned demand-oriented, common and standardised surcharge factors have to be taken into account, especially concerning the offices.

In the next phase "Concept design", two sub-processes are processed, depending on the planning case. In the case of predefined greenfield planning, the development of planning variants can start directly. However, if brownfield planning is preferred, the results of the previous phases need to be reviewed in a first step, including the current initial condition of a plant. This means that, considering the identified requirements, the current plant/building need to be evaluated with regard to the previous study results. On the one hand, the required space has priority. In the case of an expansion, free spaces must be available on the property. On the other hand, potential area requirements (e.g. ESD floor, air conditioning, exhaust air) need to be analysed in terms of their implementation feasibility in existing buildings. Subsequently, initial concepts can be derived, as experts are consulted.

In the final phase, the first step is to define the factory configurations. This means that the halls are classified according to the specifications and these are transferred into fixed building standards (e.g. according to BKI). Building standards refer to more than just differences in the equipment of a building; high-quality exterior components, such as the facade, can also influence the standard classification [26]. The classes allow to quickly and easily determine the range of cost parameters for a building. In the case of a hall modification, the configuration deficits must be identified and documented. Then, using common cost estimation methods (e.g. building element estimation), the investment costs for the construction can be roughly estimated. An essential support for the calculation of the expected costs is provided by DIN 276 [27]. Investments need to be evaluated with regard to their informative value due to the dimensioning and pricing under uncertainty. For example, box plots are suitable for this purpose, as it quickly gives an impression of the range in which the data is located and spread [28]. In addition to the investment estimation, the degrees of objective fulfilment of each planning variant should also be portrayed. This can be done, among other things, by using a utility value analysis [29]. In addition, further risks should be recorded for each planning variant in order to enable comprehensive preparation for an investment decision.

5. Conclusion & Outlook

This paper describes the challenges of a feasibility study in factory planning and the need for research, as it is not properly established in a practical way by means of standardised procedures and tools. It is clear, that some existing approaches are useful for such a feasibility study especially in handling planning uncertainties. However, no approach is yet provided, that supports companies in selecting the right factory planning project from a construction and process perspective. The discussed approach in this paper offers a first framework to adequately prepare the selection for strategic factory planning projects. Further research is needed to develop dimensioning under uncertainty in a feasibility study. In addition, standardised processes are still needed to evaluate the investment costs in a project in terms of costs, as well as in terms of their objective fulfilment and the existing risk potential arising from implementation.

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Biography

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