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Improving The Planning Quality Through Model-Based Factory Planning In BIM

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Abstract

In recent years, Building Information Modeling (BIM), which originated in the construction industry, is increasingly finding its way into the planning of factories and production environments. In the scientific assessment of this change and possible future scenarios regarding BIM, the research mostly focuses on the planning process and the influence that the use of BIM has on it. However, improving the outcome of a factory planning project enjoys priority over optimizing the planning process itself regardless of whether BIM is being used or not. This paper therefore aims to build a bridge from a process-side view to the planning result. The concept of BIM is to be explained from a technical point of view establishing a reference to the concept of synergetic factory planning. For this purpose, the process view of the factory planning and the spatial view of the building construction will be examined and the BIM model will be characterized with regard to different levels of development in the planning process. The goal is to show how the use of BIM in factory planning can ultimately improve the planning result. For this purpose, the factory targets are considered and their optimizability through the use of BIM is investigated.

Keywords

Factory planning; Building Information Modelling; Factory targets

1. Introduction

To master the complexity of current factory planning projects, Building Information Modeling (BIM) is being used successfully to an ever greater extent in factory planning [1] and is used in this context to plan a wide range of factory properties. The most prominent function is object-based modeling, which not only represents the geometry of all factory objects, but also describes their non-geometric properties using alphanumeric information [2].

This comprehensive digital transparency is becoming increasingly important, among other things, with regard to the increased requirements in factory planning [3]. As manufacturing companies face an uncertain and turbulent market environment, constant adjustments and changes in factories are necessary, making factory planning an everlasting task [4]. Consequently, the "technical quality" of the model in the sense of unambiguity, freedom from redundancy and maintenance of consistency - also required in the course of the digital factory [5] – supports factory planning in meeting the set requirements.

Factory planning projects in the early phase are often characterized by the fact that the overarching concept is composed as a collection of information in different media and multiple models are only later brought together, detailed and planned out [6]. The use of BIM helps to increase the “organizational quality” in

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factory planning by synchronizing the planning steps in order to create a clear design of the factory with central and holistic data management at an early stage.

But with new target fields becoming evident, the requirements for a factory are everchanging leading to a potential shift in prioritization. High planning quality in factory planning is essential due to the rising requirements due to the megatrends digitalization and climate change. Especially sustainability has changed over time from “a motivator to a hygiene factor” – comparable to what has happened with the change from 2D to 3D planning. High data availability, consistency and transparency is needed in order to make suitable factory planning decisions to meet the set factory targets. For this purpose, the BIM model represents a possible starting point with a central storage location for further future applications in the factory planning context [7]. It has the potential to increase the “planning quality” of results created in factory plann [8,9]ing, so that the factory is able to fully meet the set requirements.

The integration of BIM into factory planning has already been discussed in different approaches [e.g. 13,12,10,11,1]. The majority of approaches focus on the technical quality of the model and resulting organizational quality of the factory planning process. The goal of this paper is to show an ideal setup of BIM in factory planning in order to ensure both technical and organizational quality. Therefore, the setup and its usefulness in project communication is presented first after the relevant fundamentals are introduced. Subsequently, the resulting potentials of BIM for the planning quality of the factory will be shown on the basis of factory targets.

2. Fundamentals

2.1 Target fields in factory planning and their evaluation

The factory can be described as a place of central value creation where industrial goods are produced in a division of labor using production factors [14]. Studying the entire factory as a single, stationary and stand-alone object is not practicable since the factory is a complex socio-technical system [15,16]. Instead, the factory as a system is to be subdivided into individual factory objects, which in turn can be organized in a hierarchical structure [17]. The process steps to be followed in planning the factory objects have been described by various authors and have been brought together in the VDI Guideline 5200 [20,18,19,14]. The main underlying concept is the approach of synergetic factory planning (synFAP) which aims at combining spatial planning (HOAI) with processes planning (VDI) and the production system in order to create synergies through intensive dialog [17]. To ensure implementing the phase-oriented process according to the targets of the factory and the planning project, the target definition stands at the beginning of the phase-oriented process. In a target and project definition workshop, the factory and project targets are defined based on the corporate strategy and the specifications of the management [17]. The meta-target of a factory is economic efficiency or profitability throughout the life cycle, which is to be achieved in the factory planning process with the help of target fields of factory planning as shown in Figure 1 [15].

Figure 1: Target fields in factory planning based on [17]

Based on the combination of the process view of the factory planning and the spatial view of the building construction, first concepts are developed, which are further detailed in the course of the planning. In the target definition workshop, qualitative and quantitative targets are derived from future scenarios [17]. Subsequently, with the help of these targets, task packages as well as criteria for the later evaluation of the project's success can be defined [21,16]. It is a part of planning a factory to develop a feasible factory concept that best meets the factory targets defined in the target setting process [14]. However, it is not possible to directly influence the target fields. They are determined indirectly through planning the factory objects [18]. Each factory object can be assigned to the design fields of technology, space or organization and to a hierarchical level of the factory [17].

Over time, these targets have changed. Likewise, the design segments of factories have changed, as has the entire planning process. So-called change drivers require continuous adjustment of the targets and their implementation so that companies can remain competitive in the long term. The overall target of a factory, economic efficiency, remains the central target, but is increasingly influenced by other target fields [19]. The target fields are logistics efficiency, resource productivity, quality, sustainability, communication, changeability, appeal, standards and transparency. The general target fields provide orientation when going through the factory planning process and are intended to maximize the quality of the planning results [22]. By deriving evaluation criteria for each target field (e.g. material flow length for logistics efficiency), the target achievement of planning results of a specific planning case can be evaluated so that the requirements are met and planning quality is ensured. Usually the planning results consist of different variants (e.g. layout variants) from which the most advantageous must be selected. For a target-oriented evaluation and selection, the criteria are therefore weighted relatively to each other in a pairwise comparison.

To this end, a qualitative utility analysis based on joint discussion and supported by experiential knowledge is carried out. Apart from the monetary perspective, this type of evaluation cannot ensure objectivity. The objectivity and quality of the evaluation depends largely on the competence and experience of the planning or evaluation team, which in turn leads to low transparency of the process [23]. In addition to this qualitative decision-making process, numerous procedures have been developed for the quantitative evaluation of layouts and factories, e.g. based on simulation models. These evaluation procedures go back to the concept of the digital factory [5]. Figure 2 shows an overview of the methods and tools of the digital factory.

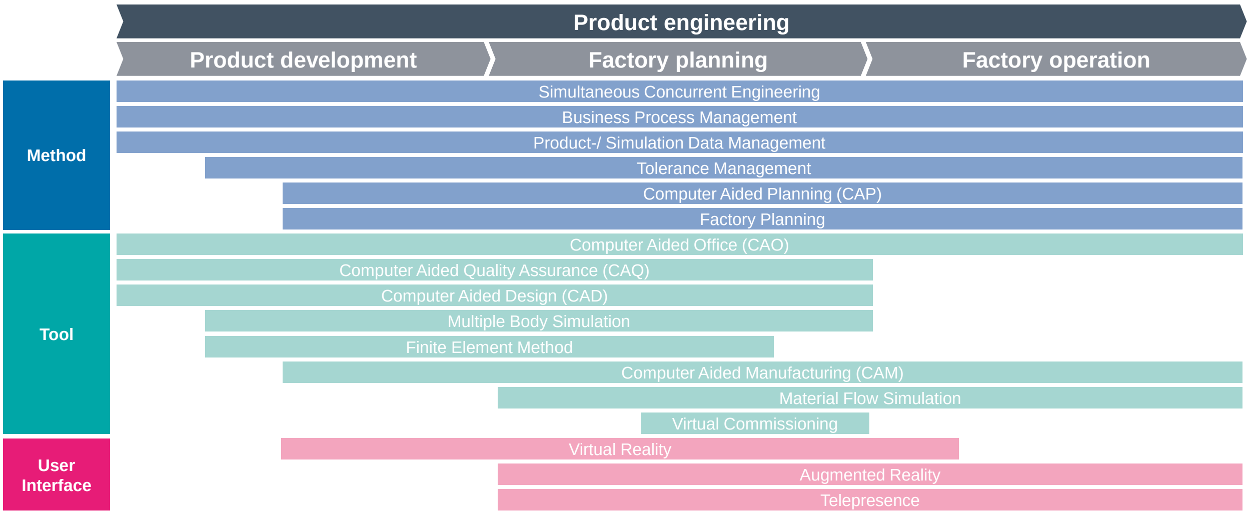

Figure 2: Methods and tools of the digital factory based on [24] and [25]

The digital factory aims at planning, assessing and improving processes as well as structures and resources belonging to the real factory by utilizing digital tools, models and methods [26]. The concept of a digital factory covers many different hardware and software tools supporting the planning process showing a further increase in variety resulting from the increasing use of information and communication technology. The tools belonging to the concept of the digital factory can be classified according to their intended purpose e.g. factory or operation. First of all, factory planning tools are important for factory planning, information from product development comes in through the CAx systems as well as through the interfaces of the visualization tools. [24] Beside tools, the digital factory also takes into account methods, because the planning processes must first be designed from an organizational point of view and communicated to the users before the supporting tools can be meaningfully integrated into the planning processes [27]. Figure 2 therefore complements the method view as a further subdivision of the digital factory. A method as a systematic target-oriented approach to solve a variety of problems defines at which point in time and by which person certain tools are used, so that user interfaces as an additional view cover the interfaces between the user and the tools [25].

The production can be mapped digitally as a virtual model using different tools making it possible to review and improve the operation continuously [21]. The goal is to uncover and resolve potential conflict situations even before the factory is built [28]. In this way, testing of the functionalities can take place in time and any necessary replanning can be carried out. The entrepreneurial risk is reduced, since later mistakes can already be avoided in the planning phase. Planning time and cost can be reduced tremendously this way [29]. Additionally improvements in quality and communication in the factory as well as the degree of standardization along planning processes may be achieved [21]. If factories are evaluated quantitatively, this is usually done one-dimensionally with regard to a logistical target value such as the optimization of the internal material flow. In addition to the material flow, in recent years the flow of personnel, information and communication in particular has been considered for factory planning [17]. However, since a factory is usually planned with regard to several factory targets, this one-dimensional view falls short and does not reflect the actual requirements of a company.

Based on the regulatory scheme in Figure 2, the following method classes can be formed: Methods for data collection, design, mathematical planning and analysis, simulation, artificial intelligence, visualization, collaboration [5]. All of these methods can be used directly or indirectly in the evaluation of different planning variants. There is often confusion regarding at what point which method or tool has to be applied or planned and how they can be used together [3]. The more holistic view of factory planning and operation as described above requires looking at tools, methods and models more collectively. Figure 3 shows that the concepts of the digital factory and BIM share an intersection resulting from the common target of supporting the planning of factories, but differ overall.

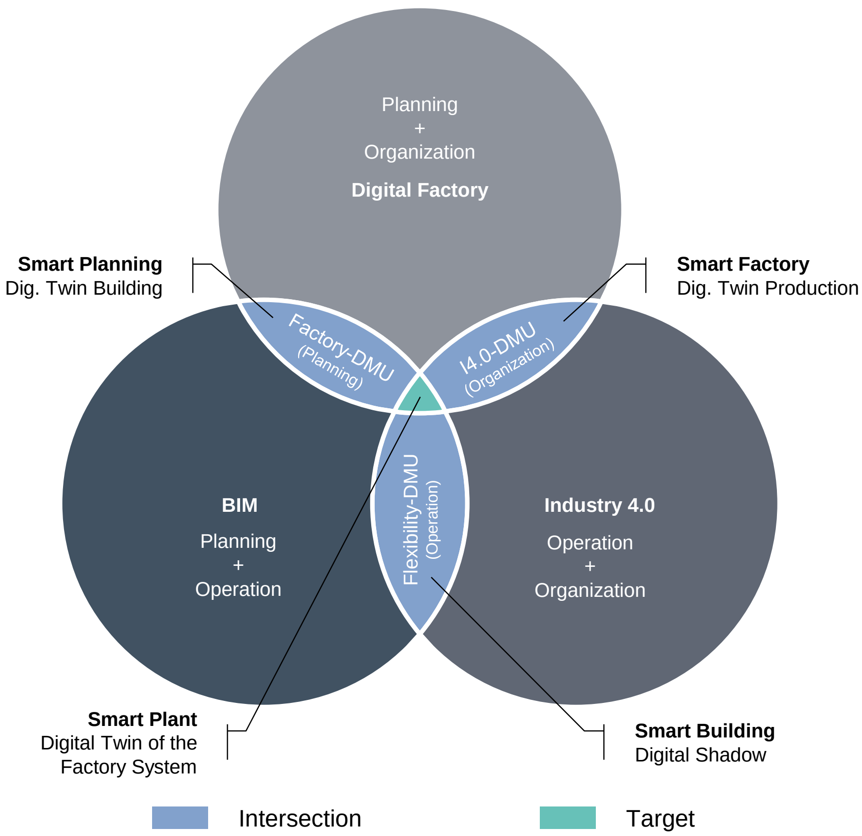

Figure 3: Interdependencies between Digital Factory, Industry 4.0 and BIM [7]

BIM aims at planning and operating a factory opposed to planning and organizing it as for the concept of the digital factory. This means that BIM is an integral part of the interface between planning and operation of a factory. Therefore, it is possible to anticipate the operation of the factory already during the process of its creation. The quality of the BIM can thus support the operation in the best possible way. The handover of the planning result to the operator is a critical interface. Further explanation regarding the differences and the overlap can be found in [7]. The following chapters of this paper aim at describing BIM further taking into account the target fulfilment in factory planning.

2.2 Basic explanations about BIM

According to the Association of German Engineers (VDI), BIM is a "methodology for the planning, execution and operation of structures with a collaborative approach based on a digital building information model for joint use" [30]. In particular, the emphasized position of the central model should be noted here: For BIM, this is not only the place of data storage and creation of digital planning documents but is also the communication medium for transporting building-related properties of the individual disciplines in planning and operation. This is the background for considering BIM not only as a "software package" but also as a working method for planning, project control, execution and operation throughout all life phases of the structure [30]. The life cycle concept means that the model created accompanies the building through the various phases (Figure 4), which means that many different participants work on the digital image of the building over time.

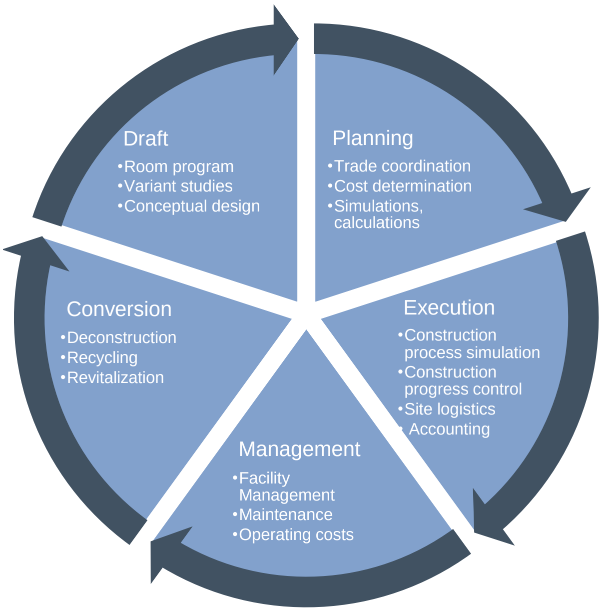

Figure 4: Continuous BIM data model over the building life cycle [31]

This way of working requires a clear assignment of access and editing rights to users and to user groups by assigning roles with corresponding properties [32].

The model is thereby created through object-oriented modeling, i.e., the parameterization of building elements. The level of detail of the elements increases continuously during the development process (LoD - Level of Detail), whereby alphanumeric information (LoI - Level of Information) is also integrated in addition to the geometric characteristics (LoG - Level of Geometry). In order to enable the project to coordinate the information required and to be supplied at defined milestones, corresponding levels of completion (LOD - Level of Development) are agreed [2,30].

This approach also offers advantages for factory planning and has therefore been transferred for several years [9,10,1]. In this context, the collaborative way of working on a central data model has been particularly emphasized. However, it can be observed that due to the requirements described at the beginning, an increased focus on the "technical quality" of the resulting model is necessary. In this context, BIM is not an end in itself, but must meet the demand for clear and comprehensible formulation of implementation requirements in the higher-level project landscape. This central aspect is addressed in the following ideal setup of BIM in factory planning.

3. Ideal setup of BIM in factory planning

The model structure of the BIM methodology can be taken as the basis for collaboration in factory planning with BIM. It should be noted here that BIM, as described at the outset, is "more than just software" but also, and above all, represents the working method of component-based modeling and joint work via a central coordination model. Because factory planning with BIM goes beyond the building, a factory modeling approach of BIM has been described [13].

In order to integrate factory planning into a BIM project, it has proven useful to also separate the coordination model into factory and project planning [33] on a further hierarchical level. This allows a clear separation between the factory objects with direct production reference and the elements of the building. Below the 2nd tier coordination models, the specialized models of the trades are arranged. A possible model and project structure resulting from this is shown in Figure 5.

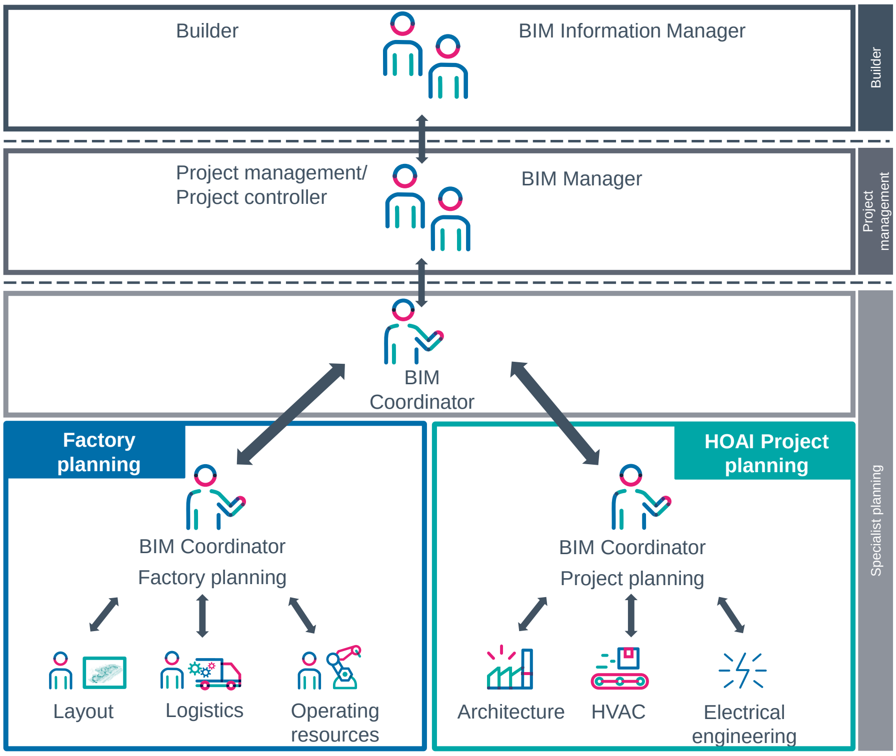

Figure 5: Model and project structure for integrating factory planning into a BIM project based on [11]
[Source: Ingenics AG]

By dividing the model, assigning clear responsibilities according to the system of rights and roles described above, each planning discipline can manage and edit the model of its own domain itself, but has access to the planning status of the other participants via the central model. For this purpose, the models are referenced via the hierarchical levels until the overall coordination model is created, which contains all information. This in turn serves the specialist models as the basis for their own modeling work. The various trades and responsibilities can be united among individuals or organizations, or they can be carried out by different participants. For example, the planning of the equipment can be carried out by an external factory planner or by the subsequent operator. In both cases, the information is aggregated and presented in the factory planning coordination model and transferred to the overall coordination model via this model.

Thus, for example, architecture has access to the necessary door and aisle widths based on the machinery (geometric information) and building services planning to the required media needs (alphanumeric information). The modeling is usually done in specialist software, the data exchange is carried out via the file type IFC (open BIM); which is a standardized, digital description of the built asset industry [34]. This avoids the inertial disadvantages of large, monolithic factory planning systems, such as those developed in the German automotive industry in the 1980s and 1990s (i.e. FAPLIS [35] and HLS [36]).

Accordingly, by extending the BIM methodology to factory planning [1], not only are the building elements as well as technical building equipment parameterized with non-geometric information, but also the operating equipment is provided with the information necessary for factory planning and operation. The described subdivision into a factory planning model and an object planning model supports the differentiation of two types of parameters: On the one hand, information of the factory planning, which can be seen as a requirement for the building structure (media requirements, necessary loads, VC-classes, etc.), on the other hand, information of the object planning, which can be understood as realization planning in the sense of a response to the requirements of the factory planning (media connections and services, static and dynamic load limits, etc.). In this form of collaboration, the communication of modeled geometric and alphanumeric information via IFC and coordination model represents a clear formulation of requirements as well as subsequent verification (Figure 6).

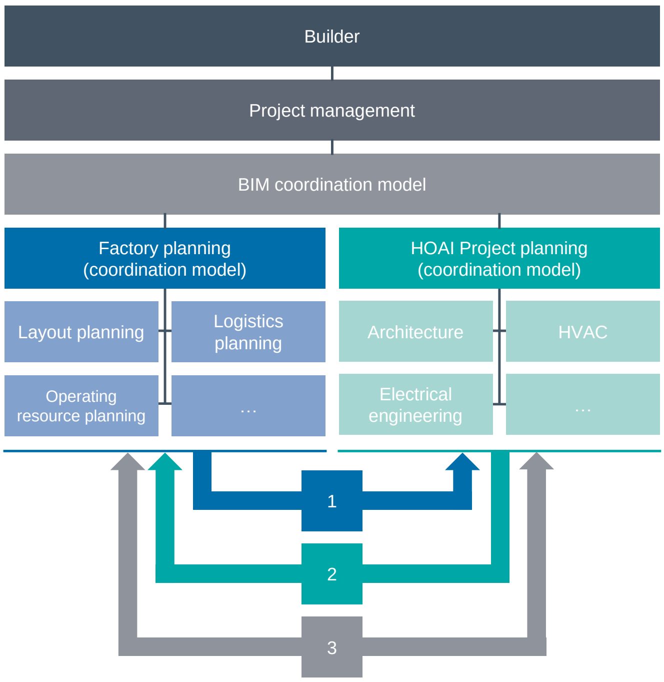

Figure 6: Requirement formulation and verification by IFC and coordination model

When working in factory planning projects and communicating requirements via IFC, three basic cases can be distinguished depending on the project setting:

1. target definition by factory planning, then joint start of the project by factory planning and object planning.
2. the basic concept is created by factory planning, object planning is integrated later ("form follows function").
3. object planning starts the project (often in the form of an architectural competition or similar), the factory planning is understood as specialized planning and is integrated later in order to plan the value stream and its facilities.

Even if case 1 represents the constellation which most likely realizes the best possible planning process and the optimal result (cf. synFAP), cases 2 and 3 are also regularly encountered in practice. In order to discuss the cases, the coordinated phase models of VDI [14] (authoritative for factory planning) and HOAI [33] (authoritative for project planning) are used for this purpose.

In case 1, factory planning creates a model of the future production in the first step (see Figure 6). Starting with the process planning the overall concept of the factory is derived and subsequently modeled. The model contains the layout, the elements of logistics as well as the operating resources. All these objects are parameterized accordingly and can be evaluated in the course of building modeling (step 1). Object planning reads this information and models the structure according to the requirements of factory planning. This model is made available to factory planning and is to be understood as a realization proposal in the sense of a response (step 2). These steps are carried out in the course of the basic evaluation as well as the concept planning or preliminary design. With the transition to detailed planning or design planning, the model is iteratively extended and adapted. In the course of this, a geometric and non-geometric collision check is carried out (step 3): The modeled information is checked for plausibility by the opposite side and compared with one's own planning. In this way, planning errors are reduced and the design of the factory is considered in a holistic way at an early stage (cf. synFAP).

The non-geometric collision check is to be illustrated by the example of the bearing loads: Through factory planning, the mass of the equipment as well as its vibration input in the operating state or even a required VC class is stored as alphanumeric information (step 1). This initial parameter set can be understood as a "specification sheet" of the factory planning with regard to the requirements to be realized by the construction planning. The construction planning determines the basic structural analysis in the preliminary design. Information on possible static and dynamic load absorption is reflected in corresponding parameters of the structure and is made available to factory planning as a model (step 2). Factory planning checks whether the load input is higher than the load input specification or whether the VC class is equal to or higher than the required class.

The geometric collision check runs in the same way, but this check refers, for example, to clear heights and widths and also includes the check with envelopes or collision areas of moving elements such as conveyor technology or sprinkler shades. Both geometric and non-geometric information clash detection is based on a distinct data model and thus avoids errors in communication.

In cases 2 and 3, the subsequent integration of the respective other discipline usually takes place at the beginning of HOAI service phase 3 (project planning) or VDI phase 4 (factory planning). In this way, one discipline takes over the basic evaluation and transfers this data to the planning phase. It is often the case that a large number of factory planning specifications have already been made before an object planner is involved in the process of new construction or conversion (case 2). This happens because the concrete project development has already been carried out by in-house planning departments or because an external factory planner was involved at a very early stage for the design. On the other hand, projects with an impact are often accompanied by an architect at an early stage in order to guarantee a corresponding external impact (case 3).

It should be noted here that, depending on the starting discipline, the focus of the project is either on the architectural concept (office-heavy research or administration site) or on industrial production (production site). When handing over the information, it is even more important due to the takeover by another discipline that the data is clear and complete and does not need to be interpreted anymore. The systematics of steps 1 to 3 is analogous. Here, the object-related modeling makes a significant contribution to the unambiguousness and completeness of the data and thus opens up constellations that were previously often unwillingly carried out by the project participants. In principle, however, the project should continue to be carried out according to case 1, since here, in the sense of synFAP, all aspects of a factory are taken into account in a balanced manner and the best holistic concept is created. Furthermore the cases apply to green and brownfield projects [37].

During the model-centered project execution, it is important to define milestones that are backed by corresponding LODs (see above), so that it is clear for all planning participants which information must be delivered, but also which information will be delivered at which point in time, in order to base their own planning on it.

These LODs must be defined on a project-specific basis, but there is already fundamental agreement in object planning. Basic considerations have also already been made in this regard in factory planning [8]. However, these considerations do not distinguish between the level of information and the level of geometry. Thus, this article is intended to provide a proposal for the degrees of completion, subdivided into LoI and LoG, depending on the HOAI and VDI planning phases (Figure 7).

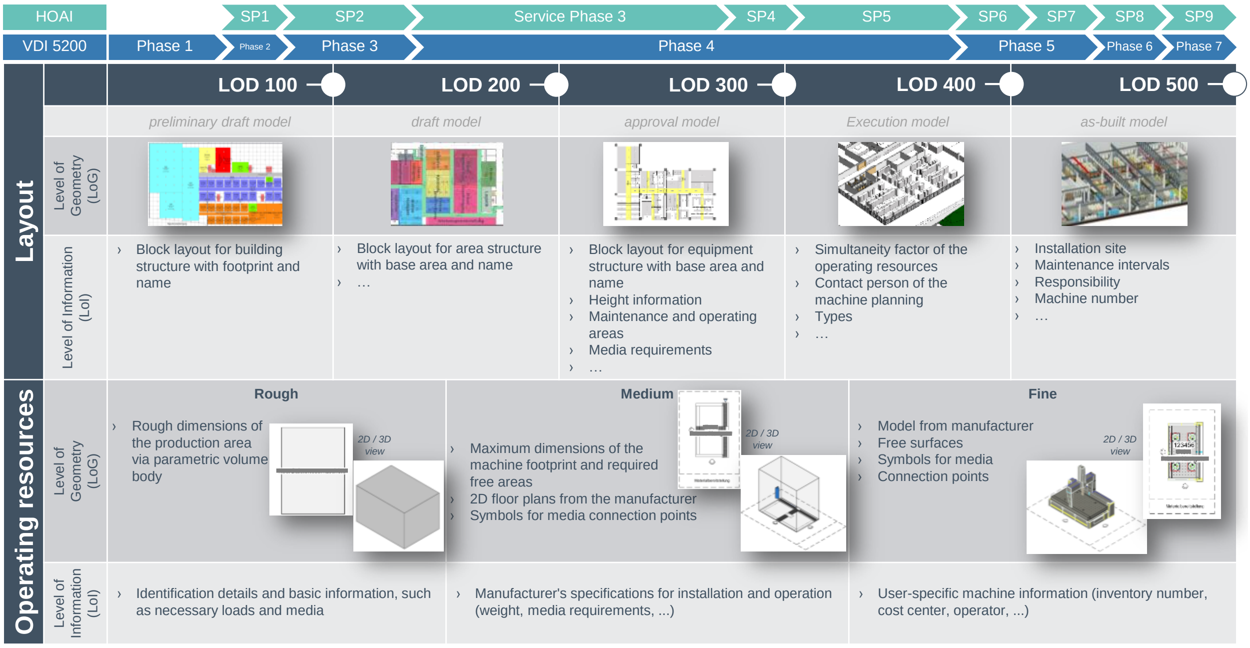

Figure 7: Modeling of factory objects in relation to the LOD [Source: Ingenics AG]

In analogy to the detailing proposals for LOD, which in the case of BIM are already available for project planning or are defined on a project-specific basis, the above figure represents a proposal for detailing the factory objects in the planning process of factory planning. Based on extensive project experience, several gradations were defined in which both the layout and the elements of the factory are planned with direct reference to production. In particular, the division refers to the required information of the project planning and is coordinated with the planning phases of the VDI [14] or the service phases of the HOAI [33]. Through this systematic approach, the formal-technical cooperation with BIM is described for the factory planning. Requirements that go beyond a concrete object reference (e.g. flexible media grids) are attached to the BIM value "Space", for example, and must then be converted into "Room" by the project planning department. For detailed information, the LoD information "Documentation" [2] can be used. Further documents can be attached here and transferred in this way. This is how the responsibility for implementation is transferred to the project planning.

Through the described concept, BIM is ideally integrated into the factory planning process by creating the necessary framework for constructive cooperation and bringing together the individual disciplines and their points of view in BIM. Thus, the interdisciplinary collaboration is clearly defined, the data exchange and the development path of the conceptualizing solution variants are designed without overlap. The resulting data transparency and standardization can release potentials that can also qualitatively improve the factory planning results and evaluability. Therefore, the potentials of BIM in factory planning will be considered next.

4. Potentials of BIM in the factory

The literature research has shown that existing approaches towards the integration of BIM focus on the planning process and potentials in particular. In factory planning, there is also a lack of evaluability of the relevant factory targets for the design of the factory and thus for the achievement of the meta target of profitability. If this cannot be guaranteed, the degree of fulfilment of the planning results and thus the planning quality cannot be assessed or ensured. For this reason, the factory targets presented in chapter 2.1 will be considered and presented individually in the following, and the potentials of BIM through the intended integration in factory planning will be highlighted. Hereby, the degree of fulfilment of the planning results and thus the planning quality can be better assessed or ensured.

Logistics efficiency is the result of the highest possible logistics performance combined with the lowest possible logistics costs [38]. Logistics performance includes ensuring the availability of resources, overcoming spatial and time disparities, providing logistics capacities, and carrying out logistics processes. Logistics costs comprise the costs necessary for this purpose.[39] The target field can be evaluated quantitatively. The relevant key figures form the production logistics target cross. This is a tension field, requiring positioning due to the conflicting character of the key figures [40]. Logistics efficiency is largely dependent on the process organization of a factory, thus the chronological process sequence. Therefore, BIM in its current form with its database background cannot contribute to the measurability of the target field.

Resource productivity describes the ratio of the output quantity to the resource used (space or employees) [41]. The production quantity can accordingly be put in relation to the space demand in order to reduce capital expenditures or in relation to the employee demand in order to reduce operating expenditures. [20] Consequently, this is a quantifiable target field that BIM can address more effectively in its final form of implementation. Through a clean development path to a volume model of the operating resources including additional areas, the space demand can be evaluated properly. If the employee demand is maintained as a parameter (LoI), employee productivity can also be evaluated.

Quality in the factory is defined as the degree of conformity of performance with requirements, either in terms of products or processes. [39] It can be influenced by factory planning indirectly and has a high significance for decision-makers regarding investments. The factory should support the process quality, as the production of high product quality with insufficient process quality is only possible with high expenditure. Process quality includes the stability of the processes, for instance. [42] Similar to logistics efficiency, the target field can be evaluated quantitatively in terms of reliability or defect frequency. However, these key figures cannot be measured using the data structure of BIM described in chapter 3 due to their dynamic nature.

Sustainability involves reducing the impact of the factory on the environment [43]. It has an environmental effect from a spatial and process perspective. On the one hand, the building must be built, operated and maintained, as well as dismantled at the end of its life cycle, and on the other hand, the processes involved generate material and energy flows [17]. These key figures are quantifiable and can be converted into emissions. By documenting the building materials and materials used for the equipment, BIM can store the necessary data for inventory balancing. Any sustainability-relevant information can be stored from the data sheets in order to be able to determine the overall energy efficiency of the factory. Furthermore, the defined maintenance intervals form the basis for preventing premature end of life and unplanned waste [44].

Communication aims to improve internal communication in the factory for faster processes and stronger innovation [45]. Both the operational organization and the spatial design can make their contribution. The elimination of communication rules in the process flow and flat hierarchies in the organizational structure support communication organizationally. Spatially, communication can be supported by short communication paths. [15,17] This is a target field that is very difficult to quantify. However, the spatial design of the factory is highly relevant, so that the ability to support communication can be approximated by spatial criteria (e.g., path length, number of communication points) [45]. By categorizing the objects accordingly with parameters, an evaluation can be easily supported by BIM.

Changeability evaluates the ability of a factory to adapt to changing requirements due to external and internal triggers at all levels and to realize them with low effort [4,17]. This includes spatial as well as technical and organizational adaptability to respond to constant changes at short notice [15]. Similar to communication, the ability to change is very difficult to measure and is indicated by spatial as well as technical and organizational criteria, whose degree of fulfilment enables corresponding necessary adjustments. However, the technical and organizational criteria are just as relevant as the spatial criteria, but cannot be easily checked in BIM for fulfilment (e.g., position of variant formation point, capacity reserves). Instead, basic requirements for the technical potential of the spatial factory objects can be coordinated and ensured through the coordination models.

Appeal can be understood as the power of attraction due to an inviting appearance. As an established target field, it has an external effect on partners, customers, suppliers and the general public, as well as an internal effect on the employees of the company [17]. It is already subjectively occupied by definition. But attractiveness can also be achieved internally by employee orientation in the form of learning support or ergonomic work processes [46,47]. The latter can be approximated by the criteria load and stress. Since spatial attractiveness cannot be quantified and thus evaluated objectively, BIM cannot support the evaluation of the target field due to its lack of scope as described in chapter 3.

Standards provide for a consistent spatial and organizational design of workstations. Legal or cross-industry standards are regarded as a basic prerequisite for factory operation. [17] It is rather a question of standardizing the layout of workstations, for example regarding the staging of materials or the dimensions and types of workstations. This can reduce search times or travel times for replenishment [48]. The target field can only be evaluated approximately with qualitative criteria such as the degree of standardization [39]. However, through standardized exchange and standardized shapes, it is possible to create the basic conditions for a standardized design of the factory in BIM. If workstations are not defined as standard shapes for the development along the defined development path, at least the spatial degree of standardization can be calculated as a relative share of the total number of workstations.

Transparency intends to increase the spatial (areas and flows) and organizational (responsibilities) comprehensibility of the factory. [19] The target field is to ensure an easy understanding as well as a better control of the factory, e.g. by avoiding visual barriers. This enables faster orientation, higher inventory awareness and team understanding among employees. [17] Since transparency is particularly targeting the design of the factory, BIM cannot provide direct support. This also gives the target field a very qualitative character, making the evaluation very difficult, e.g. in terms of visibility or acquisition time. Provided that administrative aspects are also included, BIM can support master data management and thus maintenance over the life cycle through a final LoI with use-specific machine details (non-geometric information).

Figure 8 summarizes the potentials of BIM regarding the evaluation of the target fields. They are sorted according to their measurability and listed with an exemplary key figure. Overall, it can be seen that BIM can offer support, in particular through documentation and the use of static master data. Content wise, emphasis is put on the technical machine data from the factory planning coordination model and spatial data from the architect's coordination model. As soon as the target field addresses the dynamic operational process in a factory, BIM can only provide partial support at the most. Corresponding deficits in the evaluation of the target fields in factory planning can currently only be compensated using alternative methods and tools described in Section 2.1 which are shown exemplarily in Figure 2.

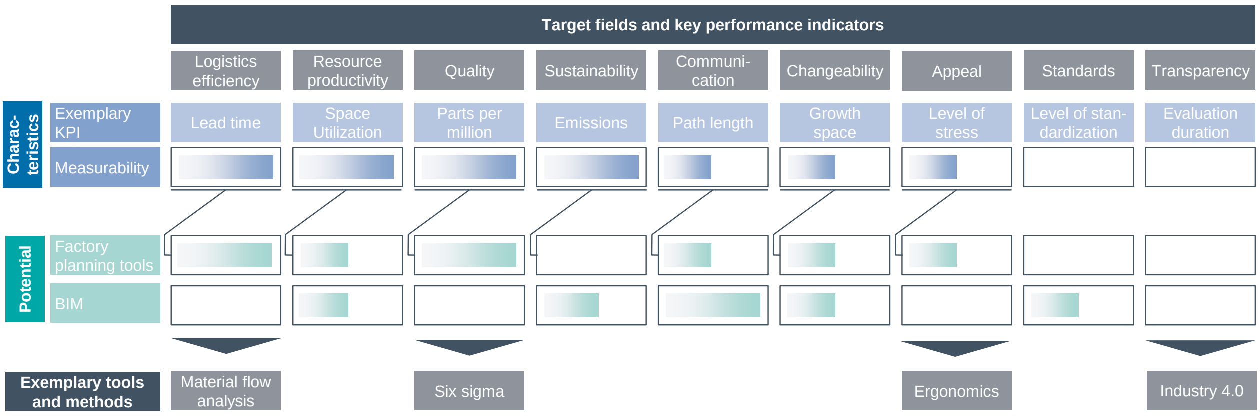

Figure 8: Potentials and deficits of BIM in factory planning

It becomes apparent that BIM can make an important contribution in the evaluation of resource productivity, sustainability, communication, changeability and standardization of a factory. Nevertheless, the detailed examination of the target fields shows that it is mostly a partial contribution. The object-based parameterization supports in particular the evaluation of the space productivity and the design footprints as well as the spatial degree of communication, changeability and standardization. For the rest of the target fields, it remains unclear at this point whether factory planning will continue to make use of a variety of methods and tools, or whether these will be combined in an overall solution. In particular, the target fields of logistics efficiency and quality require a real-time process view.

5. Conclusion and outlook

Object-oriented and model-based factory planning with BIM can be seen as the consistent next milestone in data-driven collaboration in factory planning projects. The consistent modeling of all information in BIM improves collaboration between the parties involved, as the flow of information is unambiguous. The data is collected in a central model, which thus guarantees redundancy-free and consistent data management as a "single source of truth". In this context, this paper first provides a proposal for the detailing of the factory objects in the planning phases and thus describes the formal-technical cooperation with factory planning.

It should also be noted that the described system is not only suitable for greenfield projects, but also for the brownfield approach. In addition, first investigations are already taking place to apply the described approach also in "plain factory planning" projects (without participation of HOAI project planning), for example for the regular rescheduling of assembly lines in case of product changes: The challenge here is to rearrange operating resources. The necessary media requirements of the operating equipment are stored in the factory objects (LoI), and the existing media supply in a production area, for example, can be read from the existing building model. This makes it possible to check the planed relocation quickly and precisely. Current project experience shows that the industry is already interested in creating a "factory planning BIM" explicitly for this planning case, also for the existing structures in a retrofit. The two submodels (see Figure 5) are then maintained by the factory or production planning (operations) and the facility management (during the planning phase “HOAI project planning”).

This is where further research should start and thus contribute to the independence of factory planning with BIM. An analogous approach in the sense of a Factory Information Model (FIM) could increase the visibility of the methodology, open up further target fields of factory planning and also trigger corresponding further developments and adaptations of the software used. The clear focus on the production-related factory objects of a future FIM would take into account the modeling of factory planning, which already goes far beyond the building.

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