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# General Approach And Prerequisites For Transferring Factory Planning Methods On Flow Orientation And Transformability To Hospital Systems

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**Abstract**

Manufacturing companies are faced with the challenge of operating cost-efficiently and remaining competitive in a turbulent environment with constantly changing demands on production. To meet these challenges, factory planning has developed concepts of flow orientation and transformability. Through decades of research, factory planners now have extensive methodologies and numerous principles, enabling them to design factory objects appropriately and align factories to be flow-oriented and transformable. Hospitals face similar challenges like manufacturing companies. Due to public funding, many hospitals have limited financial resources and must, for example, cover parts of their financial requirements by themselves through cost-efficiency. In addition, hospitals are influenced by ongoing developments like demographic change and recent challenges such as the COVID-19 pandemic. These and further examples not only tighten the economic situation of hospitals, but also force their systems to adapt to resulting challenges. They must successfully align their systems to remain operational under changing conditions. In contrast to factories, these issues have not been addressed sufficiently in the field of hospital planning. Therefore, factory planning approaches on flow orientation and transformability will be transferred to hospital systems in order to strengthen hospitals against globally existing and socially relevant challenges in the healthcare system. With the aim to realise this venture, this paper presents a structured approach for its implementation. It also investigates the fundamental similarities between factories and hospitals and examines whether the main prerequisites for the successful transfer of the approaches can be met.

**Keywords**

Factory Planning; Flow Orientation; Transformability; Hospital Planning; Hospital System

## 1. Introduction and need for research

Requirements for hospital systems have increased over time. This applies to those resulting from both external influences and internal properties. In Germany, efforts to economise hospitals were made with the amendment of the "Law on the Reform of Statutory Health Insurance" in 2000 [1] and was accompanied by increasing cost pressure **(external influence)** on hospitals. Hospitals are now only paid a flat rate per case according to Diagnosis Related Groups (DRG), instead of being reimbursed for the individually incurred costs. This forces hospitals to strive for economic efficiency in order to cover the costs of treatment in every case [2]. To be able to cover future investment needs independently, hospitals must also generate a profit by keeping their costs significantly below the case-based flat rates. This is necessary since federal states provide increasingly less funding in the health system [3,4]. However, operational business can only be economical if the processes run efficiently. Hospitals are characterised by a function-orientation where departments have

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a pronounced divisional thinking. Hence, the hospital system can be seen as a federal system comprised of different and independent but incompatible organisations. This leads to interface problems between different disciplines or departments and is also noticeable in hospital layouts by long travel and waiting times. Thus, a cross-departmental, more efficient form of service provision is not realisable [4-7]. Due to the process inefficiencies **(internal property)** many hospitals are unable to meet the demand for economic operations.

In addition to the above-mentioned requirements, hospitals must also cope with change drivers **(external influence)** resulting from their turbulent environment [6]. Change drivers can have many different origins. Examples include demographic changes and the shift in the distribution of disease patterns [8], the consolidation of the hospital market [9] or, most recently, the COVID-19 pandemic [10]. Hospital systems must be able to adapt to these change drivers in order to remain operational in the short term and competitive in the medium to long term. Examples from practice show that hospitals cannot meet this requirement due to their transformation inertia **(internal property)** [3,4,6,11,12].The change drivers and the changes resulting from them must be identified at an early stage, which applies not only to hospital operations but already to hospital construction planning [13], which are characterised by long planning periods. There is a high risk that they will no longer meet the requirements by the time they are put into operation [12]. Therefore, it is necessary, that the consequences can be mitigated at an early stage with appropriate measures, such as accelerated reutilisation cycles in construction [14].

As summarised in Figure 1, the performance of hospital systems is strongly affected by the external influences of cost pressure and change drivers. The system properties of process inefficiencies and transformation inertia of hospitals do not provide an opportunity to adequately address the external influences, but rather worsen the situation with an additional negative impact on performance.

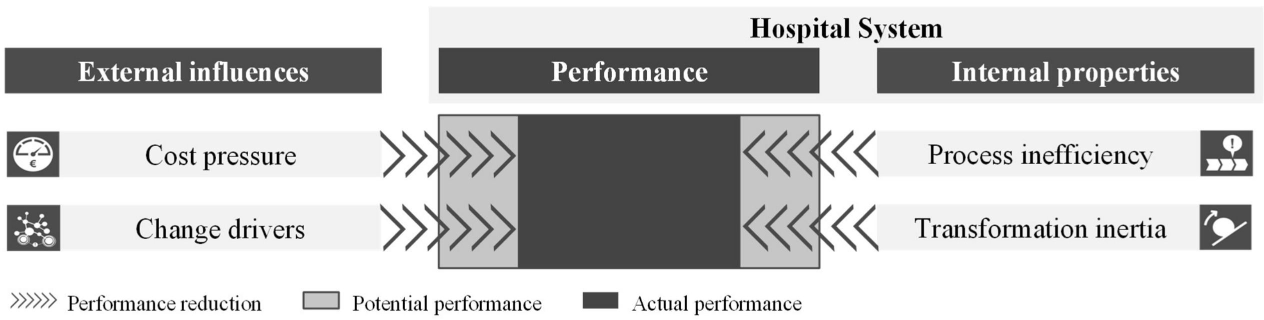


Figure 1: External Influences and Internal Properties of Hospital Systems

To increase the process efficiency, the ideal layout of a hospital must be aligned with the treatment processes to reduce travel and waiting times. In addition, the hospital system must be designed in such a way that it is prepared against the change drivers. Consequently, it requires the integration of flow orientation, i.e. the orientation towards process-oriented structures [15], and transformability, i.e. the ability to realise changes beyond defined areas and are absolutely necessary to ensure future oriented developments [16]. These two features enable the hospitals to shape the internal properties and cope adequately with external influences. Hospital planning, here also refers to hospital construction planning, has not been properly scrutinised as an object of research for decades. Hence, the methodologies in this field are lagging behind [13,17]. Therefore, there has been no approach that enables flow orientation and transformability equally important with the necessary depth of detail for hospital planning.

Regarding process efficiency, the approaches aim to reduce the effort required to provide services. For example, they maximise the utilisation of investment and operating cost-intensive resources by centralising functional areas [12] or minimise process times through lean methods [19]. The layout planning has a great influence on the process times through the determination of the travel times, whereby a process analysis for flow-oriented layout planning does not take place in the approaches examined in the current study. Existing approaches only consider the processes in the context of process management [2], during the introduction of activity-based costing [20,21] or for the implementation of IT systems [7,22]. Moreover, numerous quantitative approaches have been developed for supporting decision-making in layout planning, which arrange the spaces in individual hospital areas based on objective functions under consideration of certain constraints. The approaches considered can be divided into mathematical optimisation methods [5,23-26], simulation models [27–32] and hybrid approaches [33–36].

Regarding flexibility, existing approaches understand this term as a requirement that is becoming increasingly important due to the permanent change in the healthcare sector [6]. Flexible hospitals are recognised worldwide and are characterised, among other things, by decentralised structures [12,37], additional capacities [38,39] or variability or multifunctional equipment features [40–42]. The expandability or reducibility of a hospital due to growing or shrinking space requirements [12,14,25], the changeability of interior spaces [14,23], variable functions with a constant building structure [40,41] or modular hospital structures [12,37] are mostly equated with flexibility, but are to be understood far more profoundly according to the understanding of factory planning and are thus rather to be assigned to transformability. The flexibility in factory planning is described as the ability to react to foreseen changes within a defined area. Transformability, on the other hand, goes beyond flexibility and involves multidimensional changes and multiple areas [15].

In the following the general approach bridge the research gap explained above is described in Section 2. Further, Section 3 examines the prerequisites for transferring factory planning methods to hospital systems, before the paper concludes in Section 4.

## 2. General approach to close the research gap

Factories are also faced with the challenge of designing their processes as efficiently as possible and ensuring sustainability in a turbulent environment. Flow orientation and transformability are therefore well-known target areas in factory planning. They are already successfully taken into account within the framework of a structured procedure for the goal-oriented design of a factory's objects [15]. The factory planning tasks required for this purpose, which need expert or experiential knowledge [43], are supported by a comprehensive set of methods and design principles [15]. These are to be taken up within the framework of planning support for hospitals and adapted to the hospital system.

Factory planning distinguishes between **rough** and **detailed planning**. In the **rough planning** phase, factory planners create a feasible factory concept that fulfils the defined factory goals in the best possible way [44]. In order to achieve efficient processes, it is necessary to realise a flow orientation in the layout [45]. To support the hospital planning decisions, guiding principles are to be developed regarding centralisation or decentralisation as well as the arrangement of functional areas and rooms in accordance with the flow orientation. In **detailed planning**, the factory planners work out the factory concept and describe it in detail [44]. In this course, the factory objects, which are the material or immaterial components of a factory that it is built from [46], are designed to be transformable [47,48]. This way, factories can adequately encounter the change drivers from their turbulent environment [16,48,49]. To adapt hospitals to the change drivers that affect them, hospital planning is also to be supported with guiding principles to increase the transformability. The procedure to develop the guiding principles is illustrated in Figure 2 and described below.

Since hospitals, like factories, are to be understood as a long-lasting, complex and socio-technical systems that are subject to permanent adaptation [6], an analysis of the entire hospital as a single object of investigation is not expedient [46]. Factory planners therefore subdivide the factory into individual factory objects [47], so that these can be designed in a flow orientated and transformable manner [15].

In order to define valid guiding principles for hospital systems, the **first step** is to develop a description model of the hospital system. Analogous to factory planning, the hospital objects for later design must be identified and assigned to the previously defined system levels and the design fields [15]. In the **second step,** the flow relationships must be identified to be able to make statements about flow orientation in hospitals. For this purpose, the various flows resulting from the process flows must be combined into a holistic quantity structure and presented in a generally valid flow diagram. The service network must be depicted holistically so that all flows of patients, staff and material along the primary and secondary processes are shown. In the

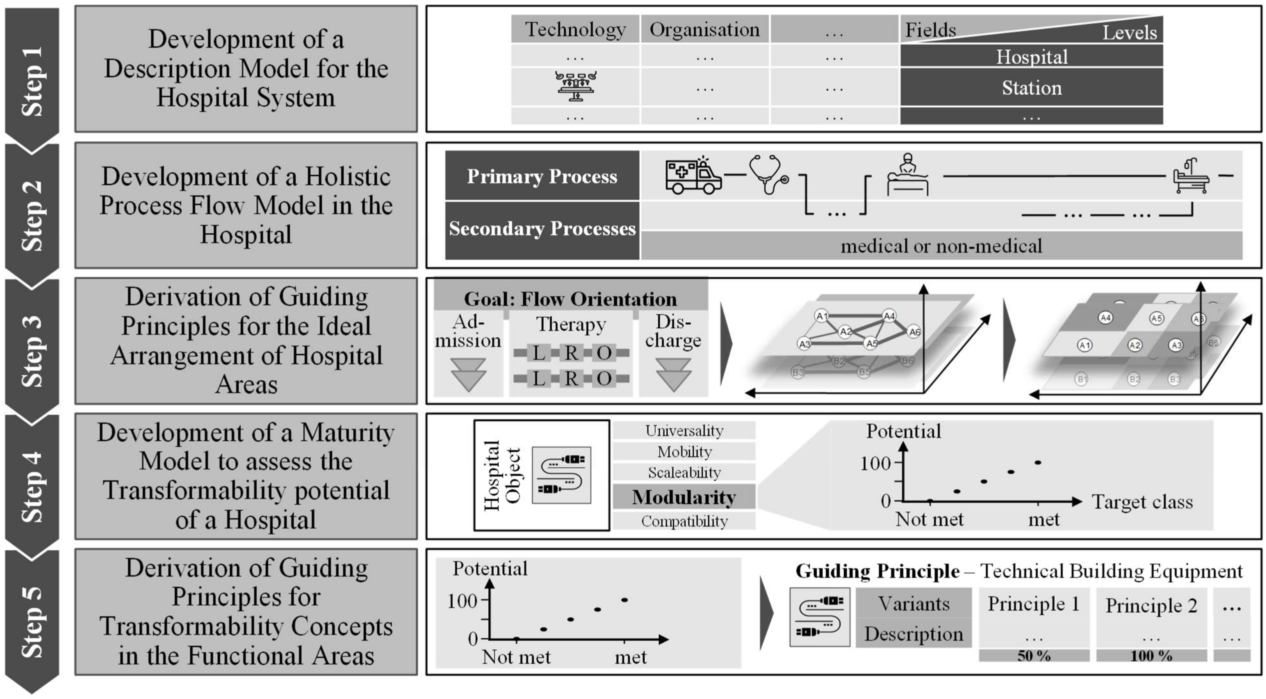


Figure 2: Procedure to develop the Guiding Principles for Flow Orientation and Transformability

**third step**, target structures are to be developed based on the factory structures [15] and divided into functional areas or departments that define the process flow. With the help of process flow models and target structures, flow-oriented function diagrams are drawn up as in factory planning [15]. These serve as the basis for creating the ideal arrangement variants, from which guiding principles for the ideal arrangement of hospital areas are then to be derived. Once the guiding principles have been drawn up, the rough planning is complete. Subsequently, the guiding principles for transformability are to be worked out within the framework of detailed planning. In the **fourth step**, a maturity model must first be developed to assess the transformation potential of the individual hospital objects. In the process, individual transformation enablers for hospital systems are to be taken into account in accordance to factory planning [15], and then, characteristics of the individual factory objects that positively or negatively influence the transformation potential are to be identified. The characteristics serve as the basis for a utility analysis to assess the transformability of the whole hospital. In the **fifth step**, the required degree of transformability for the individual hospital objects must initially be determined in order to derive guiding principles for the development of space, technology and organisational concepts that meet the requirements. To this end, megatrends in the hospital environment must be identified and the resulting change drivers for hospitals and their effects on the functional areas must be derived. Subsequently, possible planning variants of the hospital objects are to be developed, from which guiding principles are to be derived depending on the necessary degree of transformability. Finally, the established guiding principles for flow orientation and transformability are to be evaluated with the help of case studies and the active involvement of hospital practitioners such as managers or physicians in workshops.

## 3. Prerequisites for transferring factory planning approaches to hospital systems

In order to cope with external influences of cost pressure and change drivers, hospital systems are to be designed flow orientated and transformable. As described before, the approach is based on the methodical approaches from factory planning. In order to successfully transfer the described project to the hospital system, prerequisites must be met in the hospital, just as they are in factories. To design the hospital in a targeted manner, hospital objects must be identifiable (prerequisite 1). To realise flow orientation, flow relationships must exist in hospitals (prerequisite 2). In the following, the necessary similarities between the hospital and factory systems are shown and based on this, the fulfilment of the prerequisites is derived.

### 3.1 Hospital objects

As summarised in Figure 3, there are similarities between the fields and levels of both systems. As explained in more detail below, objects can be identified via the levels of the hospital and sorted into the matrix of fields and levels. The basic possibility of identifying hospital objects, as prerequisite 1, is thus fulfilled.

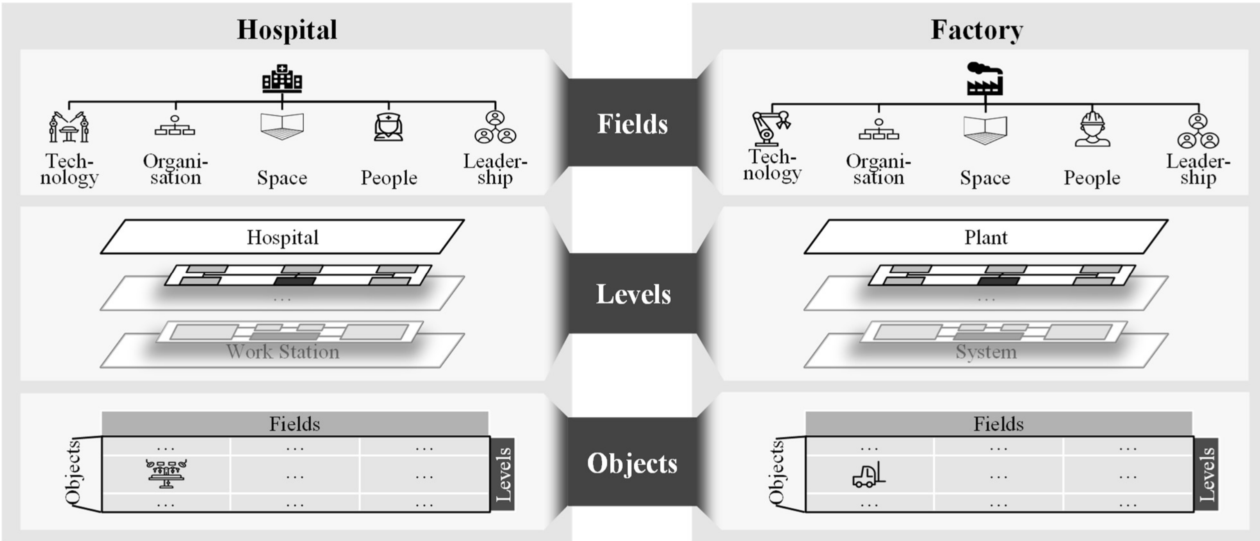


Figure 3: Similarities between Factories and Hospitals to derive Objects in Hospital Systems

Factories are divided into five factory fields of technology, organisation, space, people and leadership [46]. According to their definition, a division into these five fields can also be applied to hospital systems. Technical equipment and infrastructure are necessary for the provision of services in hospitals [6]. The objects used in hospitals differ from those used in factories, but can also be structured in production, storage, or transport. Like factories [46], hospitals have structural and procedural organisations that influence the quality of hospital services [4]. The areas in hospitals are clearly defined and structured for the building by standards and specifications according to the DIN 277 [50] and aspects such as the plot of land or the layout are also taken into account [12]. In addition, hospital employees are subject to hierarchical management [4].

The factory is hierarchically divided into five different factory levels from the plant level to the factory level, areas, sub-areas and to the work station, considering that every level encompasses all of its subordinate levels [46]. In analogy, hierarchical levels can be identified and structured for hospitals, such as from the speciality level to the work station [6]. Referring to the example that a plant may include several factory halls at the factory level, a large hospital may have several specialities at one location. These specialities are divided into various areas, e.g., surgical areas or wards, which in turn are divided into different work stations.

In the context of factory planning, material or immaterial resources are named factory objects and are classified in the matrix of factory fields and levels [46]. Different resources can also be allocated to the individual levels in the hospital and represent material or immaterial components, such as the allocation of the supply structure to the hospital level or of medications and other materials to the workplace level [6]. A definition of hospital objects and their classification into hospital fields and levels are consequently possible.

### 3.2 Flow relationships in the hospital system

As explained in more detail below and summarised in Figure 4, there are similarities between the products, the main processes, and the workflows of hospital and factory systems. This results in flow relationships; prerequisite 2 is therefore also fulfilled.

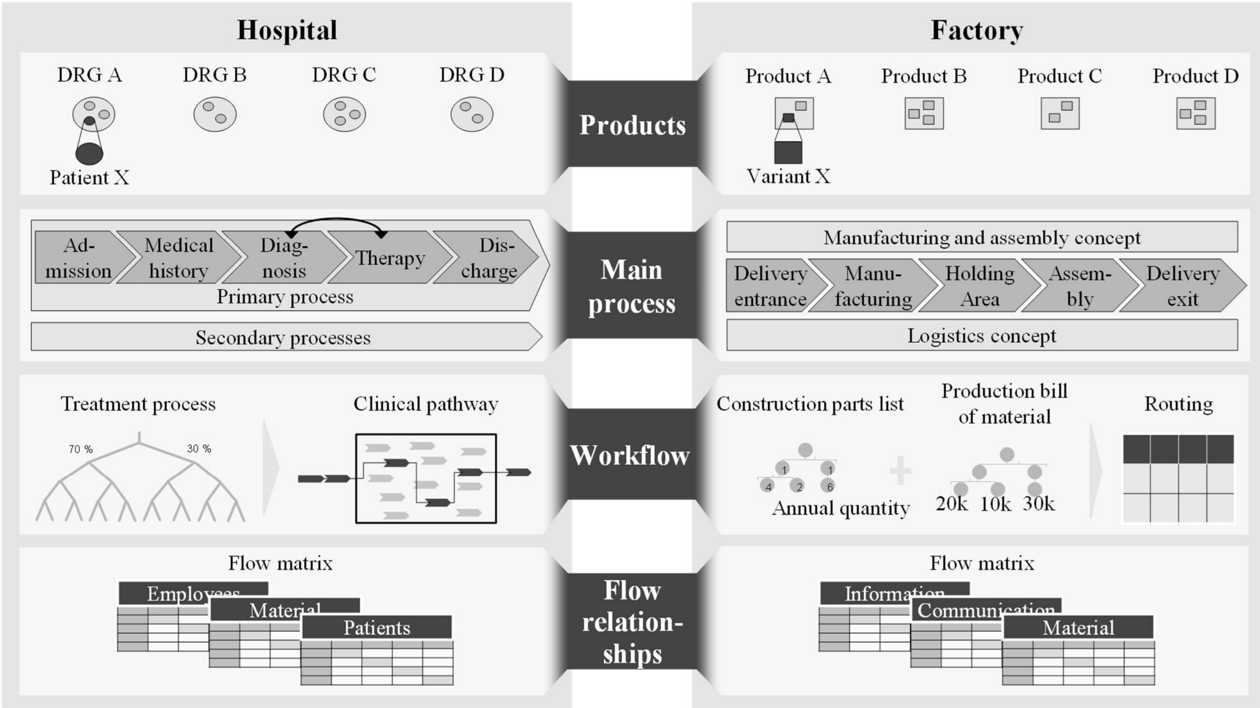


Figure 4: Similarities between Factories and Hospitals to derive Flow Relationships in Hospital Systems

Products are understood as output of a manufacturing company, which is made available to consumers for purchase [51]. The product of a hospital is the ready-treated patient. For this purpose, services are provided, such as nursing care, an examination, or an operation. In order to be able to offer the services, physical commodities or consumables are often necessary, such as medicines, X-rays or surgical instruments. The treatment of a patient depends on diagnosis, procedures, age, sex and possible complications or comorbidities, in summary DRGs. This leads to a high variance of products and to the assumption that hospitals can be understood as multi-product factories [52]. If the products of factories are differentiated into variants per product group [15], analogously the products in hospitals can be differentiated by patients per DRG.

Hospital processes required to deliver services can be divided into primary and secondary processes. Patient treatment represents the primary process of a hospital [12]. This comprises all tasks of anamnesis, diagnostics, and therapy from admission to discharge, whereby iterations between diagnosis and therapy are possible. Secondary processes support the primary process by providing the services necessary for treatment [53]. Since the necessary processes in factory systems are also subdivided, there is a further analogy between the two systems. In factories, there are the core processes for service provision, which include storage, manufacturing, and assembly from arrival to departure of goods. These are assisted by support processes [15].

Hospital and factory systems have defined workflows. For factories, this results from the work plan, which is derived from the construction and production bill of materials [15]. Workflows in hospitals are determined by clinical pathways. Clinical pathways are developed for disease patterns and group individual cases into a homogeneous group based on certain indicators or symptoms [4,54]. Starting from a diagnosis, the clinical pathway represents a consensus across professional groups and institutions for the succeeding sequence of diagnostic and therapeutic measures within the framework of inpatient treatment [20,54].

For the various diagnostic and therapeutic measures, patients pass through different clinical departments of the hospital for treatment [55]. The combination of primary and secondary processes results in a network of services in the hospital consisting of internal customer-supplier relationships [56], similar to factories [57]. This leads to a multitude of flow relationships, for example, of patients, employees, or material. In case of availability of necessary flow information, the relationships can be represented in a structured and clear manner in matrices, as they are also used in factory planning.

### 3.3 Differences between hospital and factory systems

Of course, hospital systems are not comparable with factory systems in all aspects. Hospitals have routine patient treatments, but also a large proportion of emergency cases. The occurrences of emergency cases is normally taken into account, however the individual and highly diverging treatments can only be determined after examining the patients. In addition, in large incidents, it is difficult to plan not only the activities to be carried out but also the number of treatments [58]. This short-term order planning is unusual for manufacturing companies; they plan in advance and adjust their factory operations accordingly. Although the emergency degree is not comparable with those in hospitals, and they do not deal with human lives, manufacturing companies in the field of maintenance, repair and overhaul are familiar with these challenges. Before they take action, similar to patients in hospitals, the product must be assessed to determine the next course of action [59,60]. In general, this fact plays a subsidiary role in transferability of factory planning methods to hospital systems, as long as the individual characteristics of hospitals are taken into account accordingly. For flow orientation, flow relationships must consider all activities and procedures, routine and emergency treatments, as well as their respective frequencies (prerequisite 1). Further, hospital objects must ensure that all possible objects from activities and processes of emergency treatment are included (prerequisite 2).

## 4. Summary and outlook

External influences such as cost pressure and change drivers require flow orientation and transformability of hospital systems, with internal characteristics counteracting this. Demands for flow orientation and transformability already exist for factories. Over time, factory planning has developed successful methods with which systems can be designed accordingly. Since these have been lacking for hospital systems so far, this paper presents a procedure with which the factory planning methods for flow orientation and transformability can be transferred to hospital systems. However, a condition for the successful implementation of flow orientation and transformability in hospital systems is the similarity between the two systems. Hospital objects and flow relationships between structural elements must exist in hospitals. These prerequisites were also examined, leading to the conclusion that hospitals and factories are comparable. Like factories, hospitals can be divided into levels and fields from which hospital objects can be derived. Since both systems have products and a superordinate main process, flow relationships between the structural elements can also be developed. On this basis, it is possible to describe the hospital system in a structured way analogous to factories.

Having examined the similarities and prerequisites of both hospitals and factory systems, the next step is to develop the guiding principles using the approach mentioned. The to-be-developed guiding principles should facilitate the practical and implementable transfer of factory planning methods to hospital systems.

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## Biography

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**Lennart Hingst, M.Sc.** (*1989) studied technical logistics at the University of Duisburg-Essen. After his studies Lennart Hingst worked in the industry for years. Now he works as a research associate in the specialist factory planning group at the Institute of Production Systems and Logistics (IFA) at the Leibniz University Hannover since 2019.

**Prof. Dr.-Ing. habil. Peter Nyhuis** (*1957) studied mechanical engineering at Leibniz University Hannover and subsequently worked as a research associate at IFA. After completing his doctorate in engineering, he received his habilitation before working as a manager in the field of supply chain management in the electronics and mechanical engineering industry. He is heading the IFA since 2003.

**Prof. Dr.-Ing. Kunibert Lennerts** (*1963) is holding the professorship for Facility Management at Karlsruhe Institute of Technology since 2000 and was appointed to the first university professorship in Facility Management in Germany. His main research areas are facility management and sustainability with special focus on huge real estate portfolios and hospitals.