INTERNATIONAL STANDARD

ISO 18828-2

First edition
2016-10-15

Industrial automation systems and integration — Standardized procedures for production systems engineering —

Part 2: Reference process for seamless production planning

Systèmes d'automatisation industrielle et intégration — Procédures normalisées pour l'ingénierie des systèmes de production —

Partie 2: Processus de référence pour la planification de la production sans couture

Reference number
ISO 18828-2:2016(E)

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Foreword

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The committee responsible for this document is Technical Committee ISO/TC 184, *Automation systems and integration,* Subcommittee SC 4, *Industrial data.*

A list of all parts in the ISO 18828 series can be found on the ISO website.

Introduction

This document describes a reference planning process which aims to establish a consistent understanding of production planning processes in the lifecycle stage of production preparation addressing the phase in between design and manufacturing (see Figure 1). The primary application domain of the reference planning process is planning of production systems, e.g. “make-to-stock” or “assemble-to-order” production.

Investigations in the area of manufacturing lucidly show an increased utilization of digital planning tools to master product and process complexity and respond to continuous cost and time pressure. Production planning today uses many different IT-tools. These tools are mostly standalone solutions that are highly oriented towards specific use cases. The isolation of the IT-tools hinders sustainable system consistency. The heterogeneity and incompatibility of the IT systems hampers interdisciplinary planning across multiple phases. A lack of clear structures for each phase leads, for example, to inefficient planning and redundant processes, multiple work, transformation failures, and incomplete information. The comparison of planning results, as well as information transfer between different planning disciplines, is difficult. Despite this abundance of IT tools, as well as an overflow of various process descriptions on all kind of specialized production domains in literature, a lack of common standards is presently observable.

NOTE 1 For further reading, see Bibliography.

The reference planning process introduced within this document is illustrated in Figure 1. It is embedded between the product design process and the production process. This illustration depicts the sequential phases of the product life cycle, beginning with the concept phase, followed by the evaluation of the product design until the start of manufacturing. It stresses the major importance of a reference process for production planning as a link between product design and production itself. A detailed visualization of the planning processes is given in Annex B.

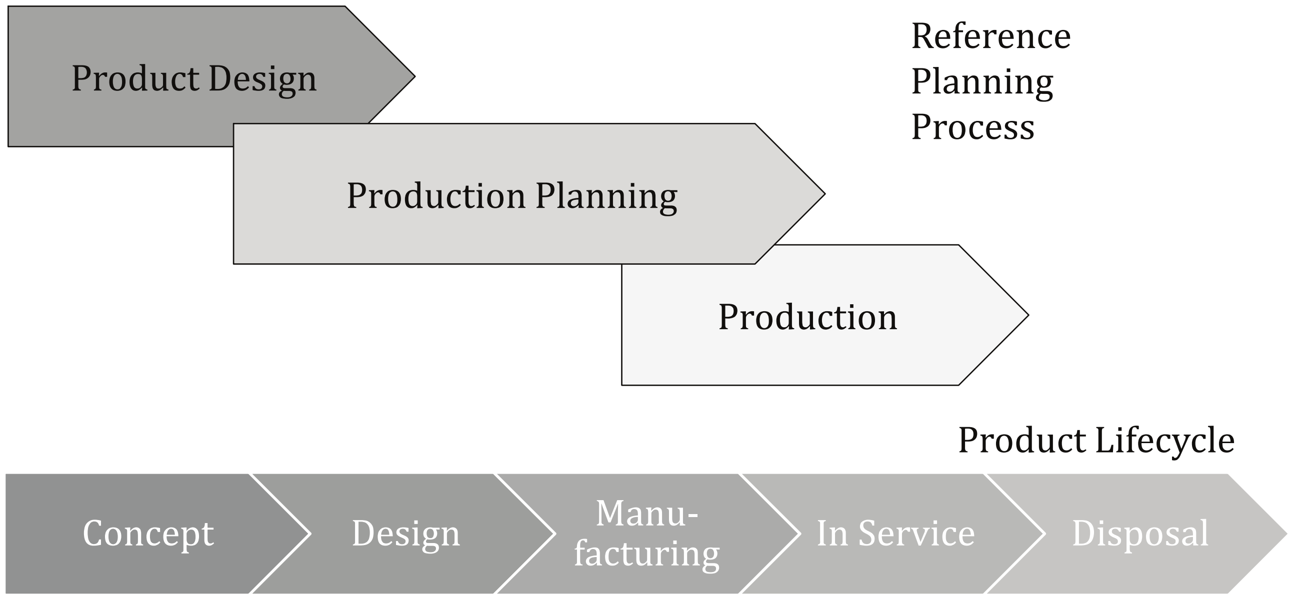

Figure 1 — Classification of the reference planning process (qualitative depiction)

To achieve the goal of a consistent planning and harmonization of the multiple processes, the development of a reference process for production planning is envisioned. Planning processes within the manufacturing phase will be analysed and merged to optimize the efficiency and transparency of each process activity. Thereby organizational, technological/technical and conceptual barriers are identified and with appropriate measures minimized or totally eliminated.

In order to integrate IT systems across the multiple phases of product development, the processes used in production planning need to be formalized and standardized.

For user specific applicability, the description of the model will be realized by the use of different levels of detail. The reference planning process, as shown in Figure 1, comprises the totality of processes within the production planning. Figure 2 depicts the reference planning process viewed as an embedded process taking input information from earlier phases of the product life cycle (e.g. as provided in ISO 10303-242) and releasing information such as work schedules to follow-up processes (e.g. as described in ISO 10303-238). A general overview and a detailed explanation of all processes within the reference planning process is given in Clause 4.

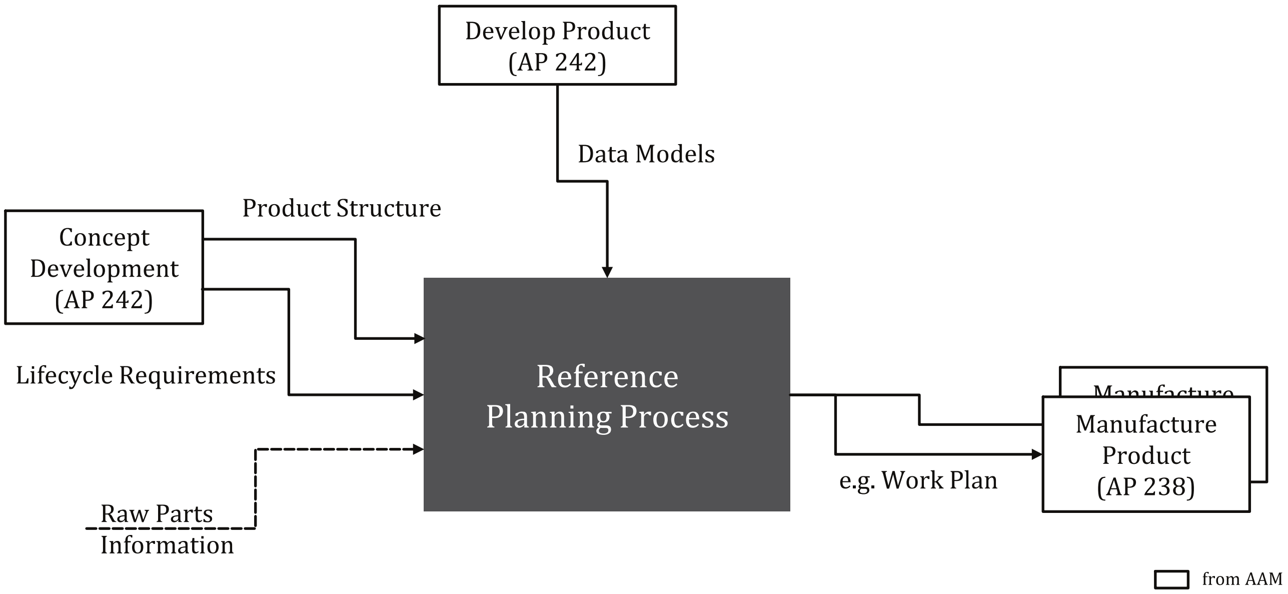

Figure 2 — Integration scenario of the reference planning process considering ISO 10303 Application Activity Modules (AAM)

NOTE 2 For further demarcation and possible integration to other standards considering industrial data, e.g. product data (see ISO 10303-1), component data (see ISO 13584-1), production data (see ISO 15531-1) and life-cycle data (see ISO 15926-1), see Bibliography.

Industrial automation systems and integration — Standardized procedures for production systems engineering —

Part 2:
Reference process for seamless production planning

1 Scope

This document describes a reference planning process for seamless production planning.

NOTE In this context, “seamless” means the consideration of multiple planning aspects (relevant planning disciplines) within the product life cycle, as illustrated in Figure 1 and Figure B.1.

The scope of the discussed reference process focusses on the planning of production systems such as make-to-stock or assemble-to-order production. The analysis of the process activities has been limited to those within the production planning. The following aspects are within the scope of this document:

— general overview of the reference planning process;

— basic principles of the process model;

— description of each level identified within the reference planning process for production planning;

— structure of activities and relations within each planning discipline;

— dependencies of interdisciplinary activities.

The following items are outside the scope of this document:

— material requirement planning/manufacturing resource planning;

— production order control;

— production process;

— early stage product design;

— order management, inventory management, purchasing, transportation, warehousing;

— production facilities planning/manufacturing facilities planning (physical plant and equipment), including any kind of resource that is not directly related to the manufacturing process;

— value chain (inbound logistics, operations management, outbound logistics, marketing and sales);

— resource visualization;

— process simulation.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15531-1 and the following apply.

3.1.1
container concept
explicit choice of a transport container, such as blister packs, lattice boxes or small parts containers

3.1.2
delivery concept
strategy adopted to supply individual parts, modules or finished products to the assembly and manufacturing resources

3.1.3
product
thing or substance produced by a natural or artificial process

[SOURCE: ISO 10303-1:1994, 3.2.26]

3.1.4
production process management
planning process during the production phase

Note 1 to entry: After the start of production, the production process management is involved if process or product changes (requests) occur which lead to a new planning iteration. It does not include the operation planning, planning of materials and resources or the planning and control of production.

3.1.5
operating resources
movable and immovable resources that contribute to production

3.1.6
planning scenario
combination of certain planning variants from all planning disciplines

3.1.7
process chain
sequence of process activities

3.1.8
product design process
process of design of a product from the idea for a product through to the last engineering bill of materials (EBOM)

3.1.9
product structure
structure providing a functional classification of all items, parts, components, sub-assemblies and assemblies of a product

Note 1 to entry: The hierarchical "as-designed" product structure which is defined during product design allows the creation of an engineering bill of materials (EBOM).

3.1.10
reference planning process
process from the initial product definition to delivery of the last work plan in series planning

Note 1 to entry: The reference planning process does not include production control.

Note 2 to entry: The initial product definition usually corresponds to the end of the concept phase.

3.1.11
work system
system used to fulfil a work task and described by the seven system terms (work task, work progress, human, resource and equipment, input, output, environmental influences)

3.2 Abbreviated terms

assy	assembly
BOM	bill of materials
EBOM	engineering bill of materials (BOM from the design perspective)
EOP	end of production
ext	extended
MBOM	manufacturing bill of materials (BOM from the production perspective)
mfg	manufacturing
PLC	product life cycle
SADT	structured analysis and design technique
SOP	start of production

4 Reference model for production planning process

To provide information for different user groups and use cases, the reference process model for production planning is based on a multi-level structure. The process is detailed by progressive stages in a top down approach. The degree of abstraction decreases by drilling down the levels. The number of available levels depends on the processes and the connected sub processes. Here, the main processes are broken down into several sublevels. To reach an appropriate degree of abstraction, especially for the main planning functions, five levels are defined. These levels are illustrated in Figure 3. The notation of the elements within the process represents their respective model level in order to reach a better orientation while going through the description of each process. Except for the root process A0 at model level 0, each process refers to the model level according to the number of numeric digits in the notation (e.g. the process A2.2.1 contains three numeric digits and belongs to the model level 3).

NOTE 1 Syntax and semantics are used according to the functional modelling language ANSI/IEEE 1320.1.

NOTE 2 A functional model describes the functions (e.g. activities, actions, processes, operations) of a system (e.g. product design, production planning, production) and their relationships. The functional model represents what is done rather than how it is done. The content of the model represents all possible functions of a system. For company specific implementation not every function needs to be applied. Functional models such as activity models are frequently used in normative context (see Bibliography).

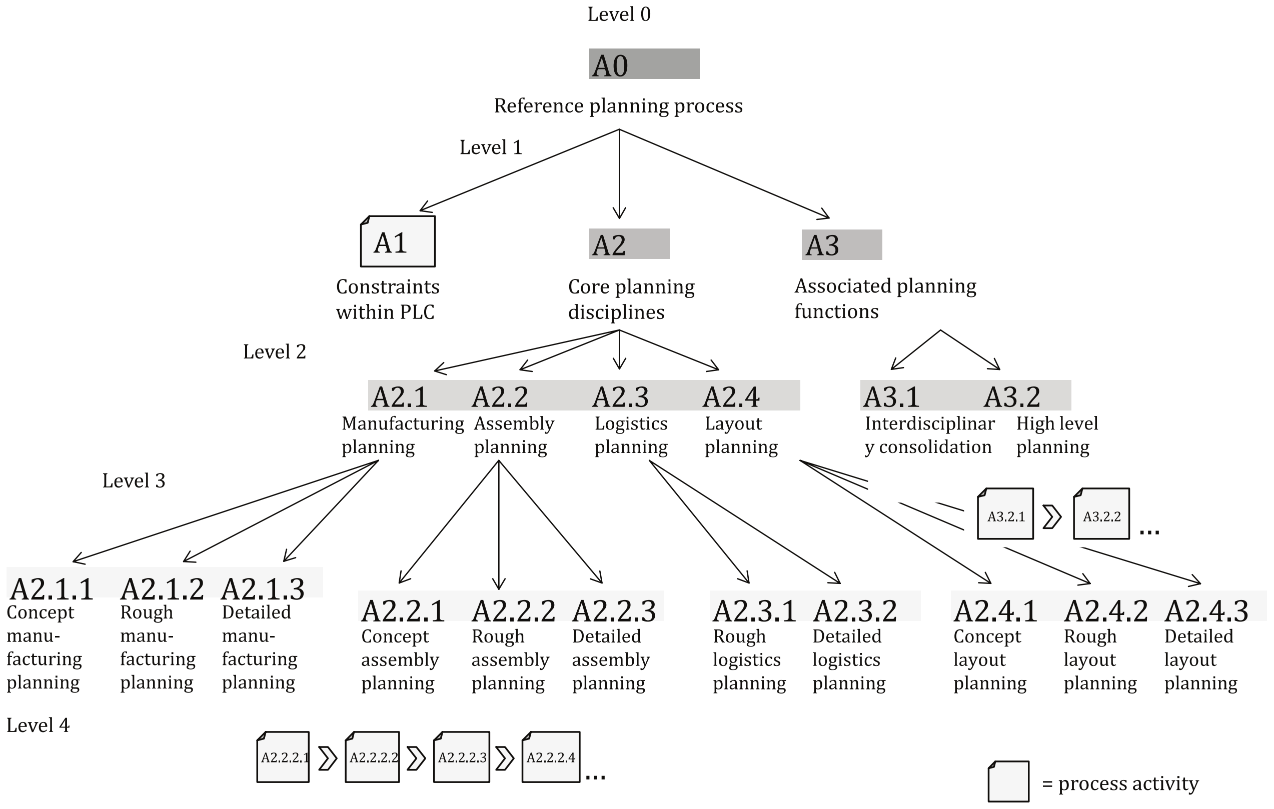

Figure 3 — Structure of the reference planning process model

The consideration and control of the complexity are essential for the development of the reference planning process. The modelling makes use of combining recurrent functions and constraints into aggregated modules. As a result, clear structured planning processes consisting of input and output data, control mechanism and methodical support have been modelled. Thereby both, functions at the interface of the reference planning process and consolidations within the planning disciplines are combined at the root level. This aggregation leads to a significant increase of clarity of description and enables a prioritized view for the user at the given core discipline. The description of the detailed model levels follows the same top down approach. First the level with the highest degree of abstraction will be described (referred to as level 0), following a description of the level consisting of the main function of the reference planning process. In reference to this basis every possible characteristic planning element will be consecutively described. To ensure a consistent description of the different model levels the detailed description of the levels contains the following structure:

— the graphical abstract of the detailed process activities using structured analysis and design technique (SADT) notation;

— the textual description of the process activities;

— the additional explanation of specific model details.

4.1 Summary of the process A0 (level 1)

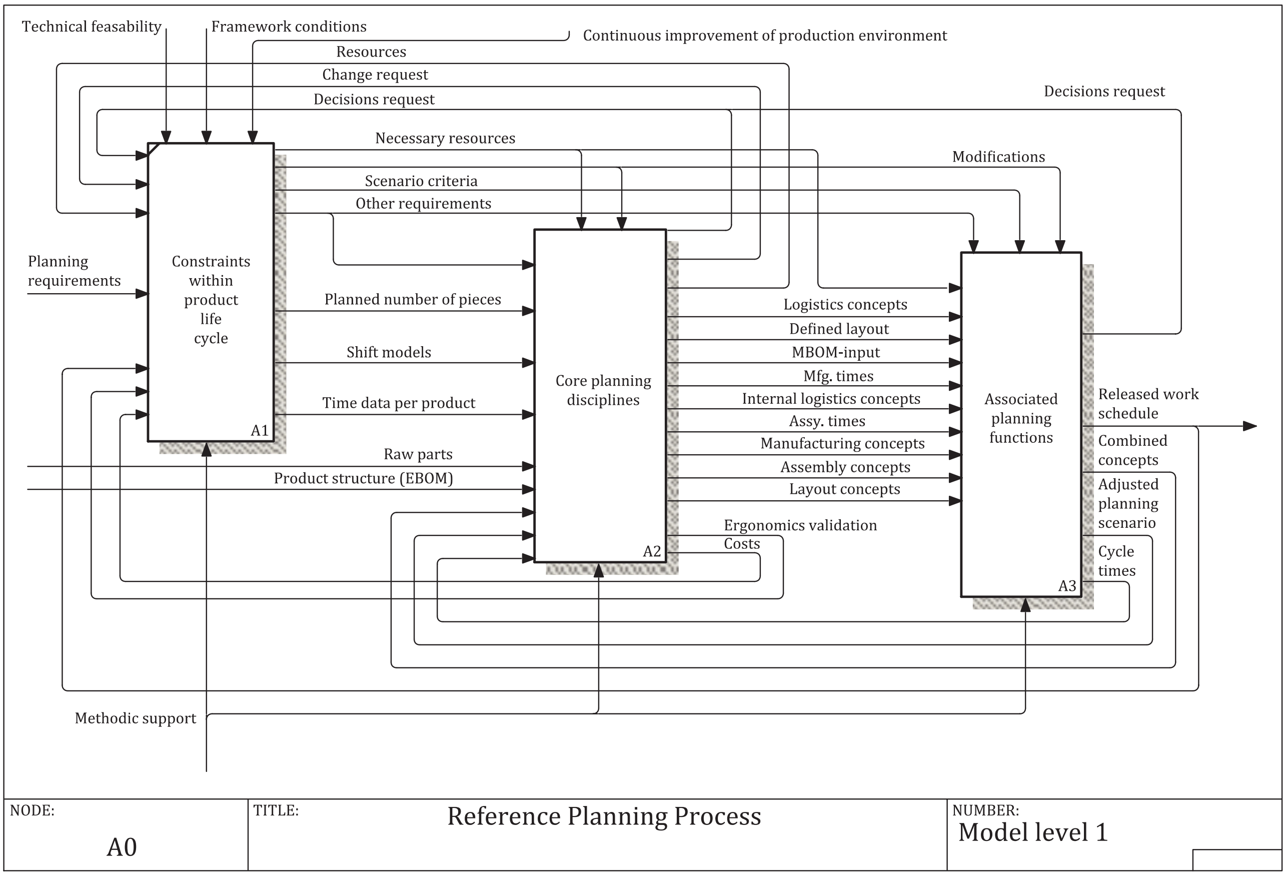

Figure 4 — Structure of the reference planning process at model level 1

Relating to the abstraction of the reference planning process, the starting point for the modelling of the reference planning process are the constraints derived from the production planning. Beside these constraints several control factors impact the production planning. As previously shown in Figure 2, the constraints from higher levels are separated into different quantities and are provided for the reference planning process. The product structure (EBOM), information about the raw parts and several planning requirements are first level inputs derived from the production planning. The control functions are represented by the framework conditions. Methodical support is provided for every process. All information and processes combined constitute the output of the reference planning process represented by the work schedule. Every iteration of the reference planning process leads to an updated version of the work schedule and in the end to the last released work schedule. These iterations are also represented in the detailed structure of the reference planning process as shown in Figure 4.

Due to the top down approach of the model the complexity of the considered process activities increases for every level. To handle this complexity, the reference process for production planning is divided into three main functions, described by the following:

— constraints within the product life cycle;

— core planning disciplines;

— associated planning functions.

The constraints within the product life cycle provide information for different planning disciplines and associated planning functions through several levels of the model. The constraints operate as a control function for other processes during the product life cycle. The constraints affect every element in every level of the model (top down approach). Through the described structure the changes caused by the decision making function can be precisely applied. The constraints provide planning requirements as input information for the core planning disciplines, as well as control input for the associated planning functions. Additional information needed in the detailed model levels that are not generated by the remaining planning disciplines is provided by other requirements.

The core planning disciplines represent the considered planning function during production planning. They receive the production information as controlled by the constraints and generate the planning data output for the start of production. The core disciplines can contain various planning functions. In the production planning field it is possible to distinguish between several types of planning disciplines. The most important, fundamental planning disciplines are identified and detailed in the structure of the reference process (see 4.2).

The core disciplines strongly interact with the associated planning functions and their constraints from higher level. The constraints provide the external input and control parameters. The internal consolidation of the output from the remaining planning functions is performed within the associated planning functions (see A3 in Figure 4). The associated planning functions are able to realize operations like the combination of the developed planning concepts during the different steps of the production planning or the request for a management decision. Another essential aspect, which is part of the associated planning function, is the production process management. The Production process management runs parallel to production. If any changes to the planning requirements or other constraints are necessary, the production process management is capable of triggering the iteration of the preliminary planning steps to which the changes apply to.

4.2 Summary of the process A2 (level 2)

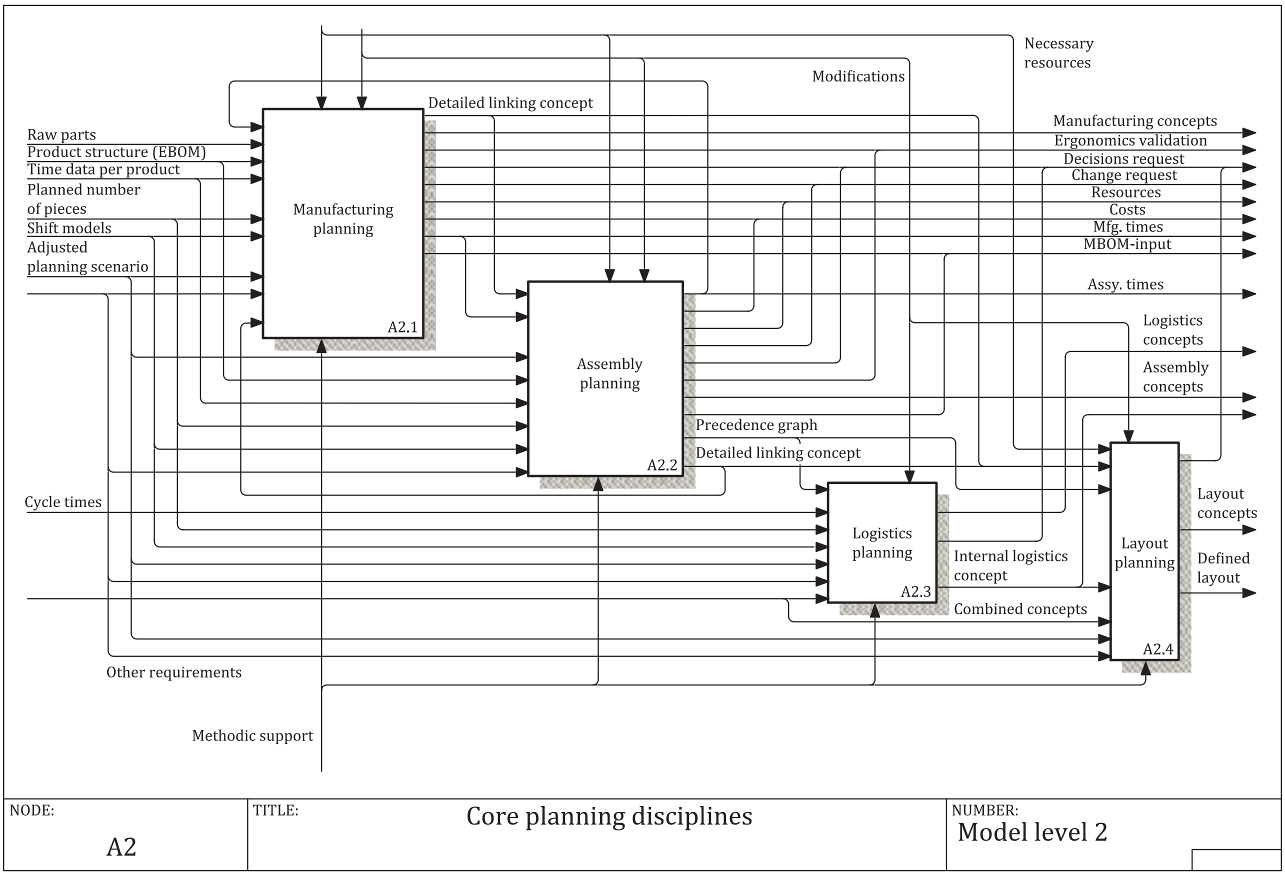

Figure 5 — Structure of the reference planning process at model level 1

When describing the production planning it is sensible to restrict these to the most important, fundamental planning disciplines that can be found in many manufacturing companies. As shown in Figure 5, these disciplines are:

— manufacturing planning;

— assembly planning;

— logistics planning;

— layout planning.

Each discipline will be structured by the degree of maturity of the planning. Thereby the manufacturing, assembly, logistics and layout planning will be broken down into three subphases:

— concept planning;

— rough planning;

— detailed planning.

The structure based on the degree of maturity will be applied to all four core disciplines (see 4.2.1 to 4.2.4).

Manufacturing planning (A2.1) comprises all the measures taken in order to design a manufacturing system, as well as the selection of the necessary manufacturing resources and processes. When performing manufacturing planning, it is particularly important to take account dependencies with the remaining planning disciplines such as assembly, logistics and layout planning.

Assembly planning (A2.2) defines the steps involved in the assembly of various individual parts to create an end product and determines the necessary equipment (e.g. lifting cranes, robot arms). This planning activity, which also includes the draft design of the assembly systems, is frequently performed by the department which is responsible for work preparation.

The aim of **logistics planning** (A2.3) is to ensure that the raw materials and semi-finished products, assemblies, subassemblies or fastening elements such as screws are available at the right place at the right time and in the correct, economically optimized quantities.

As the last of the four focused planning disciplines, **layout planning** (A2.4) ensures that operating resources are located optimally in the production area (e.g. the processes in an assembly line or in an assembly cell can run as efficiently as possible). To perform this task, it is very important that the knowledge and experience derived from the other planning disciplines is available during layout planning.

NOTE For more detailed information about the core planning disciplines, see Annex B.

4.2.1 Summary of the process A2.1 (level 3)

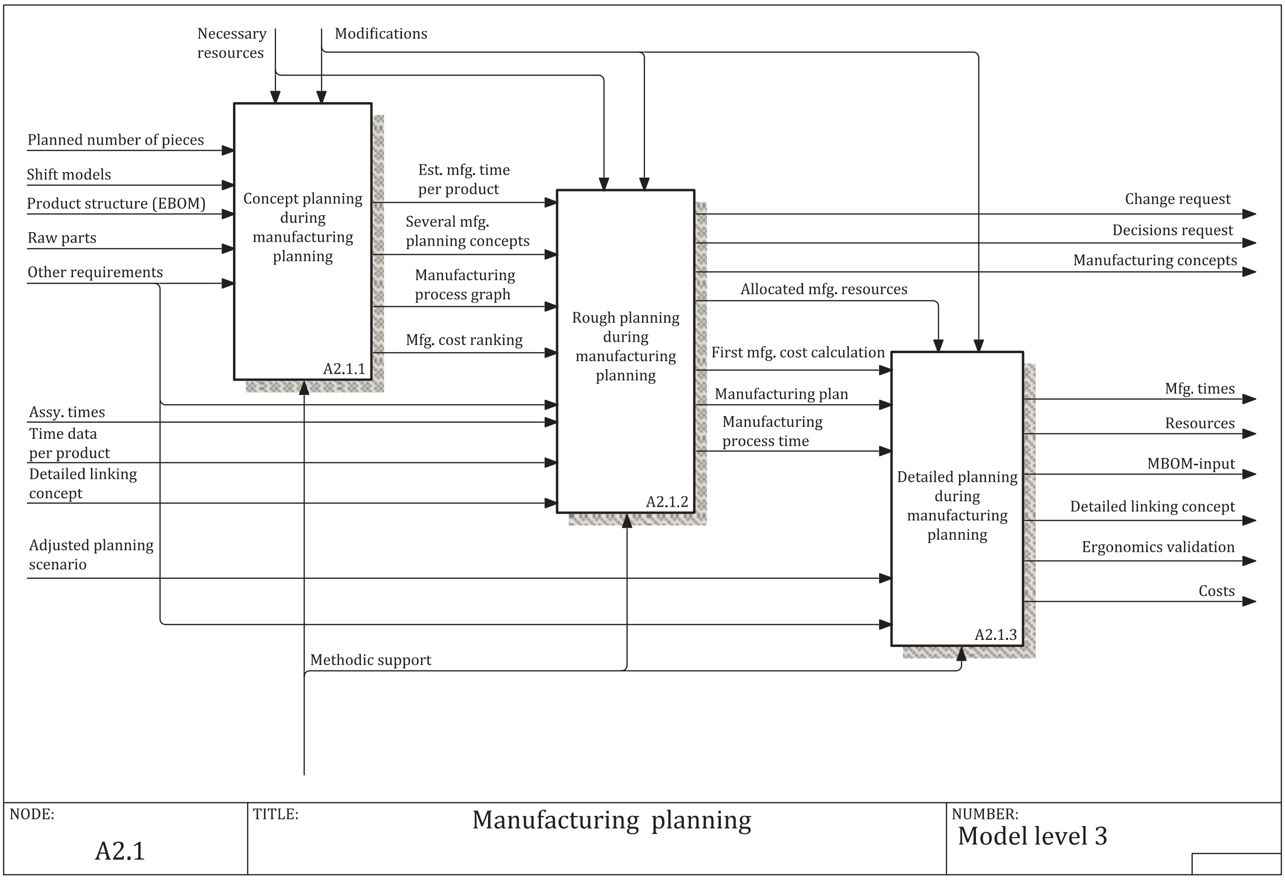

Figure 6 — Structure of the manufacturing planning at model level 3

On this level (shown in Figure 6) the dependency between the assembly and the manufacturing planning is shown. The output from the assembly planning is linked with the rough planning during manufacturing planning. This connection provides the possibility for interaction between the two planning disciplines. During the production planning, each planning discipline can progress at different times and scales.

The production data inputs for the manufacturing planning, provided by the constraints from higher level, are used in the concept planning phase (A2.1.1). With the assistance of the higher level constraints the first concept data for the manufacturing planning is created. These are essentially inputs to generate the manufacturing concepts (A2.1.2). The linking inputs for the rough manufacturing planning are the necessary information needed to coordinate the different planning disciplines. With the assistance of the interdisciplinary consolidation (see 4.3) the requested information is provided for the detailed manufacturing planning (A2.1.3). This is the last phase of the manufacturing planning and the process where the essential manufacturing information such as the manufacturing times, resources and costs is detailed

4.2.1.1 Summary of the process A2.1.1 (level 4)

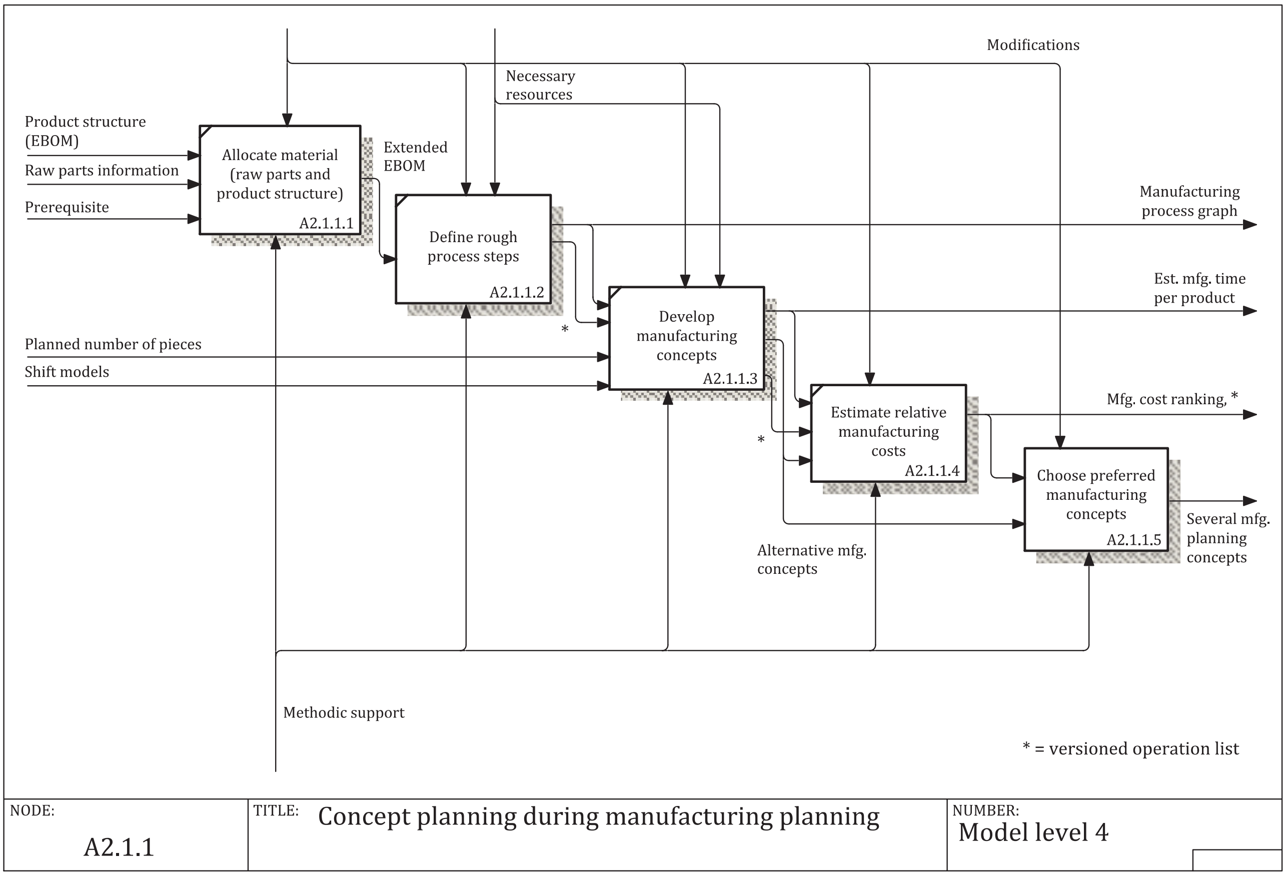

Figure 7 — Structure of the concept planning during manufacturing planning at model level 4

The main task of concept planning during manufacturing planning (as shown in Figure 7) is to collect the necessary information provided by preliminary planning activities and prepare it in a useful and consolidated form to create first manufacturing planning concepts. Different parameters, e.g. framework conditions, strategic decisions or continuous improvement of production environment, affect manufacturing planning at this early stage during the product life cycle (PLC).

The manufacturing planning develops conceptual designs and defines information about the product structure, raw parts, planned number of pieces, shift models and resources (A2.1.1.1). After the preparatory work has been completed, the manufacturing planning can be performed against different scenarios. To do this, the material is allocated in a first step and an extended EBOM including information about purchased parts is created. The material volumes and allocations are associated to the manufacturing process activity regarding the necessary resources which are provided by the constraints from higher level. An evaluation of the content and time required for the various working operations is based on comparisons, the shift model and expert knowledge. This makes it possible to estimate requirements in terms of employees, machines and work stations as a function of the planned number of pieces (A2.1.1.2). Several manufacturing planning concepts will be developed and compared without any great investment in terms of time and cost on the basis of this planning stage, which contains only a very low level of detail (A2.1.1.3). Estimated relative manufacturing costs are created by making use of the estimated manufacturing time per product and an extended manufacturing operation list. This list contains additional information based on comparisons and estimations with other projects (A2.1.1.4). The developed manufacturing concepts may differ for example in terms of used sequences and/or innovative technologies. A manufacturing cost ranking which ranks the different concepts using their relative costs builds the basis for choosing the preferred manufacturing plan (A2.1.1.5).

Several manufacturing concepts, the manufacturing process graph, a manufacturing cost ranking and the estimated manufacturing time for each product represent the final result of concept planning. It is created by this phase and handed over to the rough planning phase of manufacturing planning.

4.2.1.2 Summary of the process A2.1.2 (level 4)

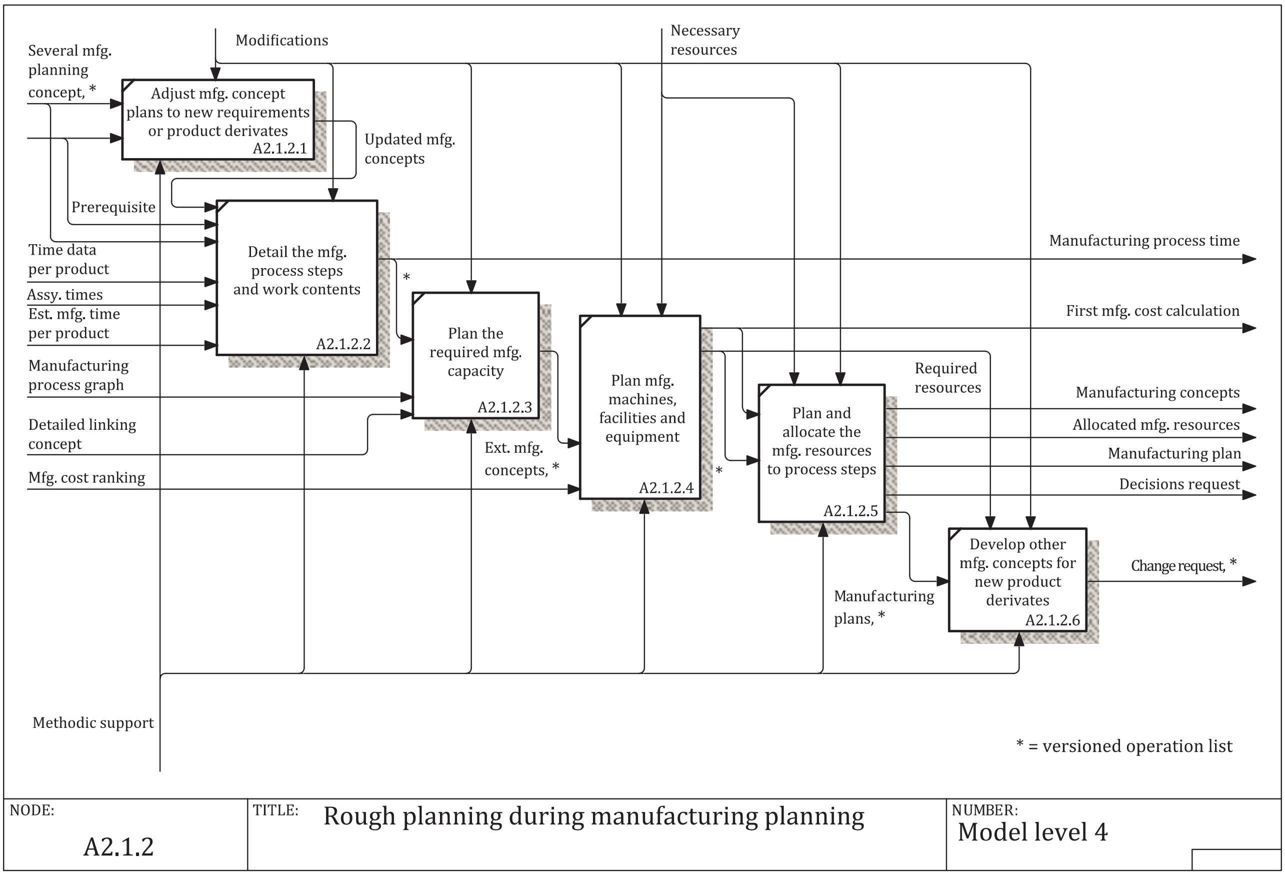

Figure 8 — Structure of the rough planning during manufacturing planning at model level 4

The rough planning as shown in Figure 8 takes several manufacturing planning concepts and works out the details to create manufacturing concepts ready to be finalized during detailed planning. At this stage of manufacturing planning, similar to the concept planning, different planning requirements occur. These planning requirements, e.g. procurement and parts manufacturing strategies, provisioning scenarios, together with quality requirements and quality assurance obligations, have an impact on the planning activities.

Within the first process activities, several planning concepts are adjusted to new requirements (A2.1.2.1). Although it is possible, that this adjustment will not be necessary. Depending on the planning tasks, e.g. a new and additional product derivate, the manufacturing planning concepts need to be adjusted. During the rough planning the manufacturing process steps with the corresponding work contents are detailed. As key planning information the manufacturing time and cost are specified. Based on the given estimations from the rough planning the manufacturing process time is determined, verified and subsequently used in work schedules (A2.1.2.2). At this point the manufacturing process time has reached a level of detail that a calculation of technology related capacity requirements is possible (A2.1.2.3). The basis for this is the manufacturing process time, the manufacturing process graph and the detailed linking concept. The approximate number and size of the machines, facilities and equipment, in combination with the manufacturing concepts extended by the capacity requirements, makes it possible to further enhance the level of detail and to calculate the first manufacturing costs (A2.1.2.4). By gathering and further processing of the production planning data in terms of a first manufacturing costs calculation, manufacturing resource requirements, manufacturing times and manufacturing plans the final result of the rough planning, the manufacturing concepts, are generated (A2.1.2.5). In some cases for instance changes of product or production requirements further development of manufacturing concepts can be necessary (A2.1.2.6). The impact of those changes affects different planning disciplines as well as process activities along the PLC, e.g. concept and manufacturing. A change request triggered by the rough planning will lead to a decision from the higher levels following a change order (modification).

NOTE For more detailed information about the interdisciplinary consolidation of planning information, see Annex A.

4.2.1.3 Summary of the process A2.1.3 (level 4)

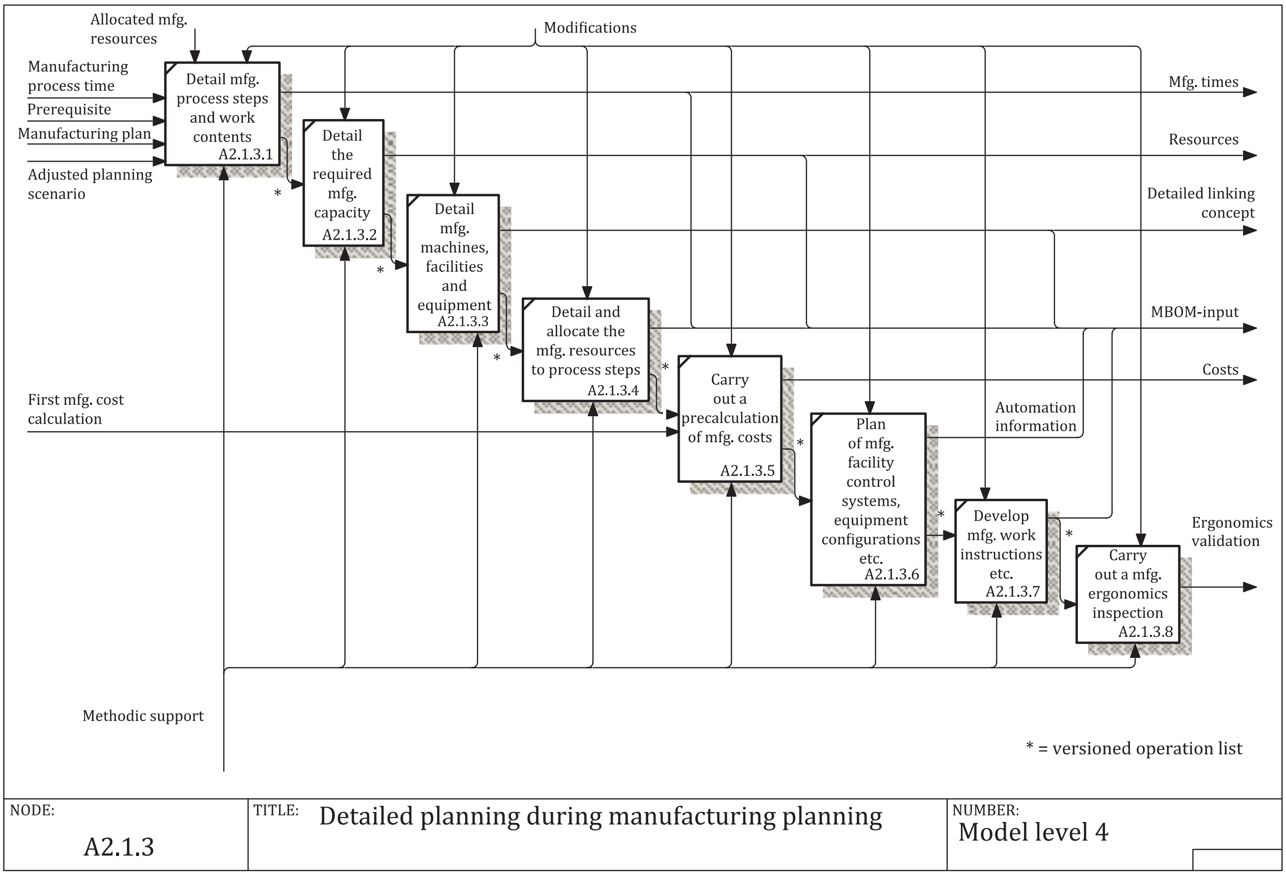

Figure 9 — Structure of the detailed planning during manufacturing planning at model level 4

During detailed planning the overall processes are defined in greater detail and broken down into process activities as shown in Figure 9. The most important aspect of this operation is determining the verifiable nominal process times in the manufacturing workflows. At process activity level, this is possible by means of IT assisted process simulations that result in a more precise identification of the time values and that can provide the underlying data for the final manufacturing plan.

Due to the description of the individual processes, this planning phase also makes it possible to detail individual operating resources and equipment and generates the specified manufacturing times (A2.1.3.1 to A2.1.3.3). This planning comprises the clear allocation of machines, facilities and equipment to the defined processes. A manufacturing planning manufacturing bill of materials (MBOM) input is developed, consisting of the automation information, the detailed linking concept, the manufacturing times and resources. Within this MBOM input, the generated output of the detailed manufacturing planning is combined and handed over to the associated planning functions (A2.1.3.4). If all MBOM inputs from the core planning disciplines are consolidated, the work schedule can be generated. On the basis of the generated data and the first manufacturing cost calculation, it is possible to develop detailed preliminary calculations of the forecast production costs (A2.1.3.5). In particular, these calculations take account of the individual availability of the planned manufacturing resources, maintenance intervals and repair times, as well as the setup and idle times of machinery and equipment. The utilization and adaptability of manufacturing resources to fluctuations in capacity may occur in different unit volume scenarios or scenarios involving changes to the product mix. These also need to be taken into account during detailed manufacturing planning. Manufacturing plans, operating and testing instructions or other documents that are relevant for manufacturing, need to be considered. It is further elaborated to the level of system controllers, the creation of automation information such as computerized numerical control (CNC) programmes and tool settings (A2.1.3.6). Finally the detailed planning defines the manufacturing work instructions which are main input for the release of the work schedules (A2.1.3.7). The digital verification of ergonomic design criteria is also possible in the field of manufacturing planning, for instance to ensure that the conduct of maintenance or repair work is possible or to make sure that manufacturing systems pose no risk to human operators (A2.1.3.8).

Specified manufacturing times, costs, resources, a detailed linking concept and an ergonomic validation are the final results of the detailed planning during manufacturing planning. Necessary information will be provided for the associated planning function to generate an MBOM and to release the first work schedule.

4.2.2 Summary of the process A2.2 (level 3)

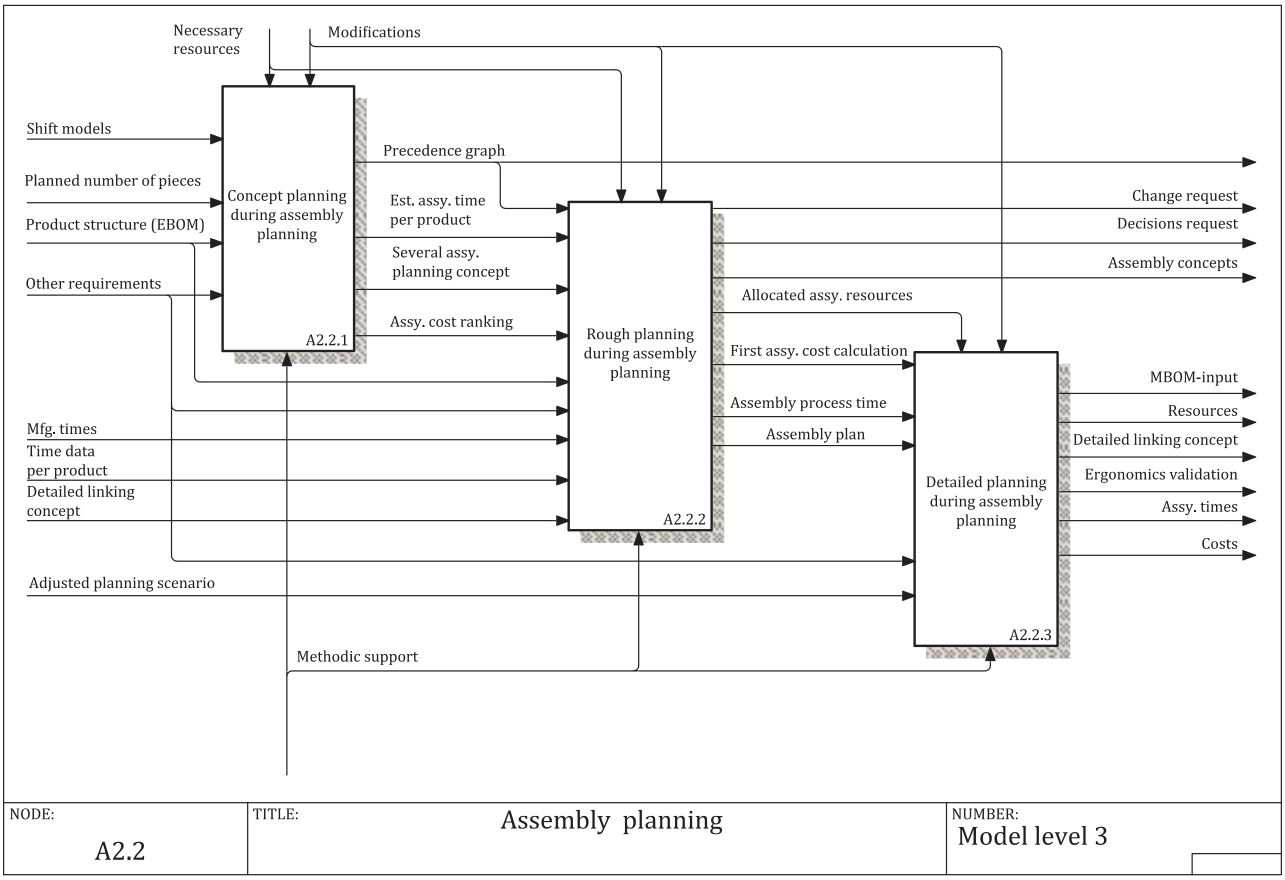

Figure 10 — Structure of the assembly planning at model level 3

Ideal assembly planning requires various types of information. Displaying this high volume of information can lead to confusion. In order to keep the focus on the process activity, only the main interfaces between assembly planning and design as well as production are considered, as shown in Figure 10.

Similar to the manufacturing, the concept planning considers the information provided by preliminary planning activities to estimate assembly times and costs, as well as to generate several assembly concepts (A2.2.1). The resulting information from manufacturing planning is used as input for the rough planning phase of assembly planning (A2.2.2). The asymmetric nature of the planning processes provides the possibility of interaction between them. Both the manufacturing planning and the assembly planning need the outcome deriving from the higher levels. With the assistance of the associated planning functions (see 4.3) the requested information is provided for the detailed assembly planning (A2.2.3). This is the last phase of the assembly planning and the process in which the essential assembly information is detailed. Information which is needed to fulfil the constraints from higher level (e.g. the costs and the ergonomic validation) is combined with the information from the manufacturing planning.

Continuously used data such as the assembly times and the detailed linking concept are provided by assembly planning for the remaining core disciplines. Consolidated information (e.g. the MBOM input) which will be used within the associated planning functions is also generated.

4.2.2.1 Summary of the process A2.2.1 (level 4)

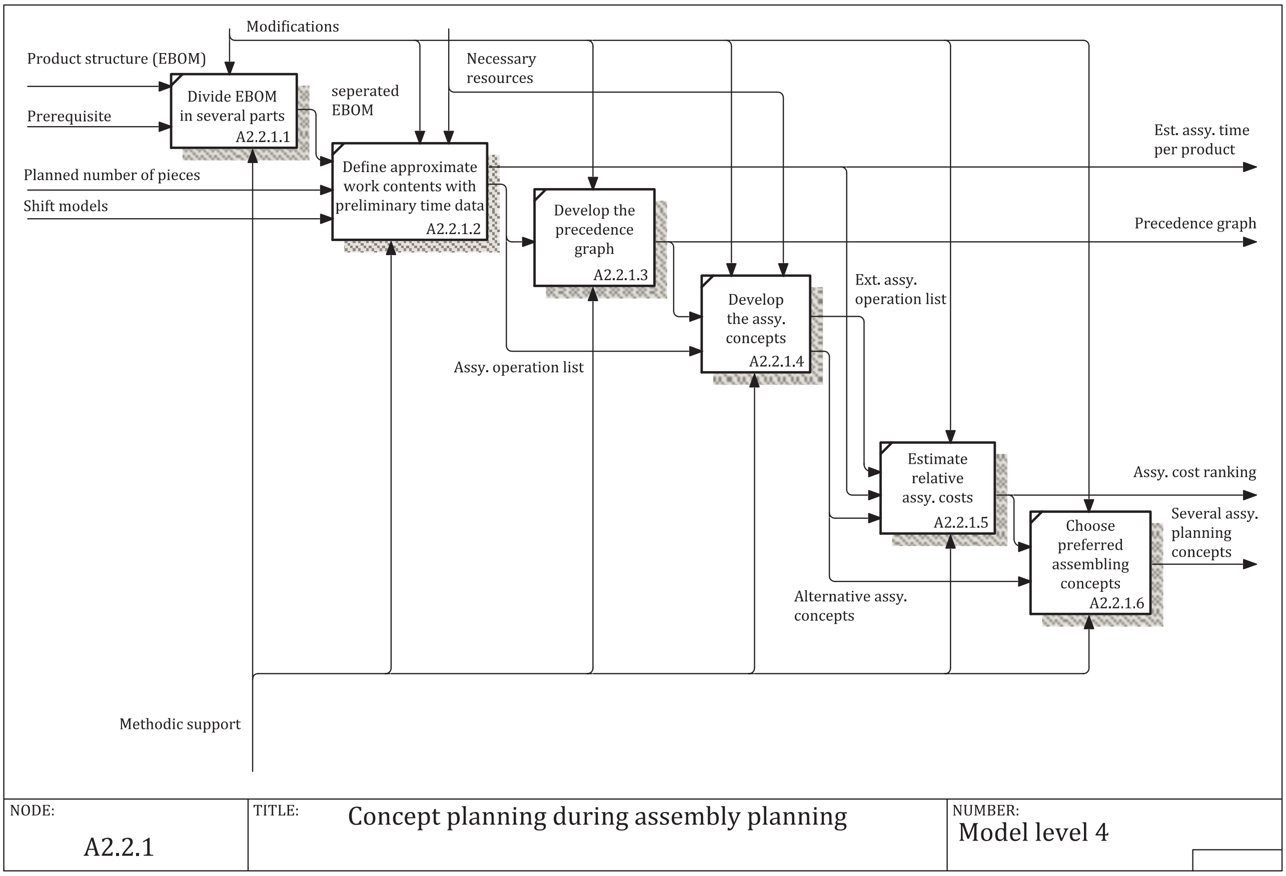

Figure 11 — Structure of the concept planning during assembly planning at model level 4

Analog to the manufacturing discipline the concept planning during assembly planning (as shown in Figure 11) needs connections between the planning functions to collect the necessary information provided by preliminary planning activities and prepare it in a useful and consolidated form to create first assembly planning concepts.

On the one hand, the input variables for assembly planning consist of information from the design department. An example is the data consolidated within an EBOM (A2.2.1.1). On the other hand, the framework data for the master production schedule need to be taken into account during the concept planning phase (A2.2.1.2). Examples are the planned number of pieces, the shift model and the resources and technologies available in the company. During concept planning, the work content for production is also subdivided into discrete, self-contained process activity. This subdivision permits the subsequent use of methods such as the precedence graph method and similar approaches. The EBOM (or the relevant BOM) is subdivided into meaningful units in the first step. In the second step rough process steps are defined. Initially they often take the form of a list (assembly operation list).

By combining the planned number of pieces with the shift models the estimated assembly time per product may be calculated. After this step is completed, the first, rough precedence graph is developed. The assembly operation list and estimated assembly time per product are used for this step (A2.2.1.3). The first rough line concepts, which already contain a rough value for the number of work stations and employees are required. Their development represents the fourth process activity of assembly planning in the concept planning phase (A2.2.1.4). The next step is to generate a cost estimate (A2.2.1.5). For this, it is necessary to take account of the various previously developed concepts, the estimated assembly time per product and the extended assembly operation list. This contains additional information based on comparisons and estimations with other projects. The fact that the cost estimation is a fixed part of the concept planning phase enhances the understanding of cost related aspects for the planner and permits the ongoing monitoring of assembly costs. The costing operation makes the frequently opaque cost structure of the products clear to the planner, and the first relative cost estimate can be performed on the basis of past values. The final step of the concept planning consists of deciding between the several assembly planning concepts (A2.2.1.6). The previously produced cost ranking provides a good basis when making this decision.

Several assembly concepts, the precedence graph, assembly cost ranking and the estimated assembly time for each product represent the final result of concept planning. It is created by this phase and handed over to the rough planning phase of assembly planning.

4.2.2.2 Summary of the process A2.2.2 (level 4)

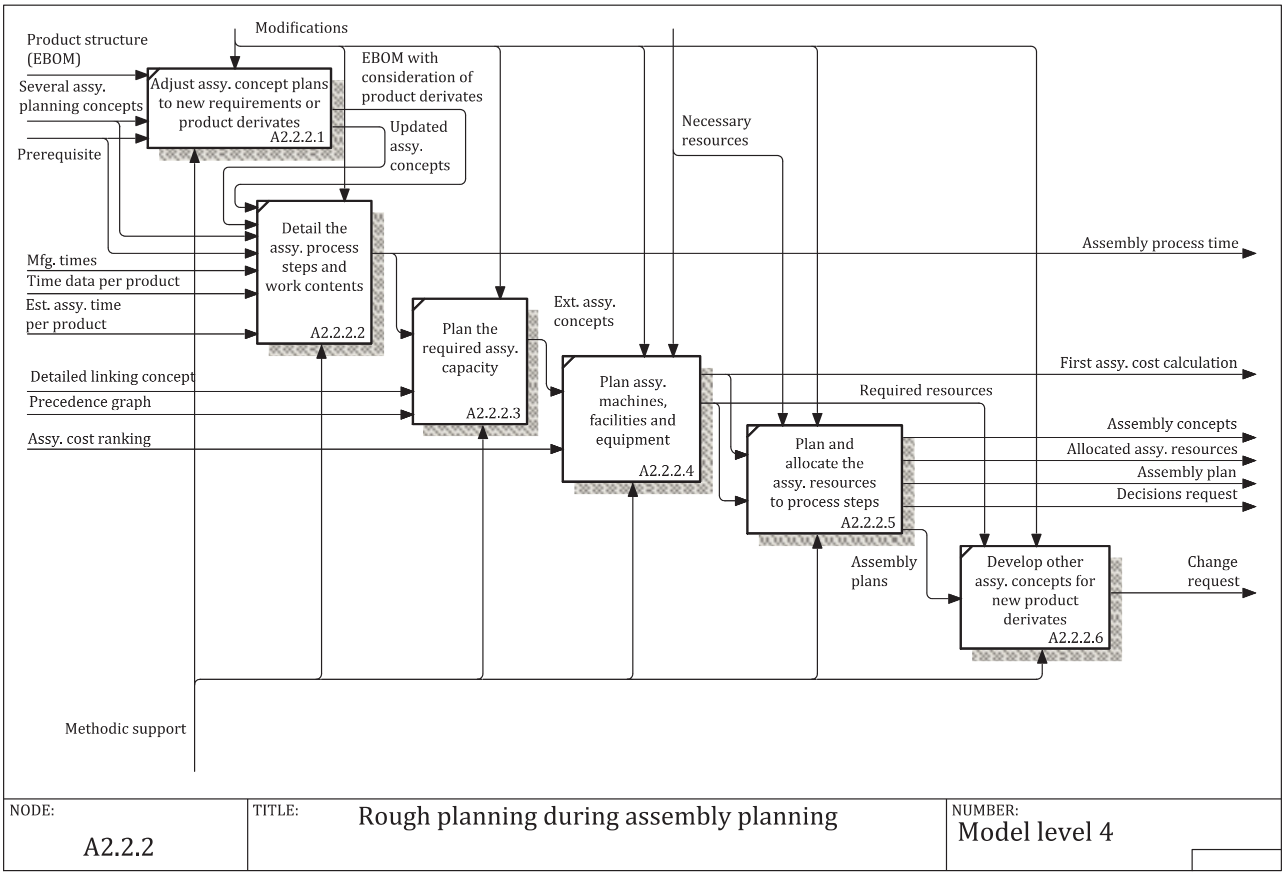

Figure 12 — Structure of the rough planning during assembly planning at model level 4

During the conduct of rough planning, the results from different planning phases are revised and adapted as shown in Figure 12.

The structured preliminary EBOM needs to be considered, as well as the approximate definitions of the process steps and the approximate line model. If necessary, the concept plans will be adjusted (A2.2.2.1). Several assembly concepts from the concept planning phase and the EBOM are updated. They are used to detail the assembly processes. The rough time data per product provided by the constraints from higher level and the estimated assembly time per product will be used to develop assembly process times (A2.2.2.2). Analog to the rough manufacturing planning, the manufacturing times can be considered for the detailing of the assembly process time. The level of detail of the assembly process time now allows a calculation of technology related capacity requirements. When planning capacity requirements are discussed, it is important to remember that during the rough planning phase only a technology related planning of resources is possible (A2.2.2.3 and A2.2.2.4). The detailed definition of the actual allocation of assembly capacities is also undertaken in the rough planning (A2.2.2.5). Basis for this is the specific order handling process and its interactions with the various planning scenarios in the product mix. The assembly concepts regarding the required resources and assembly plans can be used now. Similar to the rough planning during manufacturing planning, it is possible to adapt the assembly concepts to other product derivatives (A2.2.2.6). The impact of those changes affects different planning disciplines as well as process activities along the PLC. A change request triggered by the rough planning will lead to a decision from the higher levels following a change order (modification).

NOTE For more detailed information about the interdisciplinary consolidation of planning information, see Annex A.

4.2.2.3 Summary of the process A2.2.3 (level 4)

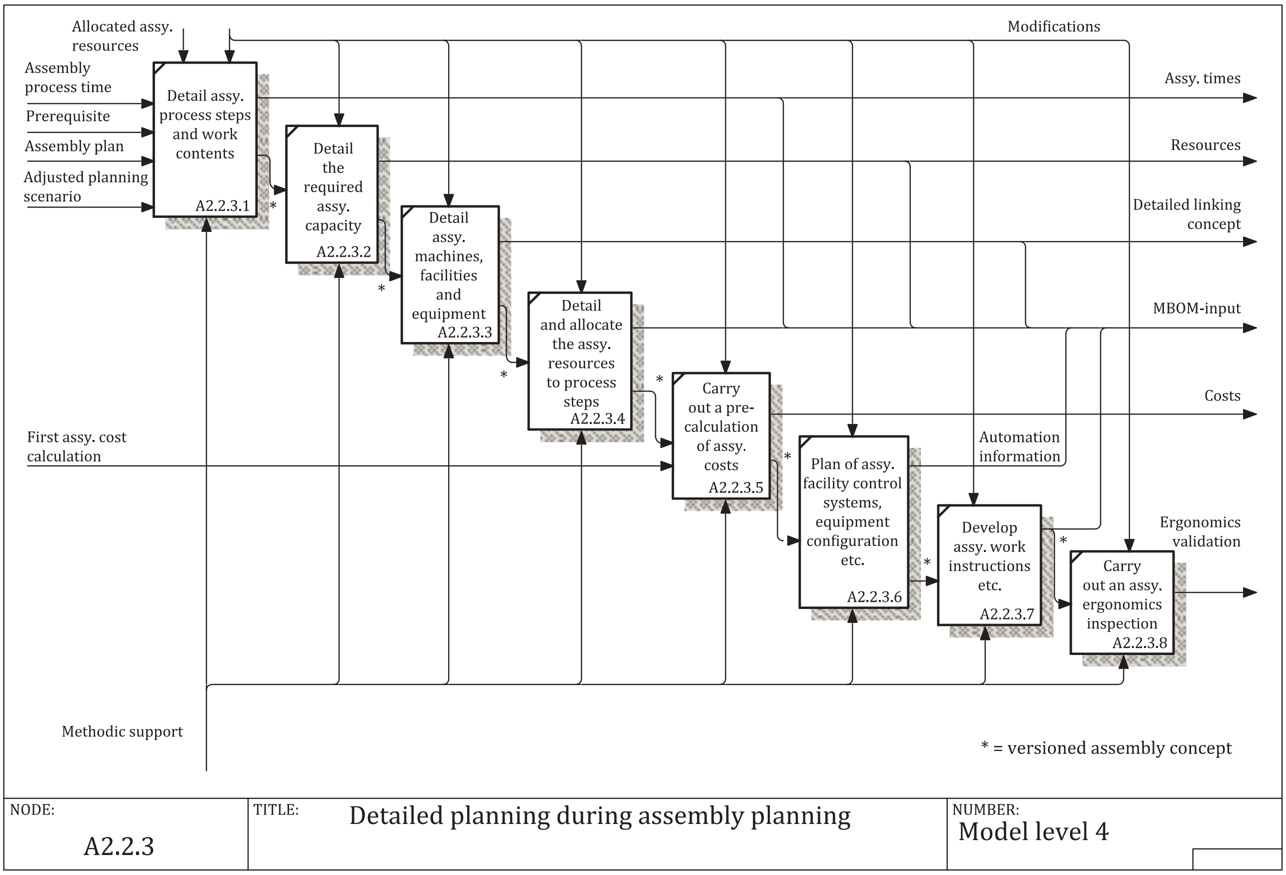

Figure 13 — Structure of the detailed planning during assembly planning at model level 4

During detailed planning the overall processes are defined in greater detail and broken down into process activities based on the assembly plan for a selected adjusted planning scenario (as shown in Figure 13).

The detailing is achieved by improving and adapting the assembly plan, for example for ergonomic assessment and production requirements (A2.2.3.1). The description of the assembly planning makes it possible to plan individual operating resources and equipment in detail (A2.2.3.2 and A2.2.3.3). The planning now includes the clear allocation of machines, facilities and equipment (A2.2.3.4). Due to the increase of the detailed information about the resources and their utilization as well as different assembly concepts, the production planner is now capable of performing a preliminary calculation of the assembly costs, for example depending on cost and benefit effects (A2.2.3.5). During the detailed planning phase it is appropriate to transpose the static cost estimate analysis used in the concept and rough planning phase to a dynamic cost calculation. The outcome is the most detailed cost statement available in the overall process. Other process activities involved in the detailed planning include system control planning and tool settings (A2.2.3.6). Based on the process steps work instructions can now be developed (A2.2.3.7). The level of detail is an important criterion during the creation of work instructions. In many cases, detailed planning should attempt to specify individual parts assessing operations at the level of individual part processing. Alongside the possibility of drafting operating instructions, it is also possible to determine detailed assembly times and costs. Further calculations, such as those required for remuneration purposes, are performed at the level at which individual parts are processed. For the purposes of their depiction in the assembly plan, these individual operations are frequently combined into work activities. The detailed information from the assembly planning (resources, detailed linking concept, automation information, assembly times) is combined into the assembly MBOM input. In the last step of the detailed planning the ergonomic aspects of the planned assembly solution are considered, e.g. for compliance with safety related design rules (A2.2.3.8). If potential improvements or a need for action are identified, the planning process passes through another iteration.

Specified assembly times, costs, resources, a detailed linking concept and an ergonomic validation are the final results of the detailed planning during assembly planning. Necessary information will be provided for the associated planning function to generate an MBOM and to release the first work schedule.

4.2.3 Summary of the process A2.3 (level 3)

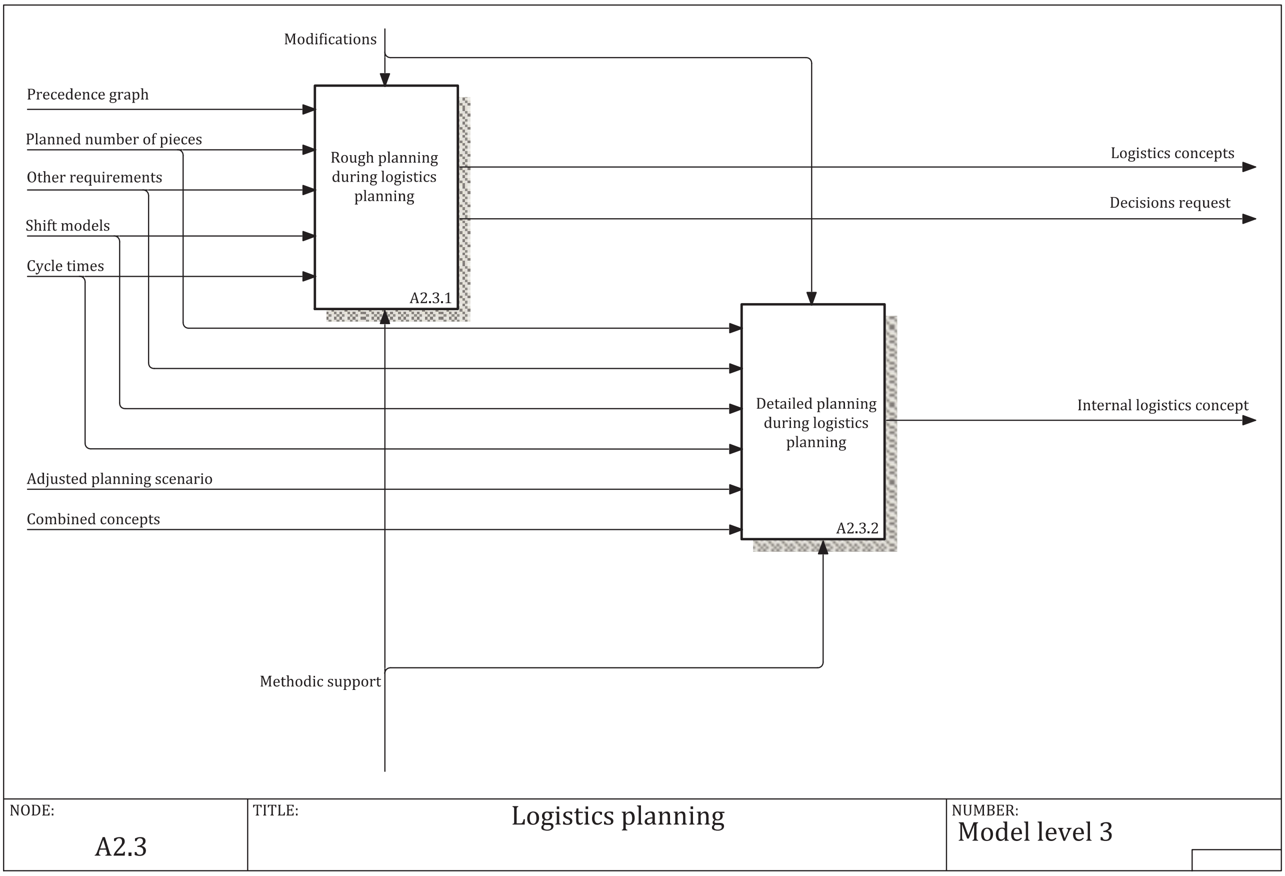

Figure 14 — Structure of the logistics planning at model level 3

The complexity of logistics planning demands an extensive range of initial data and information. Since changes in the initial data are the result of assembly, layout and manufacturing planning, they all have an effect on logistics planning. The quality of logistics planning in general can be assessed subsequently on the basis of lead times, reliability of deliveries and logistics costs. In contrast to the other planning disciplines the logistics planning is structured by two degrees of maturity. These two phases are represented by the rough and detailed planning as shown in Figure 14.

The logistics planning supports the manufacturing and assembly planning by means of organization and control of the transport, storage, distribution and warehousing of materials and finished goods (A2.3.1). The logistics planning needs information and coordination with the other planning functions. Information such as the precedence graph and basic production information such as the shift models are provided for the planning functions and result in a logistics concept. Finally the detailed planning generates the internal logistics concept (A2.3.2). The internal logistics concept represents the organizational concept of production logistics activities which are necessary to produce the planned production volume. It connects the procurement activities such as market research, requirements planning, make-or-buy decisions, supplier management, ordering, and order controlling (procurement logistics) with the distribution activities such as order processing, warehousing, and transportation (distribution logistics). The internal logistics concept needs to consider the given planning scenarios and concepts from the other disciplines.

4.2.3.1 Summary of the process A2.3.1 (level 4)

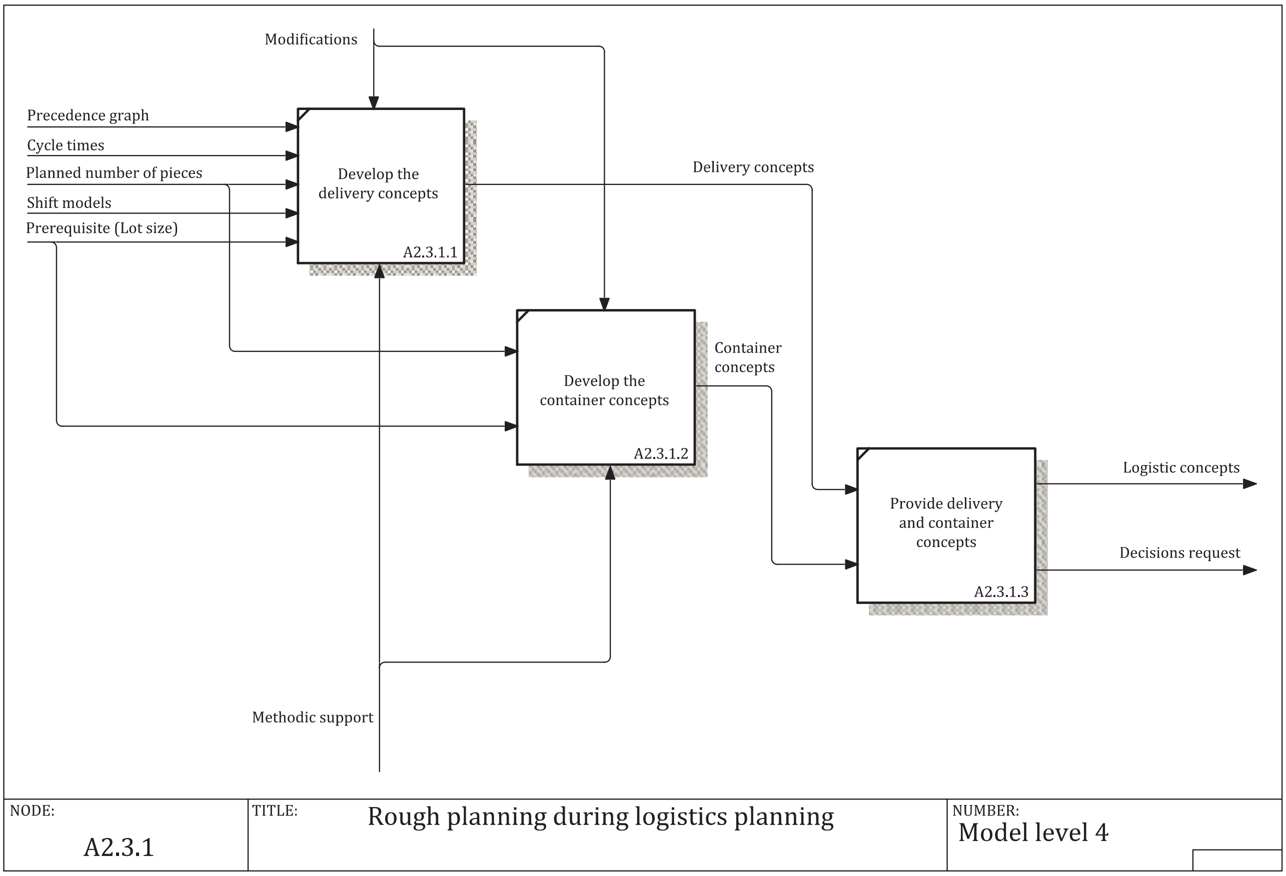

Figure 15 — Structure of the rough planning during logistics planning at model level 4

Rough planning during logistics planning as shown in Figure 15 follows up the concept planning phase of the other core disciplines and uses the given planning information to develop a concept for production logistics.

Logistics planning requires the precedence graph, the shift model, the planned number of pieces, the lot size and the calculated cycle times. Due to interdependencies the delivery and storage solutions cannot be defined independently. The delivery solutions designate the strategy adopted to supply individual parts, modules or finished products to the assembly and manufacturing resources (A2.3.1.1). This provisioning can be performed, for instance, by means of supermarkets, dual containers, just-in-sequence delivery and other concepts. The majority of inputs for the rough planning are used for the developing of the delivery concepts. The storage solutions in contrast refer to the explicit choice of transport containers, such as blister packs, lattice boxes or small parts containers (A2.3.1.2). Since the considerations of shape, but also and more importantly those of volume and ease of handling, involved in the selection of the container have a direct impact on the available room to manoeuvre. The focus of developing a container concept is on storage and warehousing the materials. On the contrary the focus of the delivery solution is on transportation. To provide suitable logistics, both the delivery and container solutions are necessary. The operations of these two process activities do not need to be performed sequentially. As a final result of the rough planning, the combination of the delivery and container concept in a logistics concept is provided.

4.2.3.2 Summary of the process A2.3.2 (level 4)

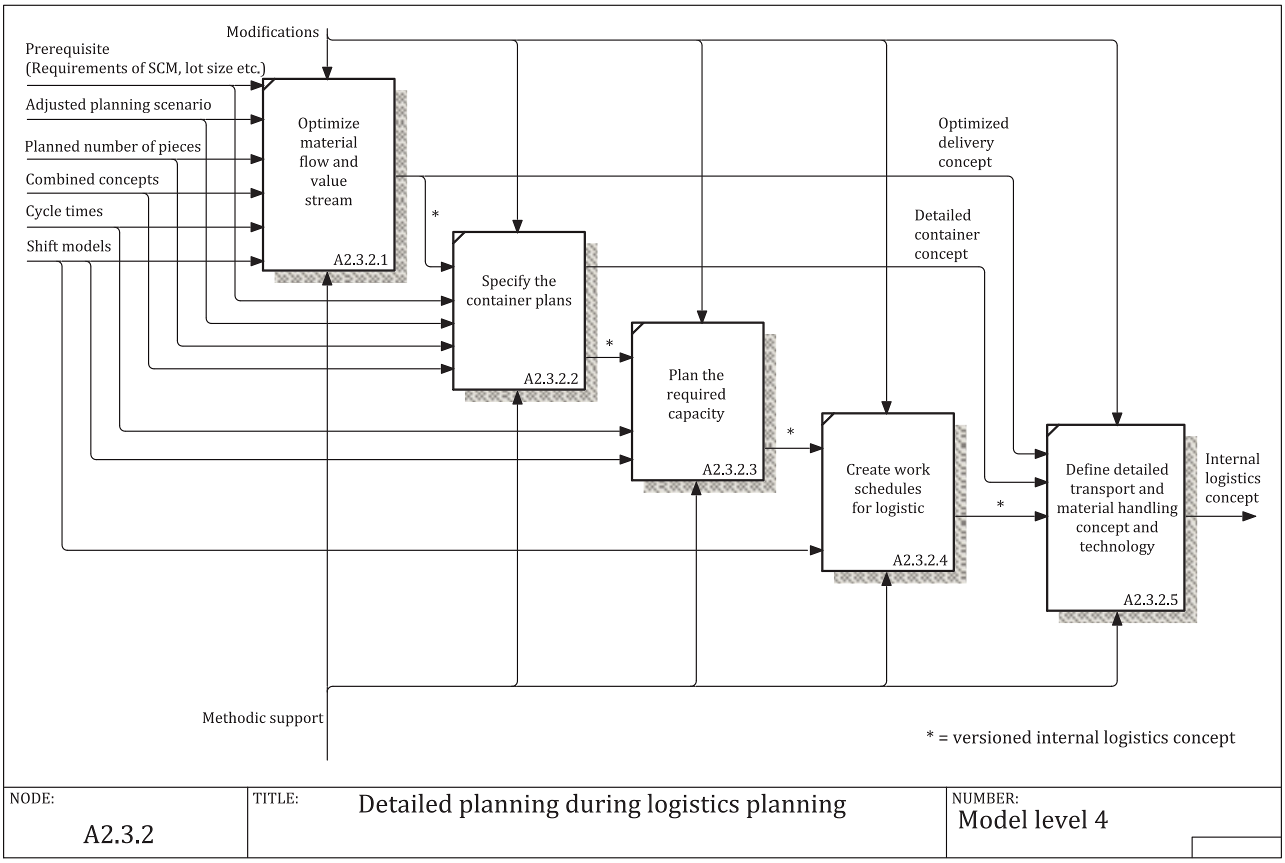

Figure 16 — Structure of the detailed planning during logistics planning at model level 4

The task of the detailed planning phase as shown in Figure 16 is to develop a detailed logistic concept. Among other things, this includes information about the transport of containers to and from the place of manufacturing, cycle times, shift models, parts that are transported in the containers and the total number of parts that are actually moved. These are basic inputs for the definition of an optimized delivery concept and a detailed container concept.

During detailed logistics planning, the emphasis is placed on understanding the interrelations that exist in complex production networks. There is now an increasing amount of methodological support for this type of systems expertise, which takes the form of knowledge about the interactions and interdependencies between different subsystems. The most common type of support consists of conventional planning methods such as value stream mapping, which permits a clearly arranged and communicable view of value streams. This visualization is combined with statistics from the assembly or manufacturing systems. On its basis key processes can be easily identified (A2.3.2.1). Examples of this type of key process are so called pacemaker processes in a value stream, as well as bottlenecks or accumulations of stock. The detailed logistics planning phase can also call on digital tools and methods that permit an even more detailed view of the relevant interrelations. A representative example is simulation. It is often used profitably, for instance, in the form of a discrete event material flow simulation for concept validation during the detailed planning phase before any actual investments are made. On the one hand the effort involved in conducting appropriate simulations is usually significantly higher than by using conventional planning methods. On the other hand, the level of information acquired and the possibility of reusing planning results and models are also improved. During the definition of the internal logistics concept, it is necessary to consider the effects of the different variants on the chaining of the work stations. These range from different work piece receivers, for instance the design of special trays, to a consideration of the variants in the light of the different chaining concepts (A2.3.2.2). The level of detail of the versioned internal logistics concept now allows a calculation of the required operating resources (A2.3.2.3), as well as the work schedules for logistics (A2.3.2.4). At this point in the detailed planning phase all required parameters to generate the internal logistics concept have been fixed. Based on the selected planning scenario, the delivery and container concept, as well as the requirements from procurement or distribution logistics (e.g. supplier management, transportation), the organizational concept of production logistics is released (A2.3.2.5). This represents the final result of detailed planning during logistics planning.

4.2.4 Summary of the process A2.4 (level 3)

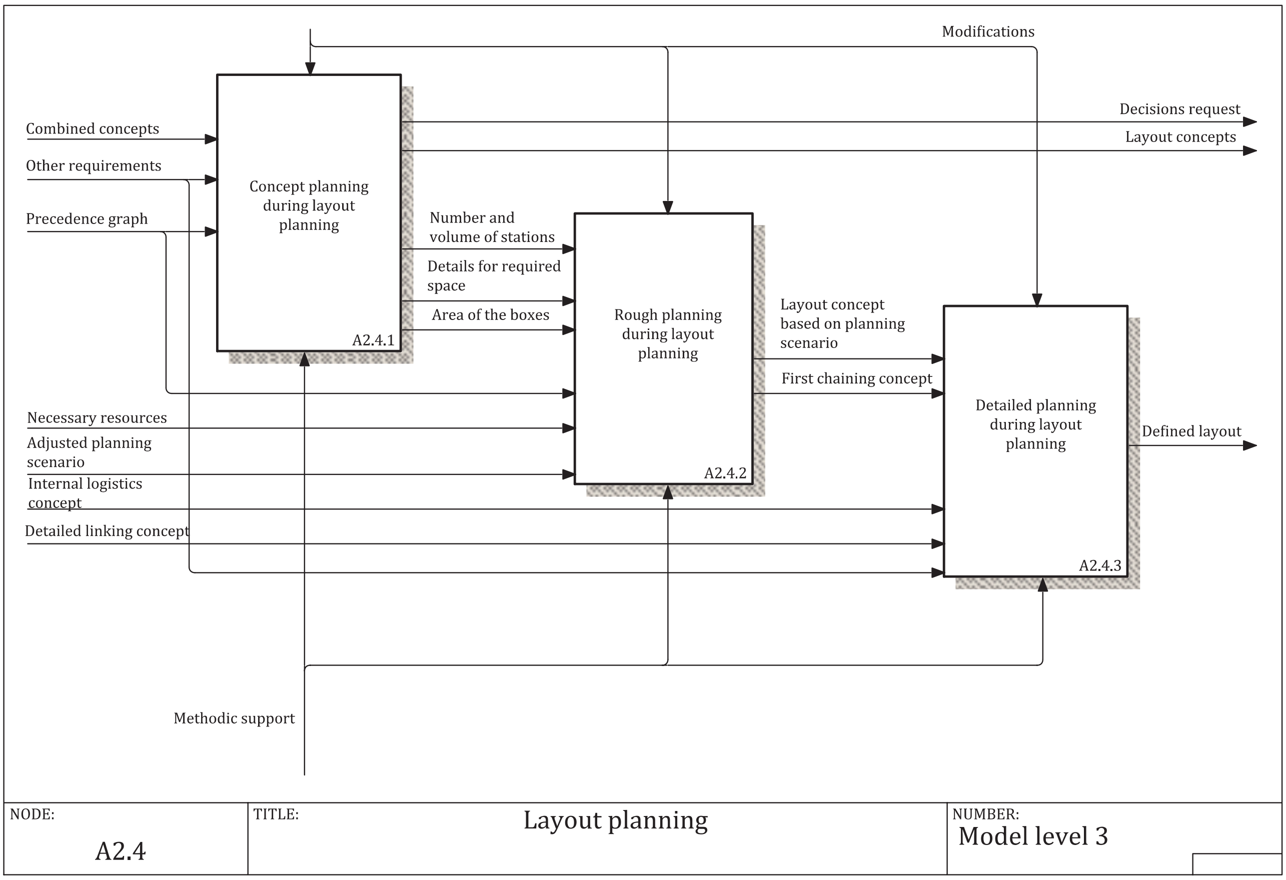

Figure 17 — Structure of the layout planning at model level 3

To ensure that the operating resources are located optimally in the production area, the layout planning needs to be closely connected with the remaining planning disciplines (as shown in Figure 17). For a reasonable layout planning, the knowledge and experience derived from the other planning disciplines need to be provided for the respective phases of the layout planning. The layout planning uses the planning concepts from the remaining disciplines to initially create and detail the layout concept during the planning phases.

To estimate the required production space, the number and volume of work stations and resources need to be considered (A2.4.1). The layout also needs to consider the area dimensions, transport routes, areas for the provision of materials and auxiliary areas (for instance areas for sanitary installations). In order to minimize transport costs, work intensive transport activities are often planned as short transport routes. As a result, the overall layout represents a combination of the building, installation and system layouts that also takes account of the sequential links between the assembly and manufacturing areas (A2.4.2). As a final result from layout planning the layout is defined. It also includes the precise, fixed spatial arrangement of the machines and facilities. It determines the supply and disposal of power and auxiliary materials, as well as routes and area utilization. All existing structural restrictions in the factory are considered in the defined layout.

4.2.4.1 Summary of the process A2.4.1 (level 4)

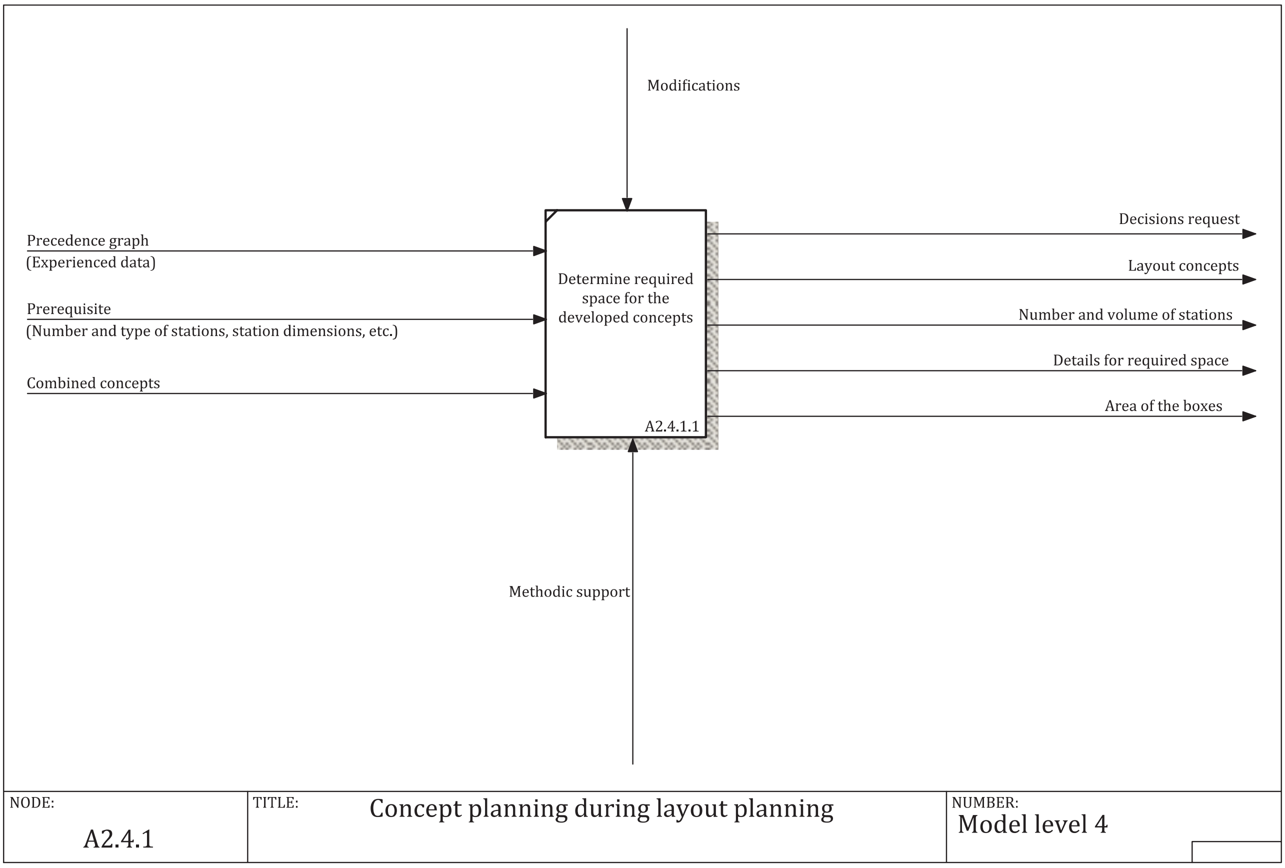

Figure 18 — Structure of the concept planning during layout planning at model level 4

The high degree of interdependence between manufacturing, assembly and layout planning also affects the concept planning during layout planning (as shown in Figure 18).

Thus the output variables from assembly planning, such as the precedence graph, the type and number of work stations identified on the basis of the planning concepts are simultaneously input variables for the concept planning. The approximate number, type and dimensions of work stations as a function of the product in question are also input variables. In addition to assembly planning during the concept planning phase, the layout planning is conducted in the same phase in order to ascertain the nature and space requirements of the initial concepts (A2.4.1.1). It is particularly important to take an early estimation into account to consider the layout planning in combination with the remaining planning concepts. These arise from the core disciplines for the purpose of adjusting the planning scenario. The layout concepts enable further consideration within the reference process such as cost estimation.

This is necessary since there is clearly a correlation between costs and space requirements. After the determination of the required space for the developed concepts, several layout concepts are available. The number and volume of stations, as well as a determined area of boxes, are the final result of the concept planning.

4.2.4.2 Summary of the process A2.4.2 (level 4)

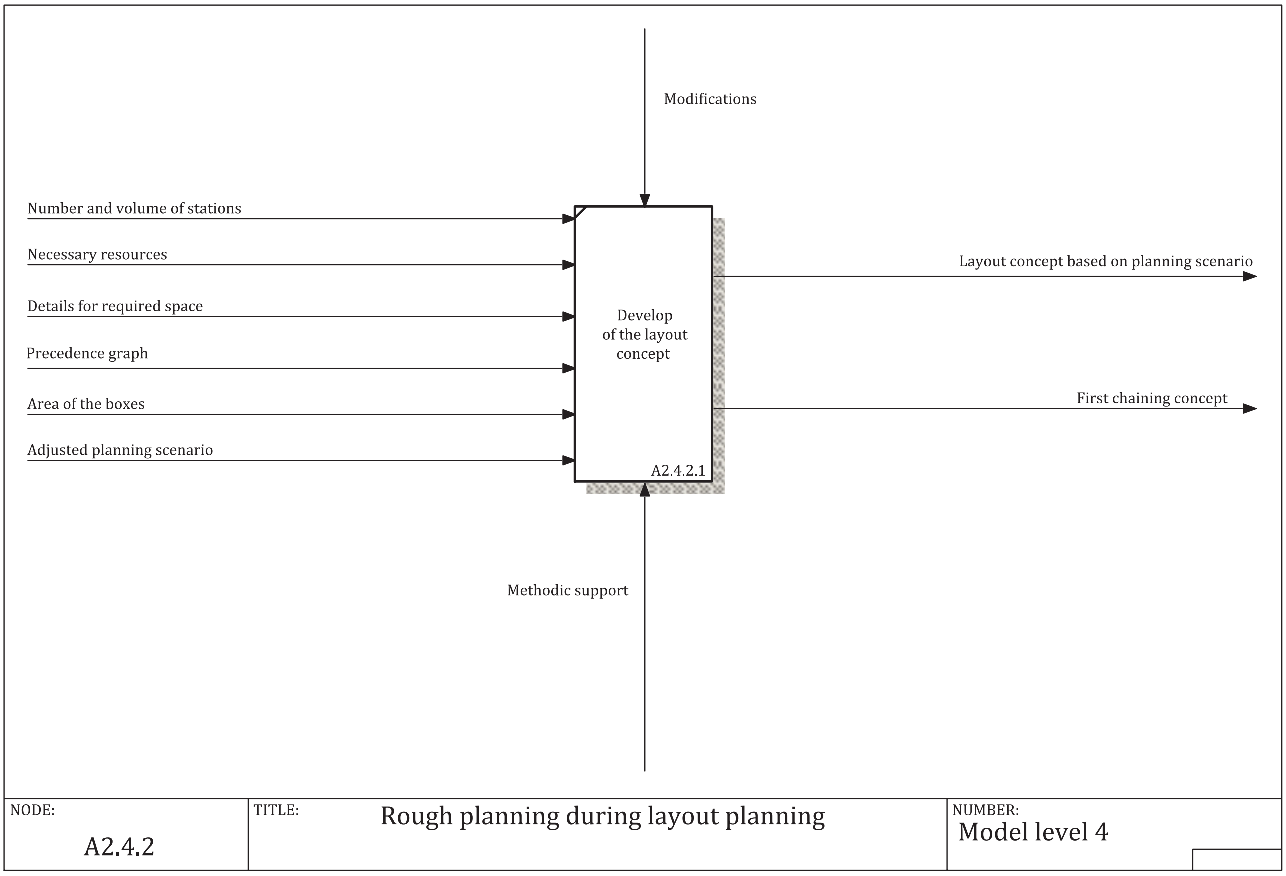

Figure 19 — Structure of the rough planning during layout planning at model level 4

During the rough planning, a layout concept is produced on the basis of the developed precedence graph, necessary resources, area for the boxes, details for required space and layout concepts from the concept planning phase of layout planning (as shown in Figure 19).

The generated layout represents a further development of the approximate space requirement calculated in layout concepts during the concept planning phase. It is based on the adjusted planning scenario provided by the interdisciplinary consolidation. At least the approximated scale of the assembly and manufacturing resources is known now. Hence it is possible to perform three dimensional layout planning during the rough planning phase (A2.4.2.1). During this operation, it becomes increasingly common to make use of the capabilities available for the visualization of digital planning data in combination with planning support in form of physical prototypes (e.g. cardboard models). Along with the spatial representation, it is also necessary to develop the first chaining concepts. These concepts constitute a real world mapping of the process chains defined in the manufacturing and assembly planning disciplines. The components are also assigned to the individual process steps on the basis of these process chains. At the technological level, it is necessary to decide how components are to be transported between the different processing stations and how the stations are to be sequenced in the manufacturing and assembly flow. The detailed configuration of this chaining sequence does not occur until the detailed planning phase.

Thus the layout concept based on planning scenario and the first chaining concept represent the final result of the rough planning during layout planning.

4.2.4.3 Summary of the process A2.4.3 (level 4)

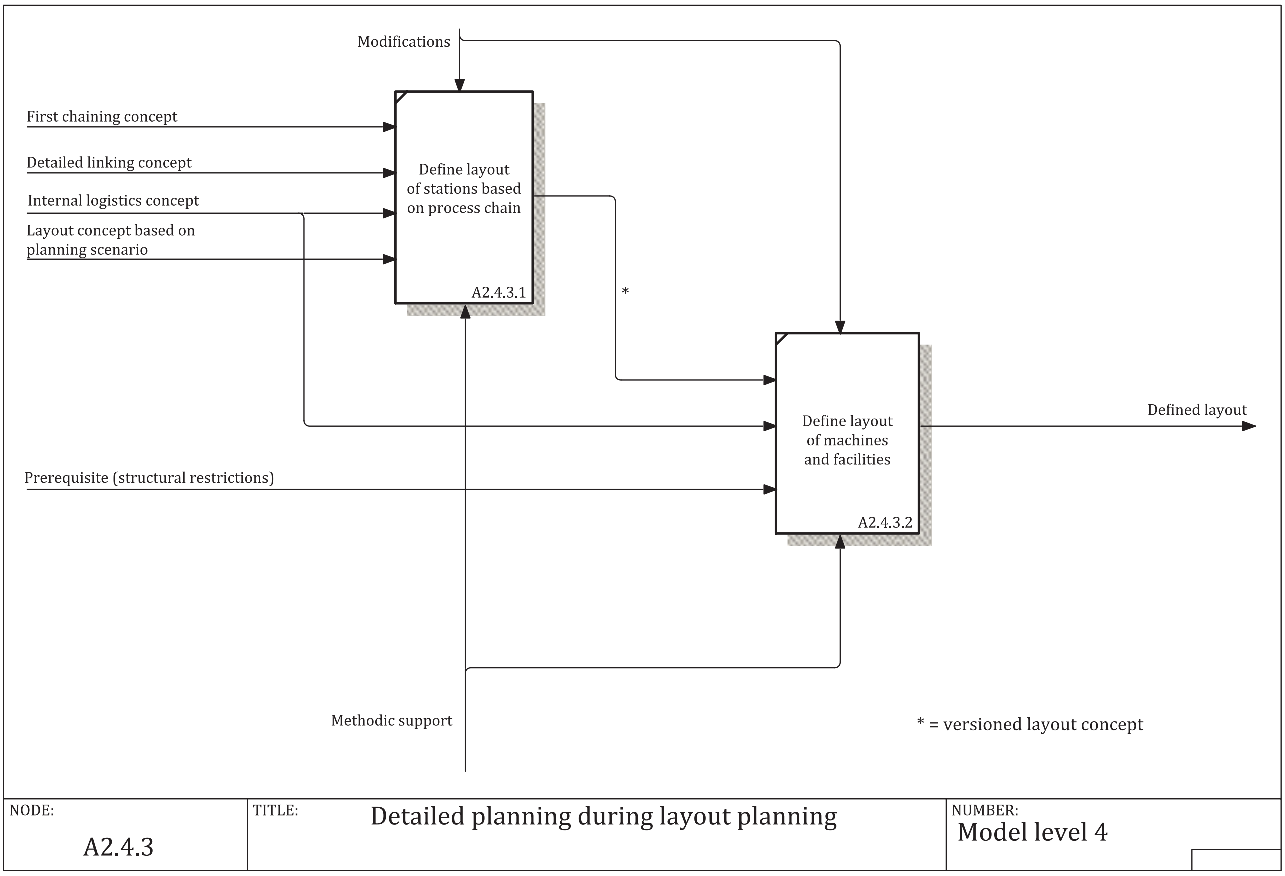

Figure 20 — Structure of the detailed planning during layout planning at model level 4

The detailed planning during layout planning as shown in Figure 20 provides the overall layout which represents a combination of the building, installation and system layouts that also takes account of the sequential links between the assembly and manufacturing areas.

During the detailed planning phase, the spatial arrangement of the work stations is completed and the defined layout of the production resources is given (A2.4.3.1). In addition to defining the precise, fixed spatial arrangement of the machines and facilities, it determines the supply and disposal of power and auxiliary materials, as well as routes and area utilization. Like the static boundary constraints (for instance due to existing structural restrictions in the building), the restrictions resulting from the supply of light, electricity, water and other auxiliary materials impose limitations on layout planning. These limitations also need to be respected during the detailed planning phase. With all these information given a definitive and binding layout is generated which represents the final result of the detailed planning (A2.4.3.2).

4.3 Associated planning functions

In contrast to the core discipline the structure of the associated planning functions is not aligned to the structure of the remaining disciplines based on the degree of maturity. The internal consolidation of the output from the remaining planning functions is performed within the associated planning functions. The associated planning functions are able to realize operations like the combination of the developed planning concepts during the different steps of the planning process or the request for a management decision. Another aspect of the associated planning function is the production process management, which runs parallel to production. If any changes to the planning requirements or other constraints are necessary, the production process management is capable of triggering the iteration of the planning activities to which the changes apply to. A detailed description of the process activities within the associated planning functions is given in Annex A.

Annex A
(informative)

Summary of the associated planning functions

A.1 Summary of the process A3 (level 2)

The structure of the associated planning functions as shown in Figure A.1 consists of planning functions with interdisciplinary character. Several outputs from the core planning disciplines need to be combined, enriched and adjusted. Processing of the necessary information strongly depends on the simultaneous consideration of interdisciplinary types of information such as times, concepts and MBOM inputs. The interdisciplinary consolidation delivers adjusted planning scenarios and has a significant influence on the detailed planning of the core disciplines, as well as on the production process management.

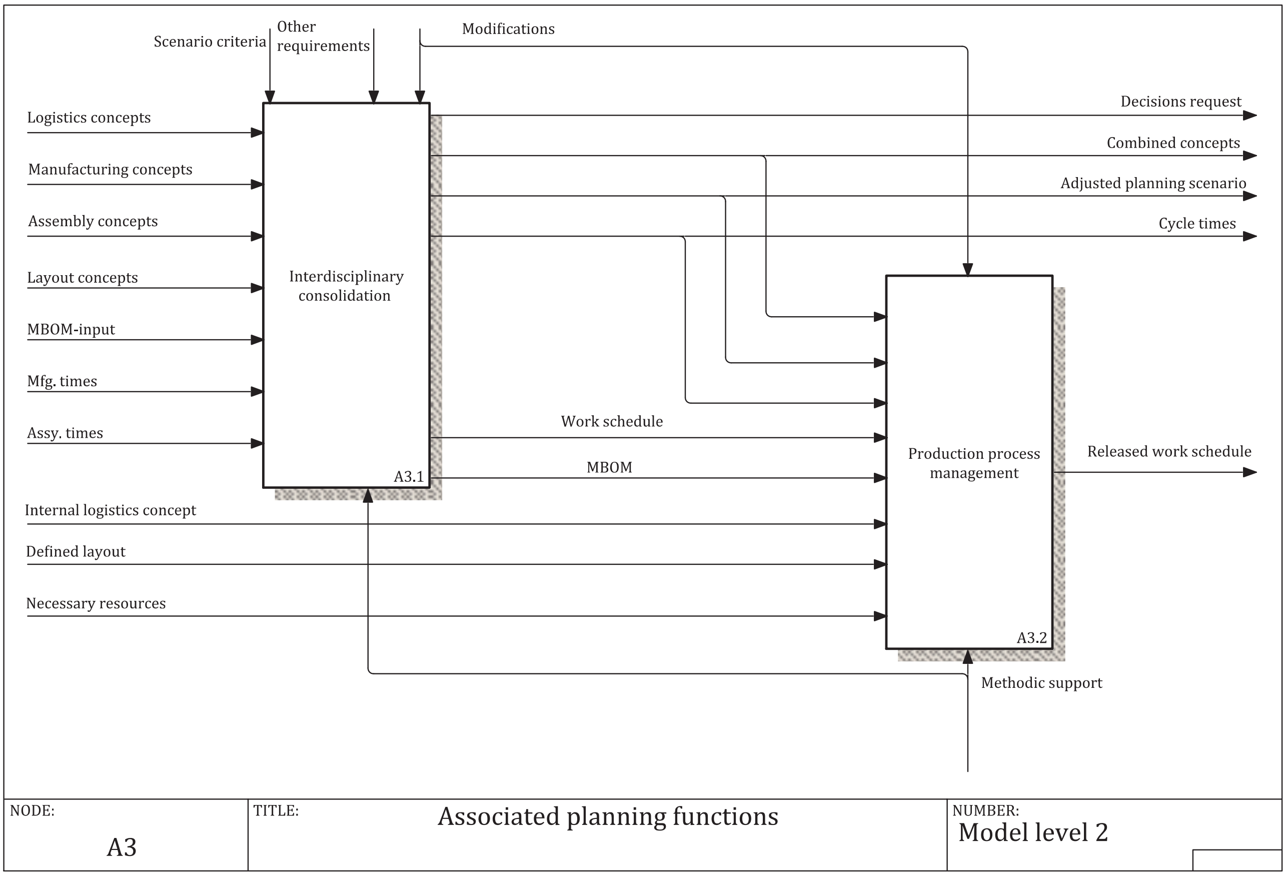

Figure A.1 — Structure of the associated planning functions at model level 2

The associated planning functions transfer the selected planning scenario and the corresponding planning information from the planning disciplines into the final production system (A3.2 in Figure A.1). Production process management can lead to a further iteration of the planning processes. Every iteration generates an updated work schedule which improves the production system. The requirement for iteration is triggered continuous improvement processes or changes to framework conditions described in 4.1. It finally ends with the release of the last work schedule which indicates the end of production (EOP) management process.

A.1.1 Summary of the process A3.1 (level 3)

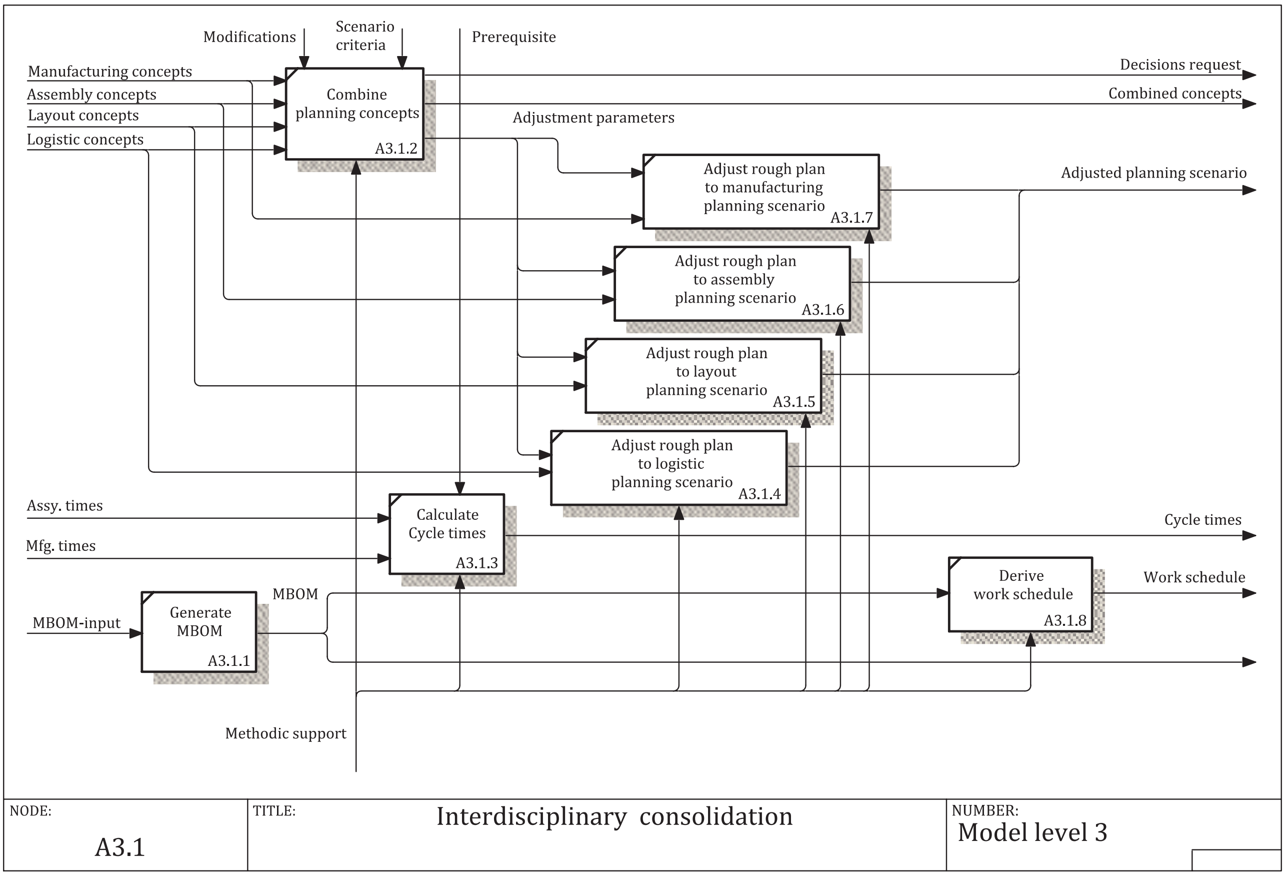

Figure A.2 — Structure of the interdisciplinary consolidation at model level 3

The interdisciplinary consolidation consists of three fundamental operations of information processing. In order to combine corresponding information gathered from all planning disciplines the interdisciplinary consolidation generates an integrated MBOM based on MBOM inputs (A3.1.1 in Figure A.2). The integrated MBOM will be used to derive the unreleased work schedule (A3.1.8 in Figure A.2) and will be handed over to the production process management. Detailed outputs from the core planning disciplines such as the manufacturing and assembly times are calculated within the interdisciplinary consolidation.

A.1.2 Summary of the process A3.2 (level 3)

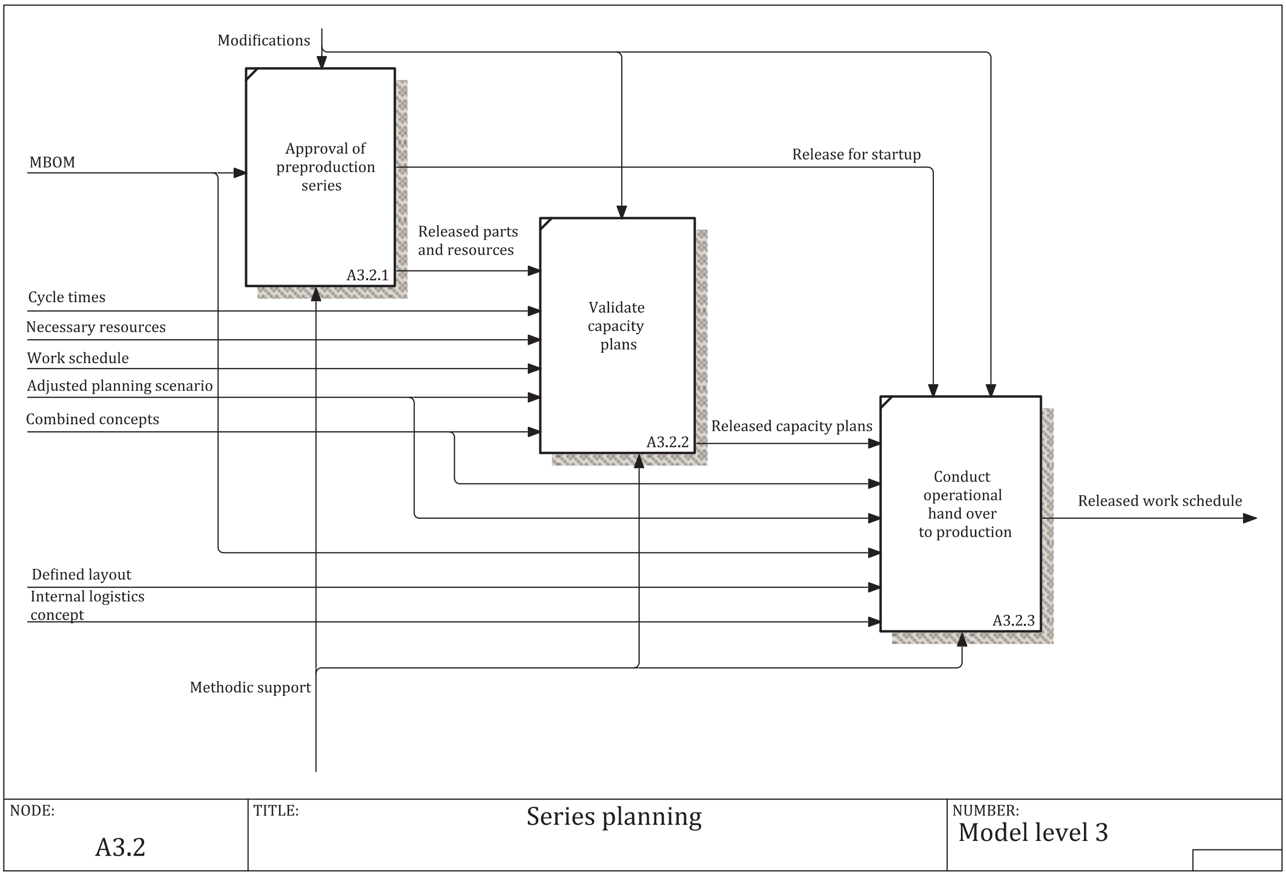

Figure A.3 — Structure of the production process management at model level 3

The production process management can be considered as a degree of maturity itself and cannot be structured or assigned to a single planning discipline. To perform an approval of the supplied goods, the raw parts and resources (A3.2.1 in Figure A.3) and various information aggregated in the MBOM input need to be considered. As a result the release for start-up (e.g. for parts and resources) is generated and handed over. The work schedule derived from the MBOM input represents the basic information for the validation of the capacity. The cycle times and the necessary resources constitute restrictive conditions. The selected and adjusted planning scenarios, as well as the combined planning concepts, need to be considered. It is necessary to ensure capacity plans which are ready for production and to release the capacity plans for the production. To enable the ramp-up of production the gathered and generated information within the production process, management needs to be prepared for the release of work schedule (A3.2.3 in Figure A.3).

The production process management provides the first work schedule for production. As a consequence modification and continuous improvement processes can lead to further iteration of the planning functions and in the same way the production process management (see Figure A.1 and 3.1.4). Every planning iteration during the phase of the production leads to an updated work schedule.

Annex B
(informative)

Production planning disciplines

B.1 General

Figure B.1 illustrates the multiple planning aspects within the product life cycle.

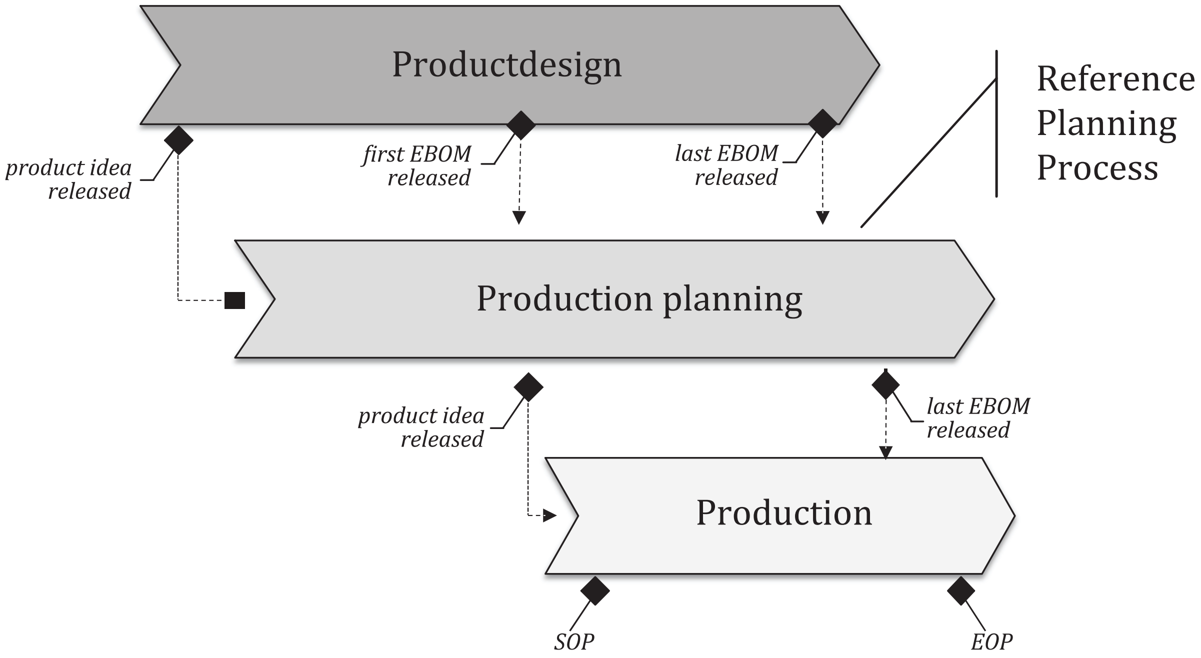

Figure B.1 — Classification of the reference planning process for production planning

B.2 Manufacturing planning

Manufacturing planning is responsible for planning the technologies required to manufacture products. It is particularly important to consider the input variables to the planning process in detail when selecting the appropriate manufacturing technologies and defining the manufacturing workflow. These represent the motivation for the subsequently selected procedures. When performing manufacturing planning, it is also necessary to define in detail how a product is to be manufactured from a raw part. The manufacturing technology requirement that needs to be met in order to achieve intended product goals of quality and economy using available resources is critical. During planning, it is necessary to take account of the constraints placed on the planning process and incorporate these in the decision making. To summarize, it is necessary to define the manufacturing technologies and manufacturing steps that are required in order to manufacture a product from a raw part in the light of the applicable framework conditions and the defined product characteristics. A further manufacturing planning challenge is to determine the future design and assignment of the components of the manufacturing system concerning the relevant quantitative, qualitative and time related considerations and as a function of the planned manufacturing process. During manufacturing planning, the design of work systems is defined independently of a specific customer's order. This independence from customer's orders differentiates the manufacturing planning process from the recurrent tasks involved in work scheduling that respond to specific customer orders. As a result, manufacturing planning provides the basis for assembly, logistics and layout planning.

B.3 Logistics planning

During logistics planning, it is necessary, for example, to define how parts are delivered and where they may be warehoused and in what quantity. Optimized logistics planning permits production with low stock levels and at minimized cost while simultaneously ensuring responsiveness and versatility. In terms of timing, logistics planning can be subdivided into two areas:

— strategic/tactical logistics planning before start of production (SOP);

— operational logistics planning after SOP.

Logistics planning before SOP has a strategic nature and a significant impact on the subsequent costs incurred during the production processes. Logistics planning before SOP is responsible for defining key numerical values such as internal investments (e.g. for containers) or necessary external logistics costs (e.g. freight costs). Tactical logistics planning can then be performed before SOP on the basis of this strategic logistics planning. Its main task is the detailed planning of the logistics processes and structures, as well as the provision of the logistical resources. Operational logistics planning details the requirements that emerge from tactical logistics planning and implements these in the various areas of the company. These activities include, for example, the design of the way the transport and warehousing processes are to be conducted.

B.4 Assembly planning

Assembly in this context designates the process of putting together the modules, parts and amorphous materials to form a product. Since assembly is frequently the last step in product creation, practically all the changes made during upstream production stages have an impact on it. This means that assembly systems needs to be extremely flexible in order to make it possible to quickly adapt when changes arise. Assembly planning includes consideration of a large number of processes in order to put together a product with a predefined geometry. The primary assembly functions consist of the various types of joining and connecting activities. The secondary assembly functions do not make any direct contribution to the progress of the assembly operation. Due to the significant influence of the design process on assembly planning, it is frequently subdivided into two different planning workflows:

— assembly planning after the completion of design work;

— assembly planning in parallel with design work.

Since parallel planning results in a significant shortening of the overall product development process, it is assumed in the following that assembly planning is performed in parallel to the design activities. Synchronization points also make it possible to harmonize adjacent processes earlier, thus reinforcing the abovementioned effect.

B.5 Layout planning

During layout panning particular attention should be paid to information from manufacturing process chains. When distributing the operating resources across the available space, it is necessary to take account of the following criteria:

— appropriate flow of materials;

— optimized subdivision of areas and spaces;

— ergonomic working conditions suitable for human operators;

— high level of flexibility of systems and equipment.

In very general terms, these criteria are reflected in the subdivision of layout planning into four typical areas: materials flow, infrastructure, operations and building services engineering. As part of the attempt to structure layout planning, it is possible to identify the potential of alternative layouts by assigning different weightings to the above mentioned criteria. The layout also needs to consider the area dimensions, transport routes, areas for the provision of materials and auxiliary areas (for instance areas for sanitary installations). In order to minimize transport costs, work intensive transport activities are often planned as short transport routes. As a result, the overall layout represents a combination of the building, installation and system layouts that also takes account of the sequential links between the assembly and manufacturing areas. This means that the overall layout provides graphic documentation of an operating state that is either being planned or has already been implemented, including the alternatives and variants. This aspect of layout planning is created during the maturity level related planning phases mentioned previously. The level of detail will be refined continuously. In the case of complex and extensive overall systems, it may be necessary to subdivide these into partial systems in order to ensure that clarity is maintained in the overall layout.

Annex C
(informative)

Object-Process Diagram

In addition to the given graphical abstract of the detailed process activities using SADT notation in Clause 4, the abstractions of the reference planning process in Figures C.1 to C.4 follow the notation from ISO/PAS 19450. The Object-Process Diagram is given for the first two levels of the reference planning process (see Figure 3).

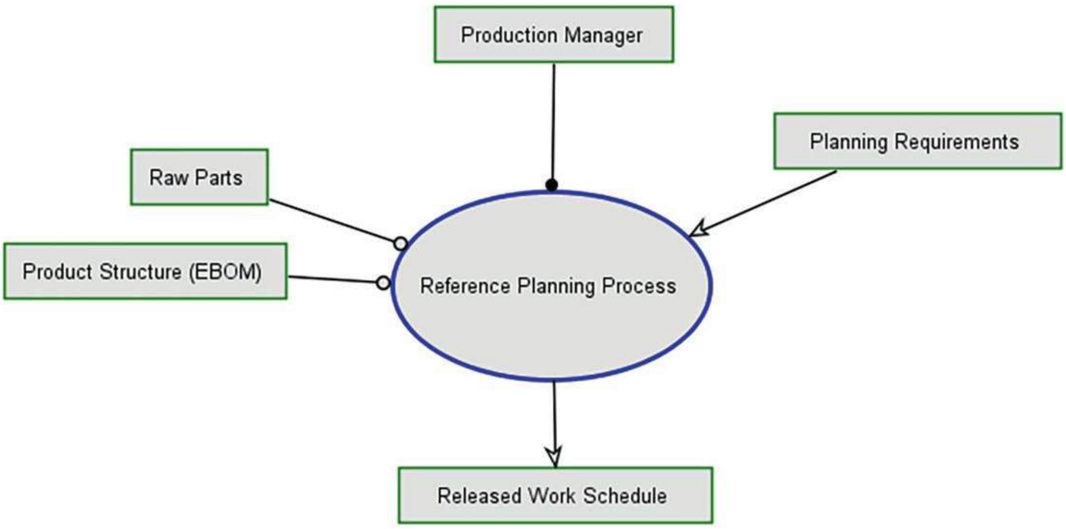

Figure C.1 — Root level of reference planning process

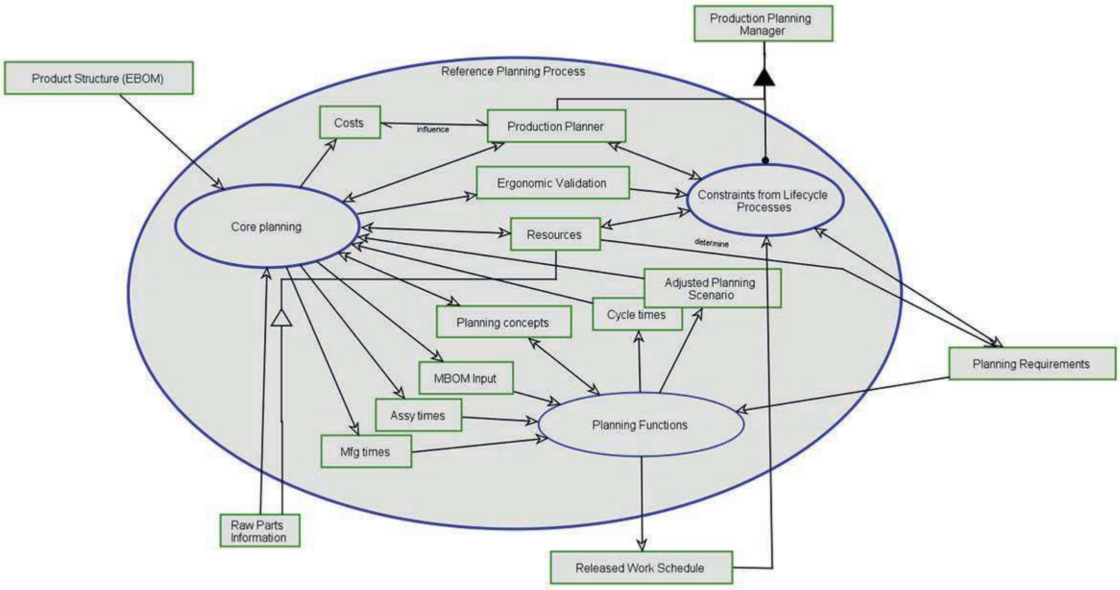

Figure C.2 — Break down of reference planning process

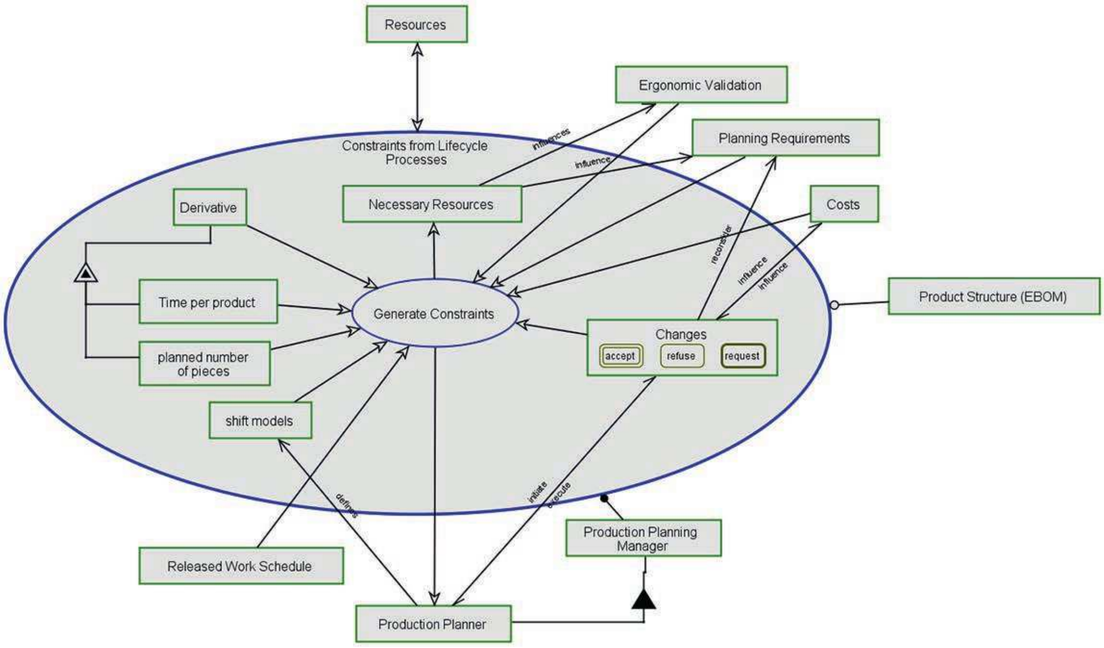

Figure C.3 — Constraints from lifecycle processes

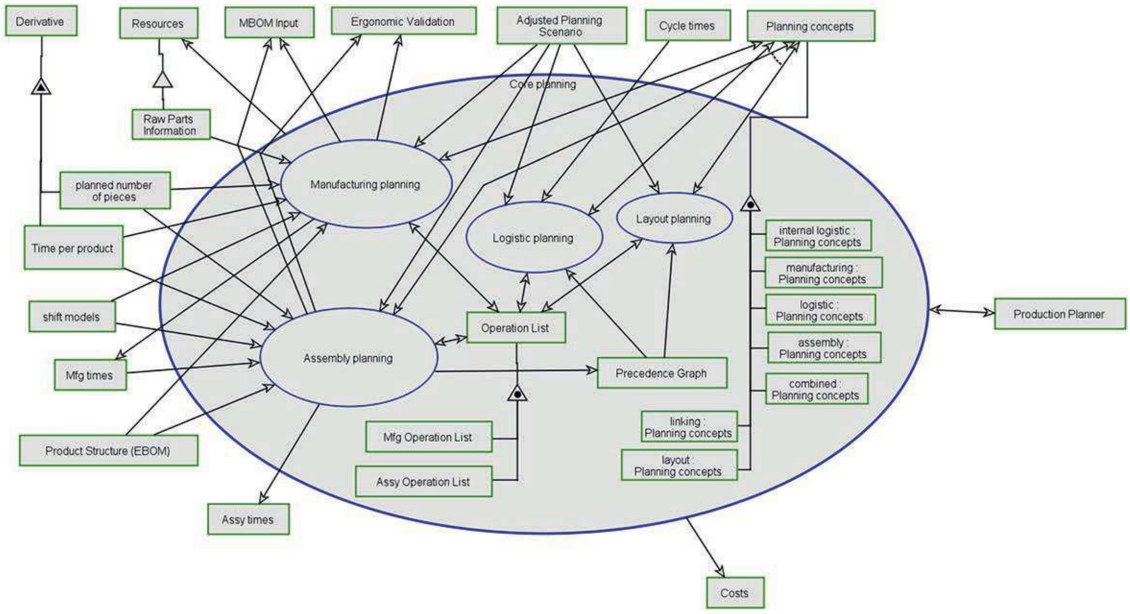

Figure C.4 — Core planning processes

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ICS 25.040.40
Price based on 32 pages