Production Management II
- Lecture 11 -
Digital Factory Planning and Simulation

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Learning target of this lecture:

• Overview of IT supported Factory Planning

• Understanding the fundamental principles of digital Factory Planning

• Knowledge of important IT tools for digital planning and overview of areas of application
Table of Contents Lecture 11:

1. Short summary
   L11 page 1

2. Introduction
   L11 page 2

3. Fundamental principles of digital Factory Planning
   L11 page 6
   3.1 Overview
   3.2 Data Management
   3.3 Virtual Reality
   3.4 Simulation
   3.5 Generic tool use

4. Tools for Factory Planning
   L11 page 15
   4.1 Tools for production structuring
   4.2 Tools for layout planning
   4.3 Tools for laying out area and workspace
   4.4 Tools for process simulation

5. Conclusion
   L11 page 26

6. Exercise
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Summary Lecture 11:

The use of IT assistance has become a fundamental requirement for success in most functions of business. In the area of planning and layout of production systems and factories, rapid changes are taking place better known as Digital Factory and Digital Factory Planning.

Shortened product lifecycles, and therefore resulting shortened planning phases, and the increasing diversification of products and product processes lead to an increase in the frequency and complexity of factory planning tasks. The growing demand for better planning efficiency and safety meets Digital Factory Planning with its numerous IT tools surpassing the actual factory planning process. Potential for improvement lies with computer-aided planning, especially when working with extensive masses of data, and provides the possibility of making the resulting plans both visible and assessable. Digital Planning can be characterized by three fundamental elements: data management as an underlying task, virtual reality as an interface for the user and simulation as an instrument for evaluation.

The data required in factory planning for the product, the production program, process, resources, etc. are generated, adapted or provided at different points during the planning process. The task “data management” is to provide a continual and up to date data structure during as well as after the planning process.

The application of virtual reality, as a means of graphic representation, for example, and as a user interface, has caught on as capabilities of computers have expanded. It is possible to follow through and view planning steps in this reality-based and computer generated environment known as virtual reality. Simulation, on the other hand, can reconstruct the behavior of complex systems. This is what provides the factory planner with the opportunity to check and correct the dimensions of production plants and the process layout already in the planning phase. A three-dimensional sequence of events, like the investigation of a collision for robot programming or the layout of an assembly line can be simulated.

The IT tools of Digital Factory Planning available on the market are differentiable as to functionality in application of product structuring, layout planning, area and workspace layout, and process simulation. The trend in programs has been moving towards modular and universal functionality in the last few years.

The technological and organizational potential of Digital Factory Planning is not yet exhausted by the tools presently available. The fact that automobile manufacturers have announced that no more plants will be built nor production processes run until they have been detailed and digitally reconstructed and evaluated, shows the importance of Digital Factory Planning.
L11: Digital Factory Planning & Simulation

- Motivation and Introduction
- Fundamental principles of digital Planning
- Tools for factory planning
- Conclusion

Picture Notes:
**Picture Notes:**

The basic steps involved in planning a production system are shown in the above picture. Future demands on a production system, with respect to manufactured products, are determined during the phase “strategic planning of a production schedule”. Then, organization and production principles of the future production system are decided upon. Planning of the arrangement of resources follows the layout planning. There is a close connection between determining the layout and determining the type and number of resources needed.
Picture notes:
The increasing need for improved efficiency and security of planning projects suggests what challenges are faced in Factory Planning. Carrying out planning steps aided by a computer can be extremely helpful to this end.

Technological developments have afforded Digital Factory Planning with the opportunity of creating IT tools with respect to the use of intricate graphic user interfaces, for example.

The occurrence of rapid technological advancements is supported by a thesis written in 1965 by Gordon E. Moore, one of the founders of Intel. Moore claimed that computer capability and transistor density doubles every 18 months – „Moore’s Law“. His thesis still applies today.
Digital Factory Planning

Digital Factory Planning is the IT supported implementation of Factory Planning tasks:

1. **Program Planning**
   - Product program planning
   - CAx Systems

2. **Process Planning**
   - Layout planning
   - Layout planning systems
   - Planning Capacity
   - Simulation of processes
   - Infrastructure planning

3. **Structure Planning**
   - Workspace & Ergonomically correct formation
   - 3D Simulation
   - Area layout
   - 3D CAD Systems
   - 3D Engineering Systems

4. **Implementation Planning**
   - Set up
   - CAE Systems

**Continuous Tasks**
- Data management
- Virtual Reality
- Simulation

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**Picture notes:**

The Factory Planning process can be divided into four simple phases: Program Planning, Process Planning, Structure and Implementation Planning. These planning processes are supported by Digital Factory Planning in the form of various IT tools.

CAX systems are primarily used in Program Planning, like CAD, for generating a bill of materials or planning systems (CAP/CAPP) for the structuring and measurement of manufacturing tasks.

Systems for process structuring, meaning the determination of necessary processing steps and resources, as well as systems for measuring capacity and flow of materials are used in planning the production process.

Layout creating systems help with resource arrangement and planning.

In order to create manufacturing processes in the Structure Planning phase, tools for process simulation are used.

3D CAD and engineering systems are used in the detailed creation of workspaces and manufacturing areas, because it is possible to create simulations of manufacturing environments that are true to reality.

In Implementation Planning, engineering tools (CAE) are used with which it is possible to see how systems crucial to operation are constructed.

There are three continual elements in Digital Factory Planning, aside from the planning process, which will be discussed later in the lecture: Data Management, Virtual Reality and Simulation.
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Picture notes:
Data Management consists of the storage, correlation and availability of various data important to the digital planning process. The data used in Factory Planning is especially associated with the product to be manufactured, with the production resources and with the manufacturing process.

The difficulty in Data Management has to do with the variety of different data types and the vast number of interactive groups in business involved in storing and preparing the data and making it available. Data Management must have a data structure at their disposal to prevent redundancy of records. This data structure has to keep all data vital to the planning process readily available and to keep track of the results of each planning step which in turn serves as input for the next step.

The fundamental tasks of Data Management can be summarized accordingly as: comprehensive data handling, the taking over (transferring) of data from one planning step to the next and the preparation of data in the form needed.
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Virtual Reality in Factory Planning

Virtual Reality (VR) has become the most important user interface in Digital Factory Planning. Aside from the pure representation of planning results, VR systems are also used in development where the planner can make changes directly to virtual objects.

The various forms of Virtual Reality used in Factory Planning can be differentiated in terms of representation area and content. In the most widespread form of VR, the context sensitive form, the planner moves in a virtual (digital) environment and gains information on relativity, like the specifications of resources, possible planning configurations or clues about possible repercussions of planning decisions.

Typical ways of using Virtual Reality are, for example, on a normal computer screen - as desktop VR, with data helmets or in VR rooms (Cave).
Simulation in Factory Planning

**Simulare** [lat]: imitate, mimic, copy

Simulation is used in:
- Decision making
- Evaluation of alternatives
- Determination of planning data
- Understanding the system
- System optimization

**Graphic 3D-Simulation**  
**Process Simulation**  
**FEM Simulation**  
**Multiple Part Simulation**

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**Picture Notes:**

The interaction of complex systems under certain conditions can be examined in a simulation, for example, for evaluation purposes or to gain an understanding of how the systems works.

Simulation is not limited to any one academic discipline and can be used on a physical or purely theoretical model. Actually, simulation is not even computer bound.

As applied to Digital Factory Planning, graphic 3D simulations and process simulations are among the most important. Graphic simulations can be used for laying out the workspaces of machines or ergonomic investigations, for example. Flow of materials, regulation of controls or resource capacity is investigated using process simulations.
Steps of a Simulation Test

Picture notes:

The course of action in simulation tests can be described in four steps:

First, a model is made of the actual system. Making a model of a system basically means that correlations are symbolized/coded (in shortened form). Therefore, it is extremely important to keep a model's purpose and function in mind when introducing symbolization. Algorithms are used to describe a model in IT-aided simulation.

Tests done on a model lead to theories about how a system interacts under special circumstances. The numerous results of a simulation are gathered, organized and interpreted using graphs or characteristic values, for example. The analysis and interpretation of key data lead to conclusions on whether or not a system needs to be changed.

Changes on a model are undergone during optimization where any influence can be determined based on the results.

New findings need to be evaluated realistically and cost/utilization factors checked before any major changes are implemented on the real system.
Partial Steps of a Simulation Test

- Modeling
  - Input
  - Model
  - Output
  - Modeling
- Simulating
  - Input
  - Model
  - Output
  - Simulation
- Improving
  - Input
  - Model
  - Output
  - Optimization

- Modeling of production resources
- Representation of production processes
- Identification of relevant performance data
- Performance of a system
- Sensitivity to changes (flexibility)
- Sensitivity to disturbances
- Deduction of action to take
- Independence of individual actions
- Evaluation of result of action
- Creation of scenarios

Picture notes:

Of central importance to simulation tests is the model which, together with input and output data, should successfully represent the characteristics of a real system.

The basic steps of a simulation test are building a model with its input and output variables (modeling), the investigation of the model’s behavior based on output data (simulation) and the improvement of the system by optimizing input variables.

The input data of a model corresponds to the variables assigned to the model, like the situation concerning orders, characteristics of machines, control regulation, etc. The output data to be analyzed is production data such as machine leading, machine time for orders, etc.
Simulation Models

Picture notes:

Simulation models can be differentiated by one fundamental characteristic: time variables and their determination, which is dependent on the type and flow of the process. Time variables show how often changes occur and become visible.

The typical form of a model in process simulation is the discreet incidence-oriented time model. The times are not pictured at constant intervals, but when particular incidences occur. For example, when a tool arrives at a machining station.
Cueing Theory

Modeling of a process at a workstation: discrete, incidence-oriented simulation in the cueing theory

Picture notes:

The discrete incidence-oriented simulation of production processes is based on the principle of the cueing theory.

Points are marked on the time axis that show a discreet change in conditions of a system. Distribution functions deliver the time intervals of the items and their machining time. The machining process starts when the first item arrives at a station and the station is in use. Following items are placed in the cue until the machining time of the first item has been completed. If the cue is empty and the previous item has already undergone the machining process, the machining station waits until the next item arrives.

Extreme and average values of machining and cueing times can be described and calculated using this relatively simple representation of manufacturing processes. Downtime and malfunction times can be accounted for using deterministic or stochastic time portions and are used to improve the nearly real behavior of production times. This is how availability and efficiency factors of various linked production items of a production system can be simulated.
Complete Digital Factory Representation

Digital Factory
is the complete digital representation of the layout details of a factory as a model

- Modularity
- Generizität
- Integration
- Transparency

Use of a universal data model
Standardized interfaces
Continual support of all planning tasks (Workflow)

Picture notes:

The trend in the development of Digital Factory Planning is a completely functional virtual safeguard of the planning phase and a continual digital synchronization of product representation and production representation. This is made possible by using a consistent data model, which determines and unites different data types, standardizes interfaces between user groups and planning phases and which allows the consistent use of tools in all planning phases.

The characteristics of a model are described as follows.

Modularity:
For reducing complexity. The connection between objects and sub-systems are understood under Modularization. Modules are independent.

Generizität:
Generic building blocks are universally valid and independent of the specifications of an object to be modeled. Specific data is derived from general, generic data.

Transparency:
The model makes the interesting correlations and aspects of the object to be modeled apparent.

Integration:
The individual building blocks are not isolated but are related to one another and build a whole.
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Picture notes:
Tools of Production Structuring

**Area of use of the software tools**
- Building product and part families
- Assigning product and part families to resource groups
- Building production areas, making block layouts
- Area structure and assignment optimizing, ex. According to material and information flow points
- Detailing layouts, deciding on machine positioning

**Examples of suitable software tools**
- FactoryCAD
- Fastdesign

**Tools of Production Structuring**

**Modularity** e.g. Resource library
**Generizität** e.g. Structuring
**Integration** e.g. Product, process and resource data
**Transparency** e.g. Representation

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**Picture notes:**

Tool for production structuring help in the planning and formulation of production tasks. The emphasis in that case is on the assignment of product and parts family to resource groups as well as building block layouts out of existing process plans and production schedules. The tools used in structuring help to formulate the production process, to guarantee a useful layout for the flow of materials, for example, or to identify and disperse useful resources.
Example Fast Design

FActorySTructure - Design
Used in data collection, layout creation and concept formation

Range of application
- Industrial Facility Management (IFM)
- Flow of materials analysis and logistic planning
- Layout planning and draft creation
- Project administration for managing all relevant documents
- Order administration for controlling internal and external maintenance tasks

Functions
- Outline and layout creation (2D or 3D)
- Resource library
- Production structuring with formation of parts families and manufacturing groups

Picture notes:
Fast Design consists of two modules. The module FASTPLAN is used to structure manufacturing areas and includes the functional groups: formation of parts families, capacity calculation, formation of manufacturing groups and calculation of flow of materials. The module FASTGRAF is an interactive, graphical user surface and is made up of the following functions: CAD-aided layout construction, editing and planning functions and ability to represent a flow of materials using Sankey diagrams. The task of data administration is taken over by an integrated data bank application which supports the preparation of basic data consisting of part, process plan, parts list and machine data. FASTDESIGN assists the planner from data collection to the creation of various layouts to the evaluation of concepts based on diagrams and tables.
Tools for Layout Planning

Area of use of the software tools
- Production structuring/ area formation
- Determination of space needs/ formation of block layout
- Layout formation based on standard CAD software (2D/3D)

Examples of suitable software tools
- Factory CAD
- Fastdesign
- Factory planning table „Build-It“

*Modularity* ex. Resource library
*Generizität* ex. Any area of use
*Integration* ex. Configuration of resources
*Transparency* ex. Visualization Planning

Picture notes:

Layout planning has the task of organizing preliminary considerations and the individual results of structure and system planning in an outline form based on the flow of materials and defined 3-dimensionally. It is primarily oriented on the given geometry and the standards set by the production schedule. The roughly estimated plans are the main source of information.
Example: Factory Planning Table „Build-It“

Interactive layout planning in a team with simultaneous visualization

Range of application
- Elaboration of block layouts
- Positioning machines
- Layout of workplace

Functions
- Table: 2D-Projection
- Wall: 3D-Projection
- Resource library
- Arrangement of resources in the layout with „Bricks“

Picture notes:
The Build-it planning table is an intuitively usable factory planning system which supports participative group-oriented factory planning.

The people involved sit together at a conference table on which an outline of the factory to be built and set up is projected. In addition, a user-defined view is projected on a screen behind the table. This way the planners get a feel for the 3-dimensionality of that which they are planning 2-dimensionally.

Interaction with the digital model occurs through so called „bricks“- small cubic building blocks for placing planning objects - similar to the usage of a graphic tray. A special software that recognizes pictures is used to record the position and orientation of the layout on the table.

A 3D model is produced with a 3D CAD system which is read by the proper VR software so that the factory model produced by the team can also be seen on the big projector.
Tools for Area and Workspace Layout

Area of use of the software tools
- Creating area layout
- Flow of materials, Fördertechnik and Austaktung
- Arrangement of machines and workplaces
- Workspace layout and ergonomics
- Assembly layout
- Graphic simulation und collision examination

Examples of suitable software tools
- Delmia Process Engineer
- Tecnomatix eM Power

- Modularity  ex. Functional module
- Generizität  ex. Method orientation
- Integration  ex. Product and process planning
- Transparency ex. Graphic simulation

Picture notes:
Tools for producing area and workspace layout use the details of production. When creating a layout for a workspace, questions with respect to automatic manufacturing machines as well as ergonomics come up depending on what area is being looked at.
Example: Delmia Process Engineer

Digital Enterprise Lean Manufacturing Interactive Applications

Range of Application
- Concept development
- Simulation of manufacturing processes
- Resource and capacity planning
- Set up and surveillance of operational manufacturing

Typical Functional Module
- Layout planning
- Quality planning
- Ergonomics
- Robot simulation
- NC-Simulation
- Process planning
- Cost calculation
- Process simulation (Quest)

Picture notes:
Delmia Process Engineer is one of the most extensive factory planning tools in existence. The focus of the Process Engineer is on the detailed production planning and area layouts. Various modules cover the tasks and steps of factory planning. The Process Engineer brings the processes within product development, production planning and manufacturing into harmony. Processes within development, planning and production can be combined and their synergetic effect exploited. With successful integration, changes and delays are realized at once and planning tasks can be pushed further along the process chain towards construction and development (concurrent engineering).

Another software available similar in capability to the Process Engineer is the eM Power software package from Tecnomatix.
Example: Ergonomic Formation

Range of Application
- Rough and refined planning of manual workplaces
- Time abtaktung
- Examination of the convertibility of tasks
- Ergonomic Analysis

Functions
- Workplace configuration
- Time analysis, ex. MTM
- Ergonomic analysis, ex. body posture and energy use
- Field-of-vision analysis
- Advanced kinematic and movement resources
- Macros for Fast Task Modeling
- Documentation (ex. ergonomic reports and animated work directions)

Examples of suitable software tools
- Delmia Process Engineer (ErgoMas)
- Tecnomatix eM Human

Picture notes:
The layout of workspaces, manufacturing and assembling tasks according to ergonomically correct methods is an important theme in Area and Workspace Layout. Ergonomic experiments suggest an improvement in the productivity of work systems and a reduction in the burden/pressure on working employees. Simulation programs help in developing safe workspace layouts quickly by providing anatomical information, like correct range of visibility for example. Grasping room might, for example, lead to increased upper body movement which in turn could lead to an increase in cycle times.
Example: Plant Simulation

Range of Application
- Planning and optimization of robot use
- Attainability and collision examination
- Simulation of manufacturing processes
- Bi-directional conversion between a sequence of movements and control specific programs (ex. eM-OLP)

Functions
- Data transfer with CAD/ CAM system
- 3D visualization
- Static and dynamic collision recognition
- Robot and workpiece library
- Automatic robot programming
- Resource and kinematic representation

Examples of suitable software tools
- eMOLD
- eMSpot

Picture notes:

Machine simulation is a big help in creating the layout of automatic manufacturing areas. Machine simulations are used to plan ergonomically correct and collision-free robot workstations in order to curb expensive positioning times and test runs. Critical factors such as space restrictions, geometric restrictions and robot cycle times are examined. It is therefore necessary to refer to robot and work piece literature.

Software programs offer the direct application of parameters onto the control programs of robots and machines.
Tools for Process Simulation

Area of use of the software tools
- Representation and examination of flow of materials and process chains
- Determination of production characteristic values ex. For capacity and buffer formation
- Optimization of existing production systems and planning of new production systems
- Development and evaluation of control strategies

Examples of suitable software tools
- eM Plant (ehem. Simple ++)
- Taylor
- Arena
- Quest

Characteristics
- **Modularity** ex. Modular programming
- **Generizität** ex. Modeling
- **Integration** ex. Combination of resources in the production process
- **Transparency** ex. Graphic evaluation

Picture notes:
Process simulation is used to evaluate the efficiency of planned processes.
Example: eM Plant

Range of Application
- Modeling, simulation and optimization of complex systems and business processes
- Examination of the convertibility of tasks
- Selection and arrangement of resources

Functions
- Object oriented, graphic or integrated work environment
- Object oriented libraries ex.:
  - „Assembly“ for assembly processes
  - „Carbody“ for pipe building processes
  - „Paint“ for painting processes

Picture notes:

eM-Plant optimizes complex systems and business processes using graphic modeling and realistic simulations. Concepts such as building block, language and list programming are all part of eM-Plant. Specific objects and production systems are preconfigured in predefined libraries containing flow of materials, control regulation and implemented variables of simulated runs. eM-Plant can be used as an integrating simulation component, part of an extensive information system, because of it’s ability to keep up real-time communication with numerous other software. The differences between business, strategy, system and process simulation have been overcome.
L11: Digital Factory Planning & Simulation

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Picture notes:
Current Developments in Digital Planning

- Continual planning workflow ⇒ Avoidance of interface and efficiency loss and of complete support of all planning steps
- Concurrent Engineering ⇒ Decreasing preparation times and preparation planning: parallel product and process planning
- Complete Representation ⇒ Planning of critical plant phase and representation of unstable system behavior, ex. Virtual ramp-up
- Integration in the business ⇒ Integration of all interactive groups of a business: development, planning, buying, selling, etc.
- Integration of the supply chain ⇒ General supply chain processes: ex. Digital product model as a service

Picture notes:
In the future, fully functional and virtual safe guards of general processes will have an increasing impact on factory planning. This means that the system functionality of tools need to be further developed, the performance of hardware increased and data formats standardized. What has become apparent in Digital Factory Planning over the last few years, is the necessity of conforming business processes to the needs and possibilities of digital planning besides the development of IT hardware and software. The organizational changes that come along with Digital Planning in view of general process chains show the challenges that are still faced in Factory Planning.
Conclusion

Approaching correlations that cannot be modeled

Vision

Layout and planning of all mechanical systems on a digital basis

Reorganization of business processes congruent to Digital Planning

Maturity of hardware and software

Standardization and compatibility of planning tools

Picture notes:

There are different hurdles to overcome on the way to a complete layout plan of production systems.

This picture shows four areas of development.