Lecture 1

Introduction

This first lecture has two parts. The first part gives an introduction and overview of the course. The second part of the lecture is a presentation of continuous production systems and discussion about how you can synchronize the various control loops involved in a continuous production plant.

Course overview

The aim of the course is to teach the basic principles for automation systems in the manufacturing industries and their dynamic interaction with market factors such as variations in demand and prices for raw material, transports, and inventory. The additional aim is to give insight into current problems and trends of companies in region, through guest lectures and projects.

The aim of the course is also to help future managers to understand the role and value of control in modern companies as well as to give them an intuition about the parallels of controlling technical systems and managing an enterprise in the market. As such, the course helps to build a bridge between managers and engineers.

The course includes:

- Lectures
- Guest lectures with representatives from industry
- Exercise sessions
- Laboratory sessions
- Project performed in groups of approx.. 4 students. The projects correspond to 1 week full-time work.
- Final examination

In the course, the word system refers to industrial production systems and the word market-driven implies some type of interaction with the surroundings. The interaction can be in terms of prices on raw-materials or demands on the product, both the price and demand can vary over time. The interaction can also be in terms of laws, regulations and standards that specify constraints under which the industrial production system operates. Another important interaction is current trends on the market, such as technological methods and tools.

Industrial production systems can be classified in many various ways. One natural way is to classify them according to the industrial sector they are acting within. Example of such sectors are; Food& Beverage, Pharmaceutical, Metal, Pulp&Paper, Chemical and PetroChemical, Refining, Automotive, Fine chemicals, Bio technology, Machine parts, etc.

Another way of classifying the industrial production systems are according to the main manufacturing process that they have. Three types of manufacturing processes exists; continuous, discrete and batch. There are industrial production systems that include all three types of processes and there are others that operate only one of them. It is common to refer to an industrial production system according to the dominant type of process.

The industrial production systems all have the same overall goal; to make money. Simply put, this is done by transforming raw materials into products through the utilization of basic production resources such as equipment, material, energy, and personnel/manpower, see Figure 1. The products produced are sold at a price making sure the company makes a profit. Even though the industrial production systems all have the same overall goal, operation of the systems are different depending on their type of production process.

Figure 1: A generic production process.

Production processes

As mentioned above there are three types of production processes; continuous, discrete and batch. In brief, continuous processes have a continuous outflow, discrete processes have a discrete output, and the output of a batch process is referred to as a batch or lot.

Continuous simply means a production process where the raw materials are consumed in a continuous stream and a product result as a continuous outflow. Continuous processes deal with materials that are measured by weight or volume, without any discrete identity for a part of the produced material. Materials pass through different pieces of equipment, where each equipment operates in steady-state performing one dedicated part of the complete process. The product continues to be made in an ongoing manner once the process starts.

An example of a continuous production process is the making product C from the chemical reaction A+B, see Figure 2. Other examples of typical continuous processes are refining, gas, powder, pulp and paper.

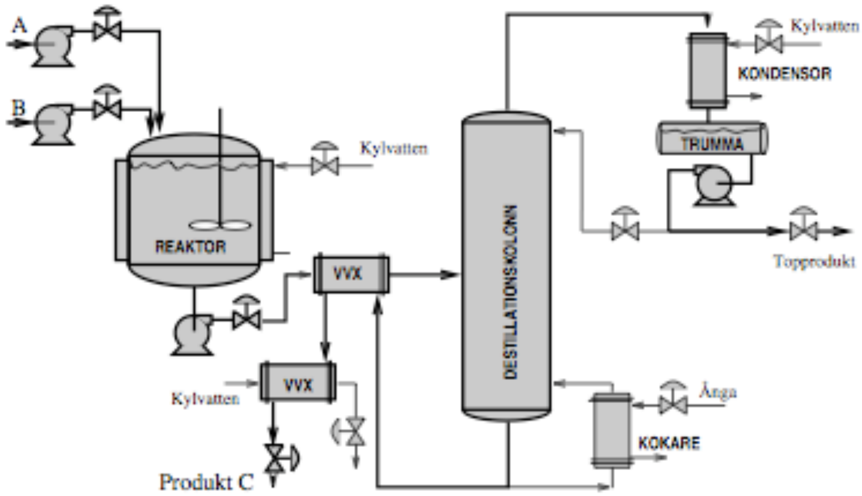

Figure 2: An example of a continuous production process.

The production via a continuous production process does not have to be made in a continuous manner; it can also be done in a discontinuous manner. However, the continuous production process increases the level of production that can be achieved. Continuous processes make the most sense when the market demand is high.

There are a number of characteristics typical to continuous processes:

- Continuous production of product, i.e. continuous outflow.
- Continuous flow of material (often fluid-based)
- Open-ended production runs
- The process is most often ”invisible”
- Disassembly-oriented production is not unusual.
- The equipment operates in steady-state

A discrete production process is the assembly of pieces and parts into products and the product result as a discrete entity. Discrete processes deal with material that can be counted. The equipment used in the process do not work in a steady state mode, but rather in a startup – operate – shut down mode.

An example of a discrete production process is the automotive industry, e.g. the production of cars, see Figure 3. Other examples of discrete processes are; Aerospace, automotive and machine parts.

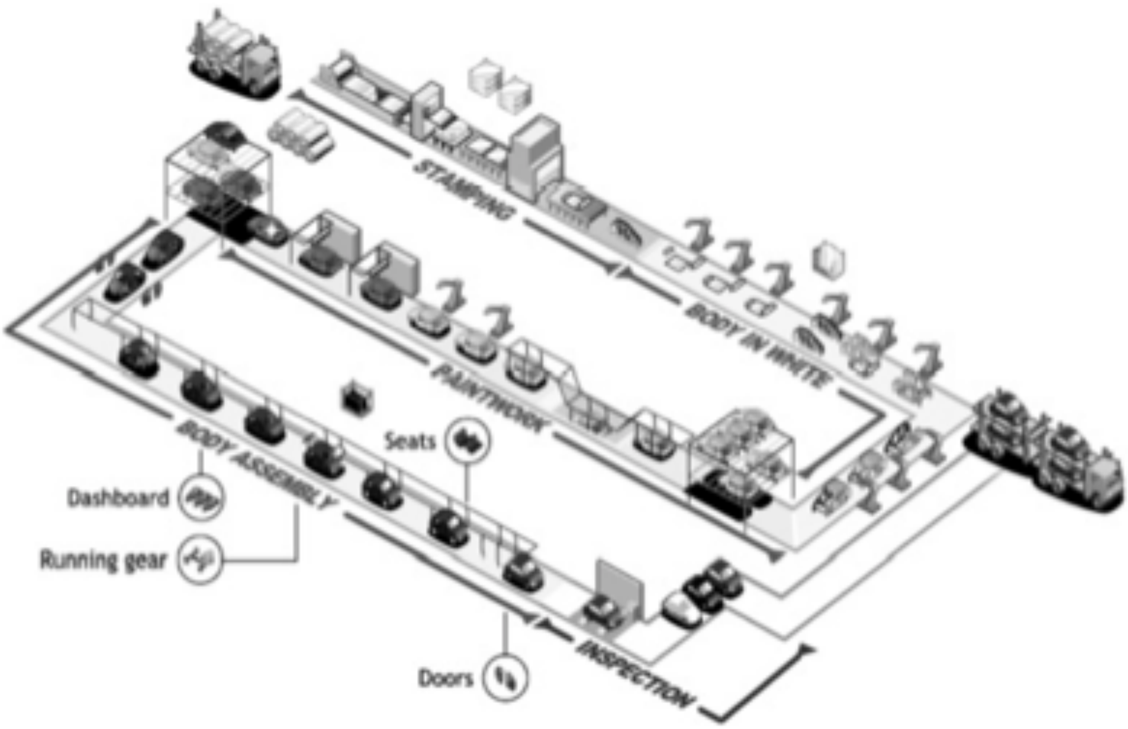

Figure 3: An example of a discrete production process.

One of the economic drivers of discrete production is to maximize production, i.e., the flow of product in plant. Automation and instrumentation comes into place in order to improve speed, quantity and repeatability. Discrete production processes offer a higher degree of flexibility than do continuous processes.

There are a number of characteristics typical to discrete processes:

- The product is a discrete entity.
- Assembly-oriented production.
- Staged production through work cells
- Well-defined production runs.
- The process is most often ”visible”.
- The equipment operates in on-off manner.

In a batch production process the product is made in batches or lots. Batch processing typically involves assembly-based processing using fluids and dry materials. Batch processes consists of a discontinuous flow of raw and processed materials. The raw materials are the ingredients; each one is typically introduced sequentially into the process in a prescribed order and in a prescribed amount. This is the recipe.

Products that are being made in continuous processing could most often also be made in batch processing. Batch processing is much more flexible than continuous processes. A new product or product-grade can be made in each batch made using the same equipment. The downside to batch processes is that they are not able to get the high levels of production that a continuous process can, simply because they do not produce continuously. Their advantage is their flexibility. Batch processing might be the better design if flexibility and agility are more important business factors than pure production.

An example of a batch production process is seen in Figure 4. Examples of typical batch processes are; fine chemicals, biotechnology, beverage, and pharmaceutical.

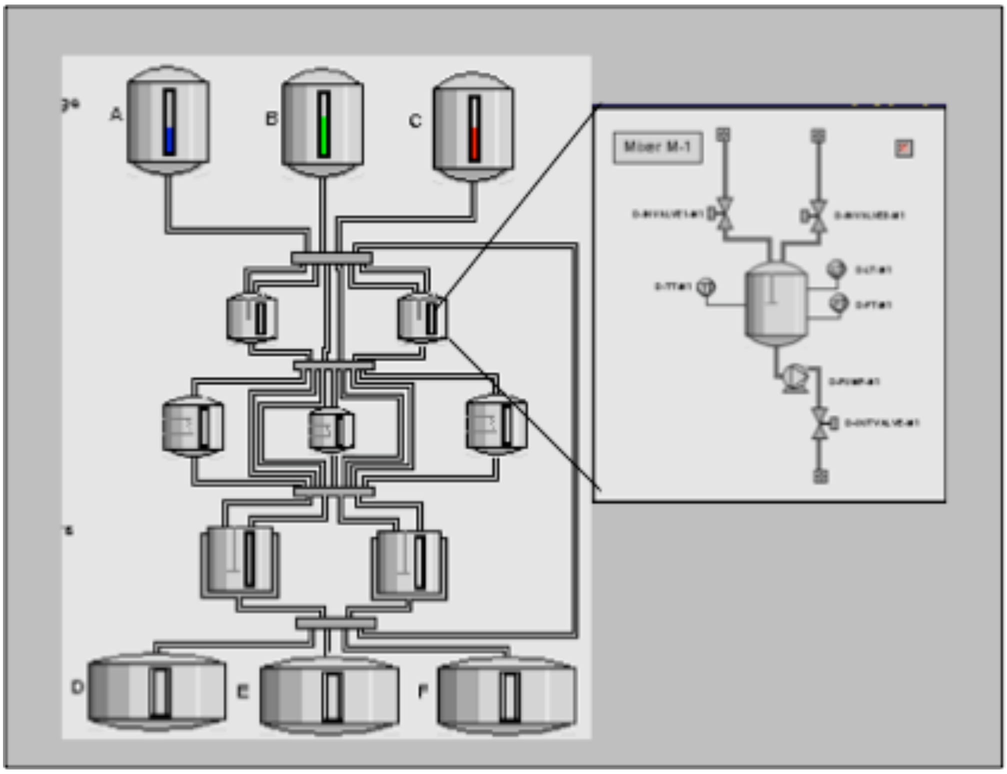

Figure 4: An example of a batch production process.

There are a number of characteristics typical to batch processes:

- Production of products in batches
- Discontinuous flow of materials.
- Production run determined by time/end point.
- Production goes through steps of operations.
- Fluid and dry processing.

Automation level

Even though, industrial production systems all have the same overall goal; to make money, the operation of the systems and the level and type of automation are different, see Figure 5.

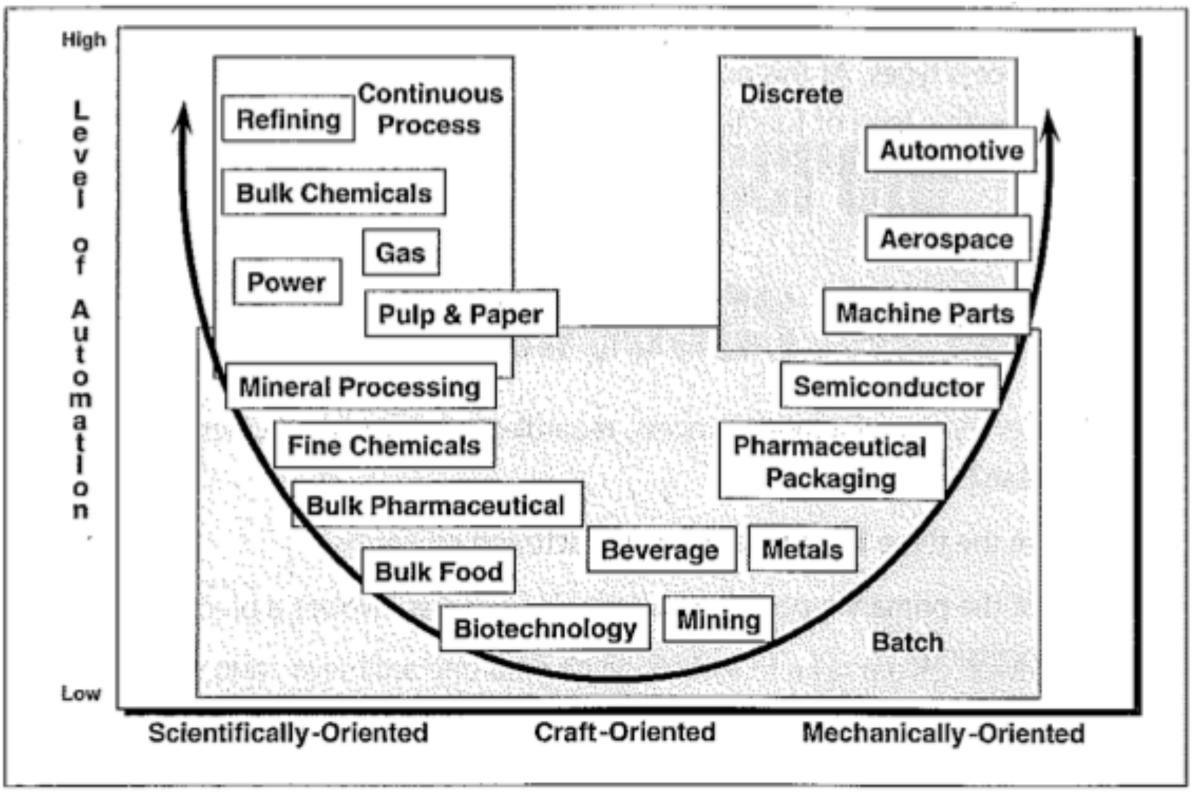

Figure 5: Automation level

Generally speaking, one could say that the continuous processes are scientifically oriented, the discrete processes are mechanically-oriented and the batch processes are batch-oriented. Continuous and discrete process industries often have a higher degree of automation than do the batch process industry. This might be due to the fact that there has been an economical value proposition having a high production volume for the continuous and discrete processes, whereas the economic value proposition for the batch processes has rather been flexibility. Due to the scientific nature of most continuous processes, their operation and automation have often been scientifically analyzed and understood to a great extent. The operation and automation of the discrete processes is understood from a mechanical perspective. The batch processes, which are more craft-oriented, have usually not been analyzed to the same extent. Since it is easier to automate a process has been scientifically or mechanically well-defined compared to the craft oriented processes, the level of automation is usually higher in these industries.

Modelling of industrial production companies

An Enterprise Architecture is a "model" or a "framework" which represents an enterprise at one point in its life cycle. This framework can be used to assist with planning and analysis of the enterprise, to select hardware and software products, to design organizational "reporting structures", and to study flow of materials and information through the enterprise. Without an Enterprise Architectural model, executives, managers, and technologists in an enterprise are essentially "running blind": making decisions based on their personal perception of the enterprise which is often not shared with the rest of the organization.

In the 1980'ies the Purdue Enterprise Reference Architecture (PERA) was defined. The purpose was to establish a framework within which an industrial production company could be understood and modelled. The work was performed at Purdue University, USA. Today The PERA model has served as an input to several international standards and various industrial and academic works.

The PERA model describes the complete life cycle of an enterprise; from enterprise definition (what should the enterprise do), through conceptual engineering, preliminary engineering, detailed engineering, construction, to operations, and from operations through decommissioning to enterprise dissolution.

The PERA model sees a company composed of three main components, see Figure 6:

- Production Facilities (Physical model)
- People (Organisational model)
- Control and Information systems (Functional model)

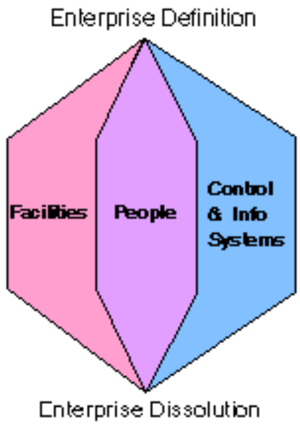

Figure 6: The three major components of an enterprise according to PERA.

The physical component describes the production facility, i.e., the structure of the company and its equipment. Since the physical plant is the most obvious component of an enterprise, many people think of a corporation only in terms of its physical assets. The Production Facilities of the enterprise may be represented by a series of "Architecture" diagrams. The architecture of continuous processing facilities (like oil refineries) are described with "Process Flow Diagrams", while discrete manufacturing (like a parts assembly plant) is described with Material Flow diagrams. For batch processes sequences can be used. PERA does not define any additional diagrams or documents for the Production Facilities, since an adequate set of these has already been evolved for most industries. However, PERA does place these documents within an Architecture which relates them to the appropriate enterprise development phase, and to the other components of the enterprise. A P&ID (Piping and Instrumentation Diagram (EAD) is a schematic representation of the piping, instrumentation, process equipment, and intermediate storage (tanks), and how these are connected. The P&ID also shows how instrumentation and control devices (like automated valves) are connected in "control loops" to effect regulatory control of the process units. Note that higher level optimization functions are not usually represented on P&IDs.

Even though they do not show up on a balance sheet, people are often equally or more important than physical assets to a company's long term competitive position. The organizational component describes the people working at the company and the relationships among them. Without an effective "nervous system" provided by a modern enterprise control and information system, the enterprise will be sluggish and soon overtaken by more agile competitors. The organizational structure of the enterprise may be represented by a series of "Org Charts", beginning with very "high level" during the conceptual Engineering Phase, and continuing to a complete definition of all positions, responsibilities and work processes by facility startup. PERA does not define any additional diagrams or documents to define the organizational and human aspects of the enterprise, since an adequate set of these has already been evolved for each industry. However, PERA does place these documents within an Architecture which relates them to the appropriate enterprise development phase, and to the other components of the enterprise.

The Functional component is used to describe the hierarchical structure of the control and information systems used within the company. The control and information Systems may be represented through a Control and Information Architecture Diagram (CIAD) or a Control and Information Network Diagram (CIND). The CIAD and CIND were developed as part of PERA.

Physical model of an enterprise

In order to depict what is available in the facility/plant in terms of assets, a Physical Model should be used. The international standards ISA88 and ISA95 define a physical model that is widely used within industry today. The physical model provides terminology and a hierarchy than can be applied to the physical equipment in the plant, see Figure 7.

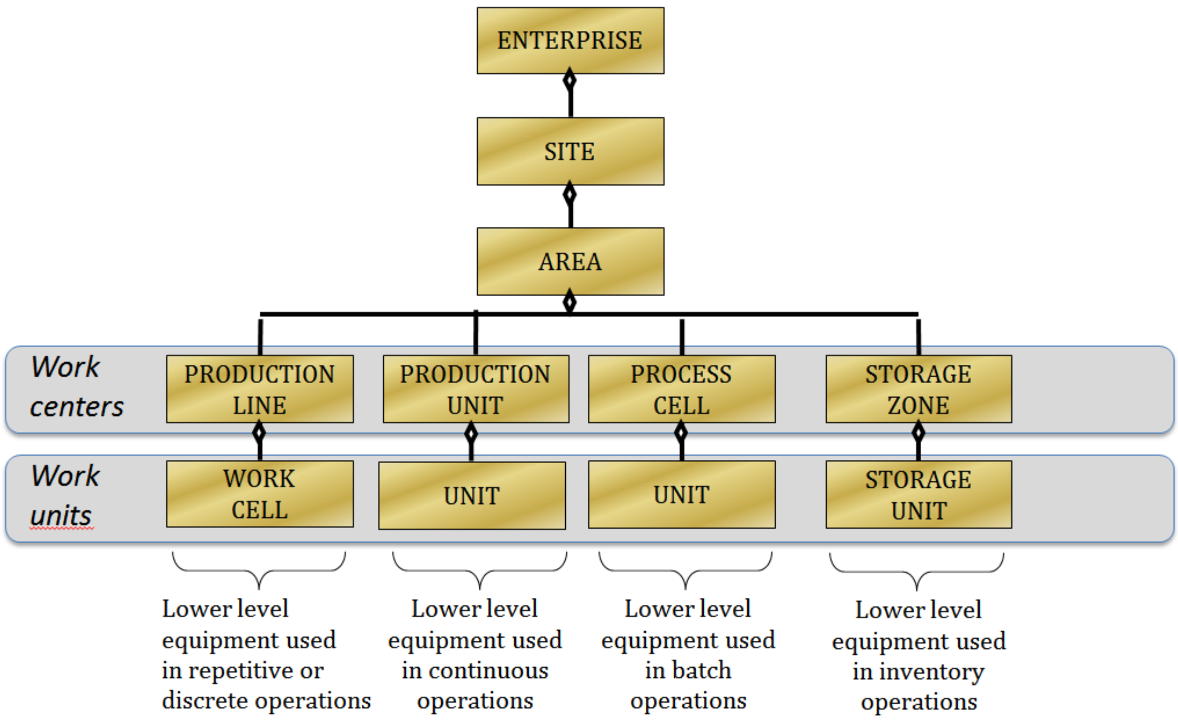

Figure 7: Physical model of an enterprise.

In the physical model, the highest level is the Enterprise, an enterprise consists of one or several Sites, a site consists of one or several Areas. The terminology used for the lower levels varies depending upon the type of industry they apply to (batch, continuous, or discrete). Below the Area we have Process Cells and Units (batch), Production Units and Units (continuous) and Production Line and Work Cells (discrete). This hierarchy is shown in Figure 7.

Functional Model of an enterprise

The functions performed within an enterprise can generally be divided in different functional categories or levels depending upon its focus and the timeframe it is acting within. The functions could be carried out manually or by various control and automation systems. The levels are shown in the functional model, see Figure 8.

Level 0 represents the physical plant. Level 1 and level 2 represent the levels with the hardest time-constraint. This could by seconds, milliseconds or even micro-seconds. Examples of functionalities that reside here are; sensing and manipulating the production process, monitoring, supervisory control and automated control of the production process. The types of functions residing within level 1 and/or level 2 also depends on the type of industry, i.e., continuous, discrete or batch.

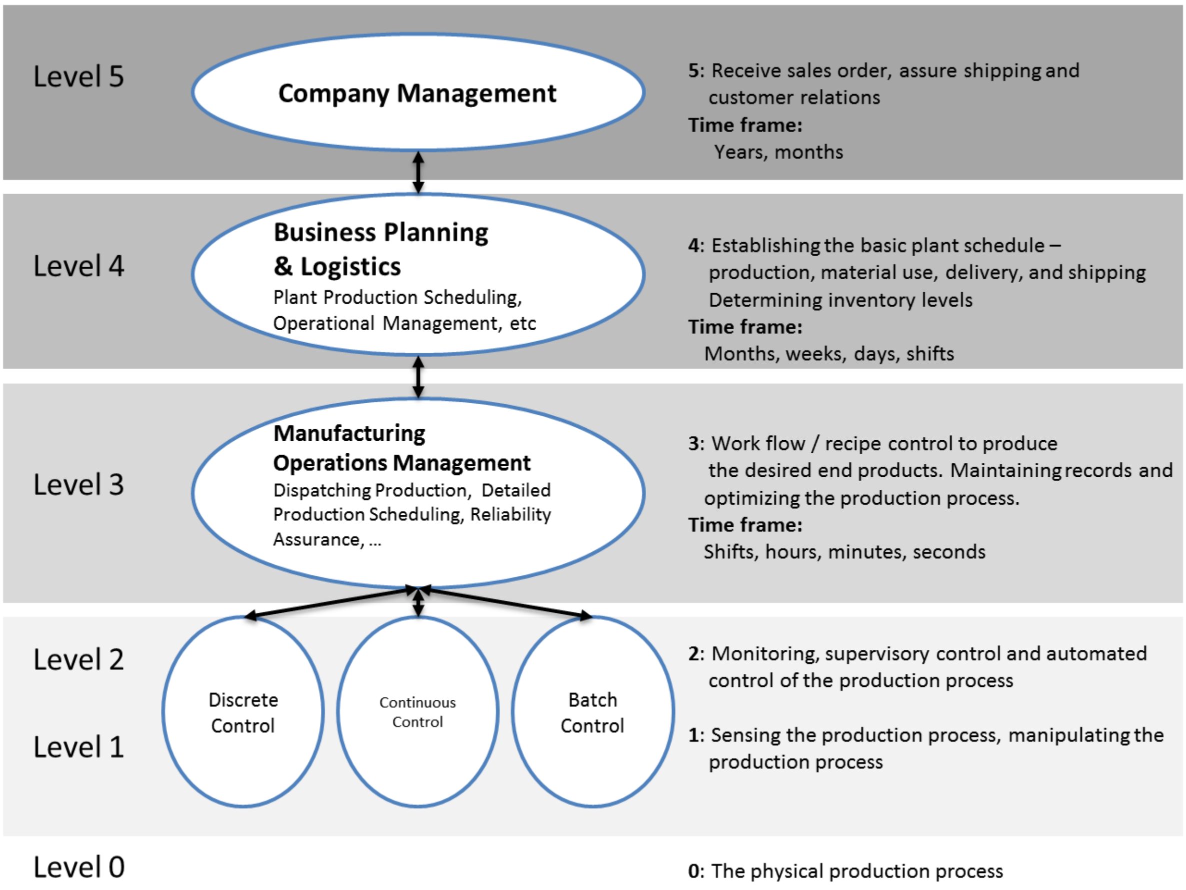

Figure 8: The functional model of an enterprise.

Level 3 is called the Manufacturing Operation Management level. Examples of functionalities within this level are; work flow control (continuous), recipe control (batch), material flow (discrete), as well as maintaining records and optimizing the production process. The time frame that these functions are acting within is usually shifts, hours, minutes and/or seconds.

Level 4 is referred to as the business planning and logistics level and the timeframe is month, weeks, days or shifts. Typical functionalities at this level are; establishment of the basic production schedule, shipping, delivery, determination of inventory levels etc.

Company management tasks such as receive sales orders and assuring shipping and customer relations are placed at level 5. The time frame at this level could be years or months.

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