# Describing, analysing and designing with the Production Description Language

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# Describing, Analysing and Designing with the Production Description Language

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## PREFACE

The Production Description Language (PDL) is a method to describe, analyse and redesign production organisations with small batch manufacturing. The PDL has been developed by Berenschot B.V. (Utrecht) in cooperation with Kienbaum Unternehemsberatung GmbH (Düsseldorf), the IFW (Hannover) and the industrial companies Windhoff AG (Rheine), Frencken Groep B.V. (Eindhoven) and Ets A & L Verhaegen SA/NV (Schendelbeke) in the EU supported research project HOPE (Human Oriented Production Engineering and Design for small batches, Brite EuRam, nr. 5670).

Based on results from the HOPE-project, a Phd-research is being executed at Eindhoven University of Technology (partly financed by Berenschot). The aim of this research project is to contribute to the improvement of the efficiency and the effectivity of production organisation redesign projects in Small and Medium Enterprises (SMEs). A method including supporting tools is developed that supports an external consultant in diagnosing a production organisation and making a redesign for that production organisation so that expertise on the field of production organisation is made accessible for SMEs. The PDL which is described in this report forms part of this method.

The author wishes to thank everybody who has contributed to the development of the PDL for their effort and useful comments.

Ir. M.J. Verweij
Eindhoven, October 1995

CONTENTS

SUMMARY

HOPE (Human Oriented Production Engineering and design for small batches) is the name of a EU supported research project that focuses on the development of a methodology to analyse and redesign production organisations with small batch manufacturing. One of the tools that has been developed in the HOPE proejct is the Production Description Language (PDL). The use of this tool in the methodology contributes to:

- the realisation of a description of a production organisation;
- the determination of a diagnosis of that production organisation;
- the development of a redesign for that production organisation.

The PDL consists of a number of Basic Types for production and supporting processes, the so called Production Basic Types (PBTs) and Service Basic Types (SBTs). The Basic Types provide an overview of the possibilities to organise the production and supporting processes. The suitability profiles indicate the situations in which the Basic Types realise a better or worse performance. To support the design process, guidelines have been developed to make combinations and configurations of the various Basic Types considering the required performance of a production organisation. Furthermore, procedures have been described to describe, analyse and redesign production organisations with help of the PDL.

Three possibilities are described to further develop the PDL:

- the use of the PDL as a morfology of production organisations
- the use of the PDL in participative design
- the use of the PDL to support of small and medium sized enterprises

## 1. INTRODUCTION

HOPE (Human Oriented Production Engineering and Design for small batches) is a EU-supported research project. The project focuses on the development of a methodology to analyse and redesign production organisations with small batch manufacturing. The methodology is based on the analysis and documentation of experiences and insights obtained in consultancy projects. The methodology consists of a rough framework with specific tools for every step in the framework. These tools can be used independent of each other, so that in each situation a "custom-made" method can be created.

One of the developed HOPE-tools is the Production Description Language (PDL). The use of this tool in the methodology contributes to:

- the realisation of a description of a production organisation;
- the determination of a diagnosis of that production organisation;
- the development of a redesign for that production organisation.

In this report the PDL is described and the possibilities are evaluated to use the PDL in production organisation improvement projects. First, a short description of the HOPE-project and the development process of the PDL is given followed by an overview of the description language. After that, the procedures to describe, analyse and redesign a production organisation are explained. Finally, the possibilities are reviewed to further develop the PDL for its use in production organisation redesign projects.

## 2. THE HOPE-PROJECT

HOPE (Human Oriented Production Engineering and design for small batches) is the name of a EU-supported research project within the Brite-EuRam II-programme (project number 5670). The project is being executed by the management consultancy firms Berenschot B.V. (Utrecht, NL) and Kienbaum Unthernehmensberatung GmbH (Düsseldorf, DE), the Institute for Production Engineering and Machine Tools (IFW, Hanover, DE), and three industrial companies in Germany, the Netherlands and Belgium.

The HOPE-project focuses on the development of a methodology to analyse and redesign a production organisation with small batch manufacturing. The project was started because current methodologies (such as Lean production and Business Process Redesign) focussed more on large batch sizes and mass production. Furthermore, analysis tools did exist in many variants while tools to support a structured design process were not available.

In the HOPE-methodology, output- and market characteristics of a company are compared systematically to the possibilities to structure the production organisation. In this way, the decision process to change the production organisation is supported. The methodology is based on the analysis, adaptation and documentation of experiences and insights obtained in redesign projects. Furthermore, experiments are executed in the three participating industrial companies to further develop the methodology (see e.g. Nelstein & Verweij, 1995). A short description of the methodology is given in EUT-report no. 73 .

## 3. THE DEVELOPMENT OF THE PRODUCTION DESCRIPTION LANGUAGE

One of the developed tools in the HOPE project is the Production Description Language (PDL). The PDL supports the description and analysis of a production organisation. Besides that, the PDL is used to develop alternatives to redesign that production organisation.

The development of the PDL in the HOPE-project is based on practical experience. The Basic Types described in section 5.2 have been developed by analysing about 30 companies that had been involved in redesign projects with guidance of consultants of the project partners. In addition to this a literature survey has been executed[1]). Case studies on production organisations and redesign projects have been analysed. In this way the use of the PDL to describe companies that were unknown to the consultants could be checked and the documented experience could be validated. The usefulness of the PDL for production organisation description has been tested by describing the participating industrial partners in the HOPE-project.

The further development of the PDL aims at making the PDL-descriptions more recognisable, increasing the insight that can be obtained from the descriptions and improving the transferability of the PDL to other consultants. A judgement on the achieved results and suggestions for improvements have been asked from a group of experts[2]) by means of a questionnaire. The questionnaire concentrated on the developed Basic Types for production (the PBT's), their suitability profiles and the procedure to describe a production organisation. Additionally, some questions have been asked to determine the domain of companies in which the PDL can be used more explicitly.

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[1]) An overview of the reviewed literature concerning the PDL is given in the section "Literature" at the end of this report

[2]) The group of experts consisted of members of the steering committee of the Phd-research project of the author. This group had been selected because the members possess expertise on the subject and were familiar with the goal of and the activities in the HOPE-project. Their involvement in the HOPE project, however, was so limited that a critical evaluation of the HOPE-results by this group was still possible

Conclusions, contradictional answers and suggestions for improvements have been discussed in a workshop with the expert group. In this workshop the presented conclusions and suggestions for improvements have been accepted by the group. The improved PDL will be explained in the following sections, after a short discussion on the domain of companies in which the tool can be used.

## 4. SMALL BATCHES

The HOPE-project focuses on companies with "small batch manufacturing". A definition for the term small batch manufacturing has been looked for to identify the type of companies on which the research project will focus. In the literature small batch manufacturing has been described in a number of ways. Botter(1991) characterises production departments as batch manufacturing if many products with a relatively low turnover are produced. Bertrand c.s.(1990) characterise production departments as one of a kind or small batch production if the material complexity is low and the capacity complexity and variety in routings are high. This complexity is caused by a low degree of repetition and a high diversity of the products.

However, the definitions given in the literature do not refer to characteristics of the structure of the production organisation but to product characteristics and/or logistical characteristics. Therefore, an exact definition of small batch manufacturing based on these descriptions will not support the localisation of the research domain. From a viewpoint of organisation structuring, it seems to be more useful to identify the relevant product characteristics and to determine the design questions that have to be solved to produce these products. A company belongs to the research domain if it produces products with these characteristics and if it has to solve the stated design questions.

Characteristics of products that are produced in small batches are:

- The products are produced in low quantities compared to the total amount of products being produced;
- The products are produced in a high variety;
- The fysical and/or the organisational complexity of the products is high;
- The products are produced in a number of production steps in an environment which is not automated completely.

These product characteristics require certain arrangements in a production organisation because the following problems may occur otherwise:

- complex communication flows;
- long throughput times and/or waiting times;
- low controllability of the production processes;
- intensive internal transport;
- long change over times.

Design questions that are important to eliminate these problems focus among others on the grouping of machines and production orders, the determination of the customer order decoupling point, and the organisation of process planning, parts supply and tool management activities. These design questions do not have to be solved in every situation nor are they as relevant in any case. Dependent on specific circumstances more or less attention has to be paid to each question.

## 5. THE PRODUCTION DESCRIPTION LANGUAGE

### 5.1 BASIC ASSUMPTIONS

The Production Description Language (PDL) has been developed to support the redesign of production organisations with small batch production. The PDL has been based on the systems theory (In 't Veld, 1992; Botter, 1991). In the systems theory, an organisation is considered as an open system that fulfills a certain function in its environment. To fulfill this function, a number of processes takes place in the organisation: production processes (directly focused on the production of the output by which the organisation fulfills its function) and supporting processes (focused on securing, maintaining and controlling the production processes). The processes consist of a number of mutual dependent activities that can be grouped into units. A unit (consisting of a group of people and their production means) in which a (part of a) production process takes place is called a production module; a unit in which supporting processes take place is called a supporting module.

A production organisation can be constructed by combining a number of production and supporting modules (called a configuration). The PDL gives insight in the processes in a production organisation by showing the internal structure of the production and supporting modules and the relationships between the modules.

### 5.2 BASIC TYPES FOR PRODUCTION AND SUPPORTING PROCESSES

The PDL contains descriptions of a number of Basic Types for production and supporting modules, the Production Basic Types (PBTs) and the Service Basic Types (SBTs). The Basic Types provide an overview of the possibilities to structure the production and supporting processes. By analogy with product modularisation, this overview has been developed on the level of modules so that an acceleration of the design process may be achieved. Therefore, such a module needs to be a subsystem in which all relationships between the elements of the system have been described. In the HOPE-project the machine configuration, the organisation structure and the communication structure are mentioned explicitly as a part of the Basic Type description. For the production modules these aspects have been operationalised by considering the people, the work stations and the data as the elements in a Basic Type.

Additionally, relationships between these elements have been determined. Various combinations of the relationships between the elements have been elaborated into Basic Types for production modules: the PBTs. The Basic Types have been characterised using the design questions stated in section 4. An overview of the possibilities to structure the production organisation is created by elaborating the Basic Types in such a way that they represent "extreme" solutions to the design questions. Six PBTs have been elaborated:

- Functional department
- Manufacturing cell
- Flexible Manufacturing System
- Multi-productline
- Flow dock
- Dock

These Production Basic Types have been elaborated and characterised using schematic representations in appendix 1.

The Service Basic Types (SBT's) give an overview of the possibilities to structure the supporting processes. The following supporting processes have been distinguished:

- Transport
- Storage
- Production control
- Quality assurance
- Process planning
- Maintenance
- Tool management
- Waste disposal

An overview of all the SBTs is given in appendix 2.

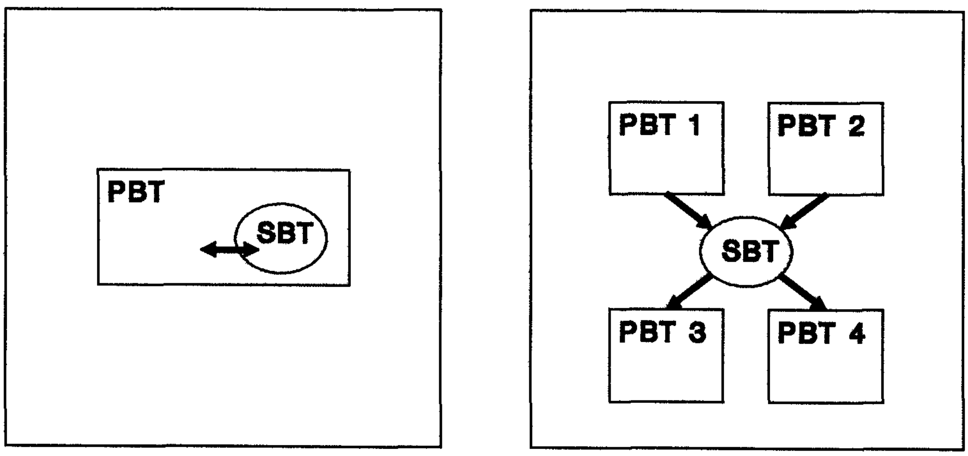
### 5.3 SUITABILITY PROFILES

Each Basic Type has certain advantages and disadvantages that influence the performance of the Basic Types in certain situations. The performance can be measured by the costs, the troughput time and the quality of the realisation of the required production programme. Specific characteristics of the production programme will lead to a choice for different Basic Types or configurations of Basic Types. The Basic Types can be mutually compared on their relative performance in relation to characteristics of the production programme. In this way an overview is created of the situations in which the Basic Types realise a better or worse performance. Such an overview is called a suitability profile of the Basic Type. The suitability profiles of the Production Basic Types together with an argumentation for the scores are given in appendix 3.

The suitability profile of a Manufacturing Cell for instance, indicates that in this Basic Type relatively high numbers of homogeneous products can be produced. Fysically as well as organisationally complex products can be handled. A Manufacturing Cell is less suited for production programmes with high fluctuations in production numbers and product types per time period because the cell is designed for a certain product group. The argumentation for this suitability profile can be found in appendix 3.

## 5.4 COMBINATION AND CONFIGURATION RULES FOR THE BASIC TYPES

A production organisation normally consists of a number of production and supporting modules that are related to each other because production and supporting processes are mutually dependent. Supporting processes basically are executed in two ways: by special departments or integrated in the production processes. In the latter case a Basic Type for the supporting process is located inside the Basic Type for production (this is called a combination of PBTs and SBTs); in the former case the SBT is located between the PBTs (this is called a configuration of PBTs and SBTs, see figure 1).




**Combination** **Configuration**

**Figure 1 Combinations and configurations of PBTs and SBTs**

To support the design process, guidelines have been developed that give an overview of the possibilities for combinations and configurations of the Basic Types and the advantages and disadvantages given a required performance that has to be realised. These guidelines consist of the following parts (the guidelines are illustrated by a number of examples in appendix 4):

*a. Combinations of integrated SBTs in the PBTs*

Resulting from the chosen solution for certain design questions, a number of supporting processes have already been integrated in the PBTs completely or partly already. For example in a Manufacturing Cell, the production control is executed partly in the cell because the people coordinate the work themselves. This part of the guidelines shows the possibilities of integrating the supporting processes in the PBTs (i.e. which SBTs can be used). Different combinations lead to a number of variants of the Basic Types.

*b. Level of integration*

This part of the guidelines considers the degree of integration of the supporting processes in the production processes. Checklists have been developed for every supporting process that enumerate the activities of the processes. These checklists can be used to determine which part of the process will be integrated and which part not. In addition to these checklists, the consequences of integration are described so that they can be analysed in a specific situation.

*c. Possible configurations of PBTs and SBTs*

A configuration of PBTs and SBTs exists if the supporting processes are executed in other departments than the production departments. This part of the guidelines shows the possible configurations of PBTs and SBTs.

*d. Preferred configurations with respect to the required performance*

The specific advantages and disadvantages of all possible configurations have been described. These advantages and disadvantages are dependent from the performance criteria set for the production organisation. If low costs are required, the developed configuration will be different than in the case of short throughput times. In this last part of the combination and configuration rules rankings are given of the configurations that promise the best results given a required performance. Configurations of individual PBTs and SBTs as well as configurations of SBTs and different PBTs have been considered.

## 6. DESCRIBING AND ANALYSING PRODUCTION ORGANISATIONS WITH THE PDL

Guidelines have been developed to describe and analyse a production organisation with help of the PDL. These guidelines support the presentation of the relationships between the production and service modules and their internal structure in a way that insight can be obtained in the processes in the production organisation. These guidelines will be described in this section.

*Domain definition and collection of data*

The first step to make a production organisation description considers the definition of the part of the organisation that will be described. The domain definition depends from the size of the organisation and the stated problem. The described domain may be the whole production organisation or a part of it that can be isolated from the rest. The production organisation consists of the production structure (= the grouping and coupling of operational functions (preparing and direct production activities) in a production system) and the control structure (grouping and coupling of norming and coordinating activities with regard to the operational functions, De Sitter c.s., 1987).

In appendix 5 a checklist is provided that contains the subjects on which information has to be available to make a PDL-description.

*Description of the relationships between production and supporting modules*

A description of a production organisation is divided into different levels of detail. The highest level of detail describes the relationships between the identified production and supporting modules. Production and supporting modules do not have to equal the existing departments in an organisation completely although normally they will be quite similar. Changes in the product flow or the location of buffers or stores are typical indicators for the identification of modules. If supporting activities are integrated in the production, they are not considered on this level. Only groups of people who have as a main task to execute indirect activities are indicated as a supporting module at this level. The modules are characterised with help of the Basic Types but are further considered as black boxes on this level; the structure of the Basic Types gives enough information. The attention is focused on the relationships between the modules. Three types of relationships are represented: production, control and information relationships. Production relationships involve the flow of any kind of material between the modules: raw materials, subassemblies, end products but tools, spare parts, etcetera. Control relationships regard the way the modules are coordinated. This involves decisions on tasks that have to be performed, priority setting, and so on. Information relationships consist of documents going from one module to another or explicit signals that are exchanged. The symbols that are used to represent the production and supporting modules and the relationships have been given in figure 2. In figure 3, an example is provided of a PDL-description on this level. The abbreviations are explained in the appendices 1 and 2.

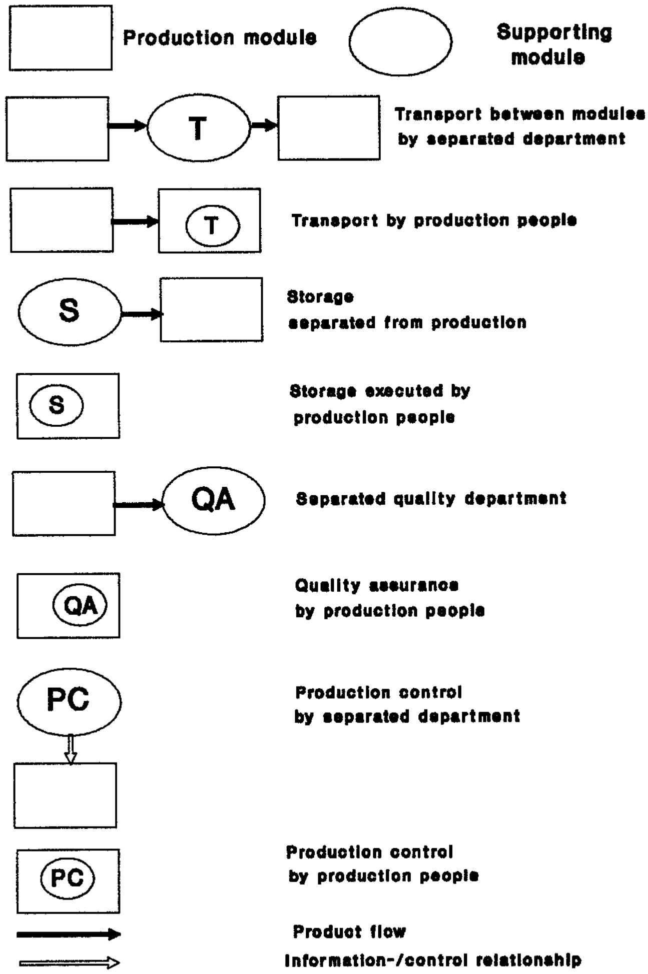



Figure 2 Picture stones PDL description

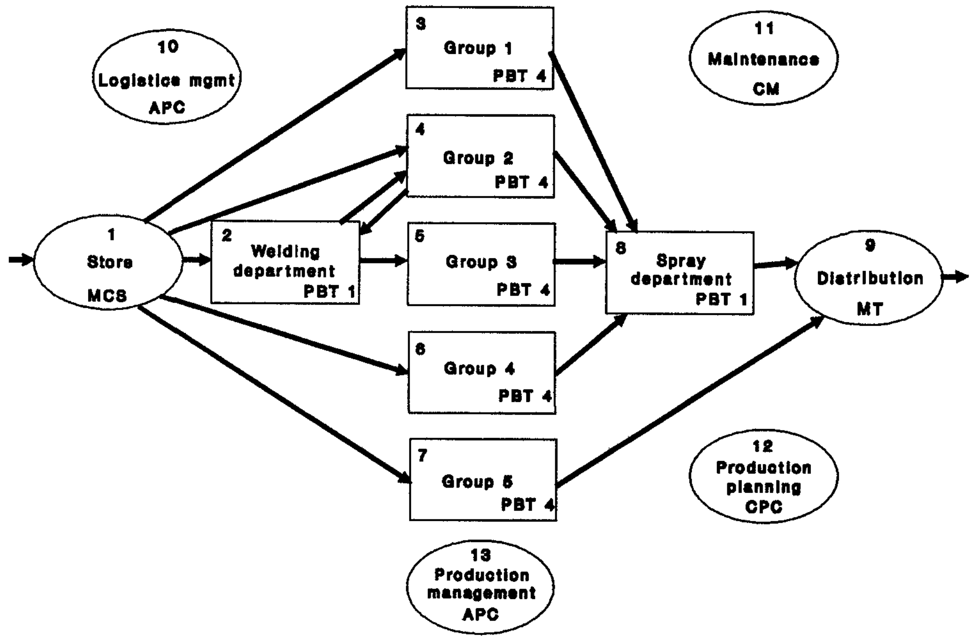



**Figure 3 Relationships between production and supporting modules**

*Description of individual modules*

A lower level of detail of a module is pictured if more information on the structure of the module is required. This information may be required, for instance, for the analysis or redesign of a certain department or the description of all activities in a supporting process. If such a picture is made, an inventarisation of all the tasks that are executed in the module is made first. Both production and supporting tasks are considered. The representation of the integration of certain tasks in other modules is already shown in figure 2. An overview is achieved over the division of tasks between the people and the departments if the described method is followed systematically. In appendix 6 a PDL-description on two levels is provided of one of the industrial companies in the HOPE-project including explanatory tables.

*Analysis of a PDL-description*

The PDL description of a production organisation can be analysed in a quantitative as well as in a qualitative way. The quantitative analysis focuses on the quantification of the various relationships (throughput times, stock levels, production flow volumes, and so on). The qualitative analysis comprises a comparison of the production programme with the suitability profiles of the identified Basic Types and a visual analysis of the descriptions. The following questions are checked in the qualitative analysis:

- Are the identified Basic Types suitable in this situation given the profiles of the Basic Types? What are possible alternatives? These questions consider both the production and the supporting processes.
- Are the described combinations of Basic Types functional?
- Do the described modules differ very much from the Basic Type structure? If so, what reasons can be found?
- Are all modules connected to other modules? If not, why are certain modules isolated?
- Are the flows that are formed by the described relationships (production, control and information relationships) useful? E.g. Can loops be identified in the flows that cause delays?
- Is the number of supporting modules higher than one per supporting process? If so, why?
- Do the flows pass by different supporting modules without passing a production module? If so, why?
- Can other remarkable aspects be noticed (e.g. a central point in which all flows end)?

The answers to these questions are possible indications for bottlenecks or possible improvements in a production organisation.

## 7. Designing production organisations with the PDL

Van Aken(1994) distinguishes three types of designs: object designs, realisation designs, and process designs. He uses the following definitions: a *design* is a model of an entity or process that has to be realised. An *object design* is a model for the situation that has to be realised. A *realisation design* is a model of the realisation process. A *process design* is a model of the design process itself, including for example the way the design specifications will be developed, how and by whom the data will be collected, how and by whom the design process will be executed (if that can be designed on forehand), how the decision processes in the projects should be structured, and so on. The PDL described in the former sections supports the creation of an object design of a production organisation.

The various steps that have to be performed to realise such a design with support of the PDL are shown in figure 4. The required information to start the design process consists of a description of the existing situation and an overview of the production programme that has to be produced by the organisation.

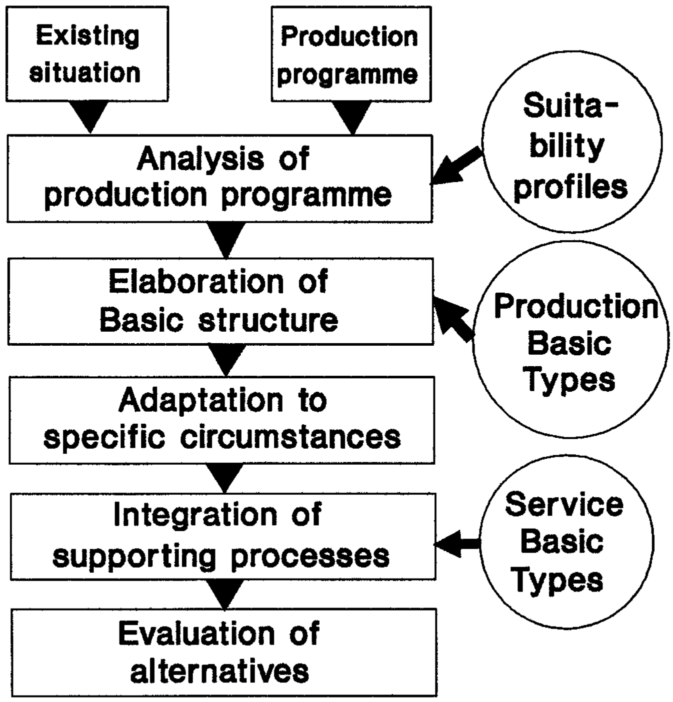



**Figure 4 Designing with the PDL**

*Analysis of the production programme*

The first step considers the analysis of the production programme. The production programme is described using the characteristics of the suitability profiles of the Basic Types. Furthermore the product flow structure is analysed: is this flow convergent, divergent or has it another structure? A description of the production process (the various steps that are executed in the production) completes the picture of the production programme. Based on this information, the production programme is clustered into groups of finished products and/or semi-finished products. These groups provide the basis for the modules that are going to be designed.

If it is not possible to form satisfying groups, more detailed methods have to be used to cluster the products. Problems to form groups may arise for example if the structure of the product flow is not clear or because the production programme is too diverse to get enough insight in the production processes with the available information. In this report this will not be explained in further detail.

*Elaboration of basic structure and adaptation to specific circumstances*

The production programme characteristics of the previous step are compared to the suitability profiles of the Production Basic Types (figure 5). From the available Basic Types those Basic Types are selected that seem to have perspectives for further elaboration. This elaboration consists of adaptations to specific circumstances in the environment for which the design is made (e.g. restrictions in production technology, floor space, etc,).

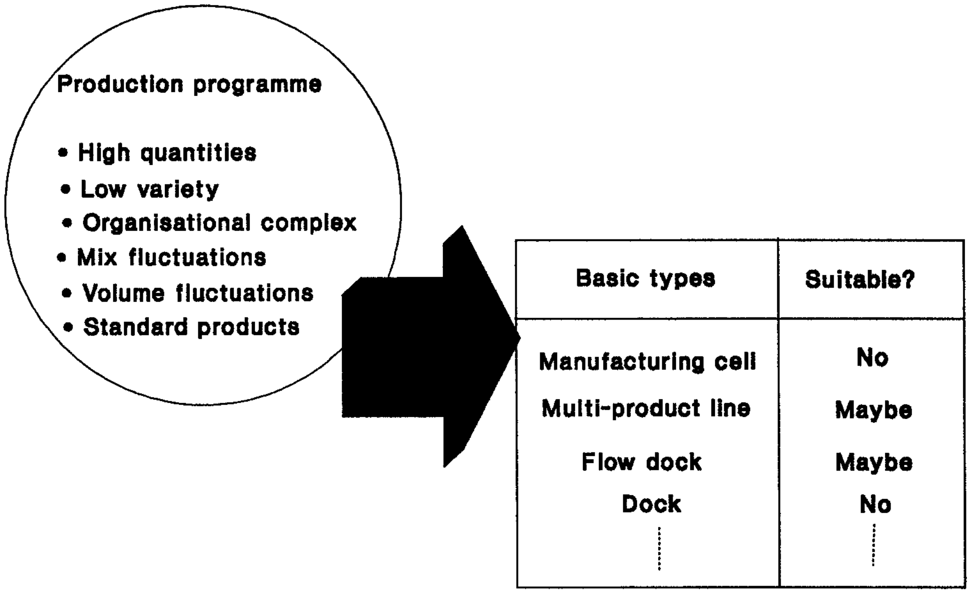



**Figure 5 Selection of PBTs**

*Integration of supporting processes*

The integration of the various supporting processes is started after the production processes have been described in a number of alternative ways. Suitable Service Basic Types are selected and adapted to the specific circumstances using the suitability profiles and the combination and configuration rules. In this process the available capacity of people and means, the education and experience of the people, the influence of integration on the production performance and possible side effects (e.g. for the system of remuneration) are considered. The number of developed alternatives may be increased if different Basic Types seem to be useful. A few alternatives for the redesign of a department of one of the companies in the HOPE project are shown in figure 6 as an illustration of this process.

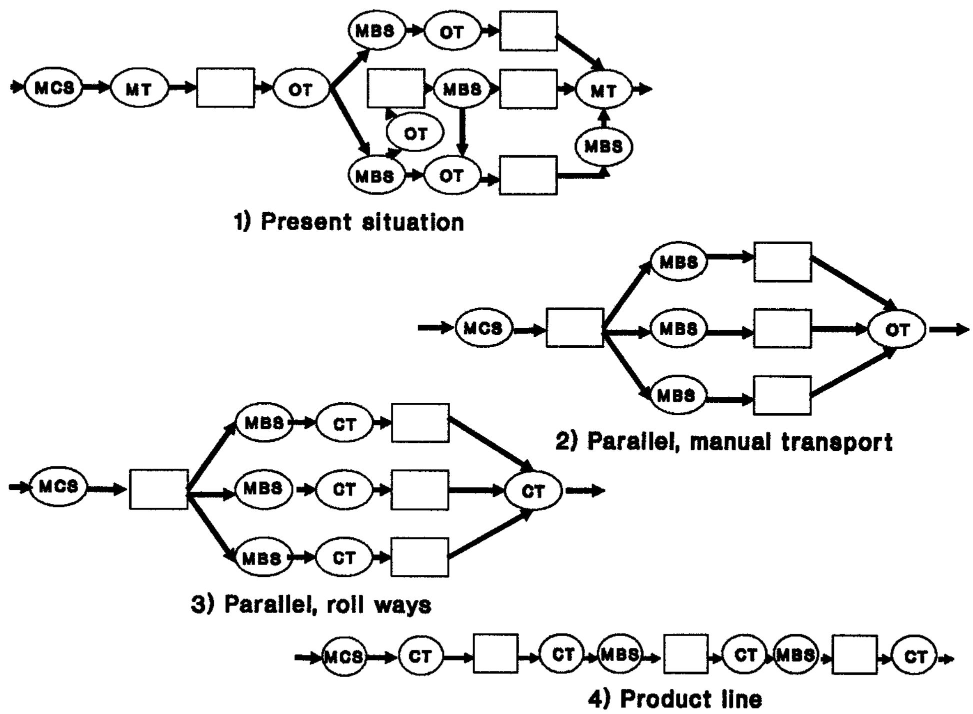



**Figure 6 Alternatives for a production department**

*Evaluation of alternatives*

The last step in the design process considers the evaluation of the alternatives that have been developed. The evaluation serves to select one of the alternatives.

## 8. FURTHER DEVELOPMENT OF THE PDL

The PDL has been developed as a tool in the HOPE methodology for analysis and redesign of production organisations with small batch manufacturing. In this last section, the possibilities are discussed to further develop the PDL. The following possibilities will be discussed:

- The use of the PDL as a morfology of production organisations;
- The use of the PDL to support participative design;
- The use of the PDL to support small and medium enterprises.

These possibilities to further develop the PDL are not new applications of the PDL nor do they exclude each other. They have to be considered as focus points in the further development of the PDL.

## 8.1 THE PDL AS A MORFOLOGY OF PRODUCTION ORGANISATIONS

Innovative processes (e.g. product innovation) are considered to be creative processes (Buijs, 1987). A creative process can be divided in a number of phases each consisting of a divergent and a convergent part. In the divergent part as much as possible alternatives are strived for; in the convergent part a selection is made of these alternatives. Creativity techniques are tools to support the divergent part of the phases. The creativity techniques can be categorised into three groups:

- Techniques based on association, like brainstorming and brainwriting;
- Techniques based on creative confrontation, like synectics and lateral thinking;
- Techniques based on systematic decomposition, like morfologies and progressive abstraction.

By analogy with product design, creativity techniques can be used to support (production) organisation design also. The Basic Types and their suitability profiles as they have been described in section 5 could be used as a basis for the elaboration of a morfology of production organisations. A morfology originally has been developed as an analysis tool (e.g. for flora). A problem (the entity under analysis) is decomposed in subproblems that can be solved independently from each other and that are combined again afterwards. A morfology becomes a creativity technique if different solutions for subproblems are combined into new designs. In the case of the PDL as a morfology, the PBTs and SBTs can be considered as solutions for subproblems (the design of parts of the production organisation) that can be used to develop a number of alternatives in a short time period.

## 8.2 PARTICIPATIVE DESIGN

Participative design is a way to structure the design process in which involved people from the organisation and a counsellor (e.g. an external consultant) make a new design together. The role of the counsellor in this process is a mixture of an expert role (in which expertise on the problem is given) and a process role (in which the design process is coached only, Van Aken, 1994). Akkermans(1995), for instance, proposes a method for "Participative Business Modelling" to support strategic decision processes. He concludes that participation leads to a better commitment to execute the recommendations from the modelling process. A prerequisite for this, however, is the willingness to communicate with each other openly.

Another example of participative design is Carpentrypoly (Ehn & Sjögren, 1991), a game with which the people in a company have the possibility to evaluate the effects of different business ideas and strategies. The game has been developed for small and medium-sized carpentry shops in Sweden. A Layout Kit and a Specification Game belong to the game tools. The Layout Kit consists of a number of cards, each with an icon of standard machines or tools. The existing factory layout is modeled by the players with help of these cards. In addition to the existing organisation, alternatives may be developed. The Specification Game supports the structuring of the results from the investigation of the factory layout. Requirement and necessary changes in the organisation are placed in different categories (product, technology, organisation, work). After the Specification Game, an "ideal design" of the layout is made with help of the Layout Kit and based on the identified requirements. In further steps this design can be further detailed into the redesign of individual work stations.

The PDL and especially the Basic Types seem to provide opportunities to develop a similar game focused on the redesign of a production organisation. The schematic representations of the PBTs (see appendix 1) may serve as a basis for the development of icons for production departments. Production organisations may be modeled in this way, after which the results may be discussed and alternatives may be developed.

Ehn and Sjögren(1991) define 4 phases for a game in which a "future workshop" can be developed:

- In a preparation phase, the consultants are made familiar with the company and meet the participants of the game;
- In a critique phase, problems are inventarised and structured. This phase is focused on the transformation of "negative" problems into "positive" opportunities for improvements;
- In the phantasy phase, ideal designs are developed without considering the possible limitations of the existing organisation;
- In the implementation phase, alternatives are developed and selected taking into account this limitations so that a realistic design will be achieved.

By analogy with these phases, a workshop could be developed using the PDL. In this workshop, a number of people from a company and one or two consultants should participate. A possible procedure for such a workshop is:

- Getting familiar with the PDL (using a case);
- Modeling the existing situation and identifying bottlenecks;
- Brainstorming on possible improvements;
- Elaborating an "ideal design" using the PDL;
- Determining a long term realistic design and short term actions;
- Evaluating the workshop

### 8.3 SUPPORT OF SMALL AND MEDIUM SIZED ENTERPRISES

The availability of knowledge in the field of organisation design is insufficient for small and medium sized enterprises (SMEs). These enterprises do not have much knowledge themselves and they ask less support from consultants or research institutes than bigger companies. The overview of the sources from which these companies may get support is unclear en diffuse. Furthermore consultancy projects can be very expensive while SMEs do not possess much time and money to spend. Consultancy projects in general and, more specific, organisation redesign projects tend to be more expensive if they are executed by more experienced consultants, if they need more time, and if they ask for more intensive support. Instruments are available to diagnose a company in a short time period. However, few tools exist to support the redesign activities following the diagnosis. Therefore, these activities may need much time to be performed.

The PDL possesses opportunities as a tool for a methodology that supports a consultant to diagnose and redesign a production organisation of SMEs. If such a methodology is used, consultancy costs for the companies could be reduced by the limitation of the necessary time the consultants have to spend and by the possibility to have the work executed by less experienced consultants.

A PDL description can be made in a short time period. A diagnosis of a company can be made if such a description is supported by some quantitative information. Furthermore, the documentation of knowledge and practical experience of consultants in the Basic Types and the suitability profiles makes this knowledge available to less experienced consultants. The procedure to diagnose a production organisation in a short time period has been elaborated in EUT-report, nr 73.

Possibilities to accelerate the design process do exist as well. A rough design could be developed with help of the PDL. In this design, the most important design questions should have been solved. Such a design of main topics, a so called sketch design, should be made in a way that the company will be able to continue the further development of a detailed design and the implementation on its own or with minimal support. One of the possibilities to develop such a design could be the organisation of a workshop as has been described in the previous subsection.

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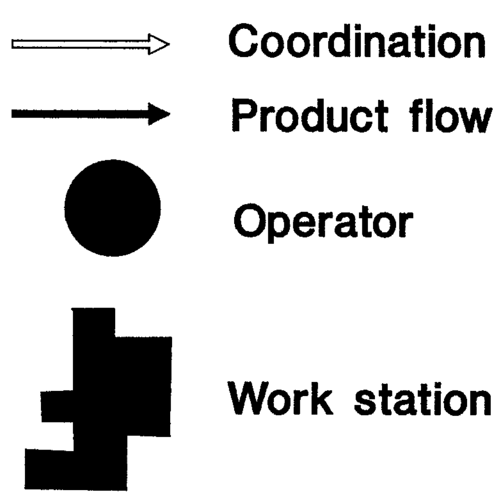
APPENDIX 1 PRODUCTION BASIC TYPES (PBTS)

The Production Basic Types (PBTs) give an overview of the possibilities to structure the production organisation. In this appendix, the 6 developed PBTs will be described by schematic representations and textual explanations.

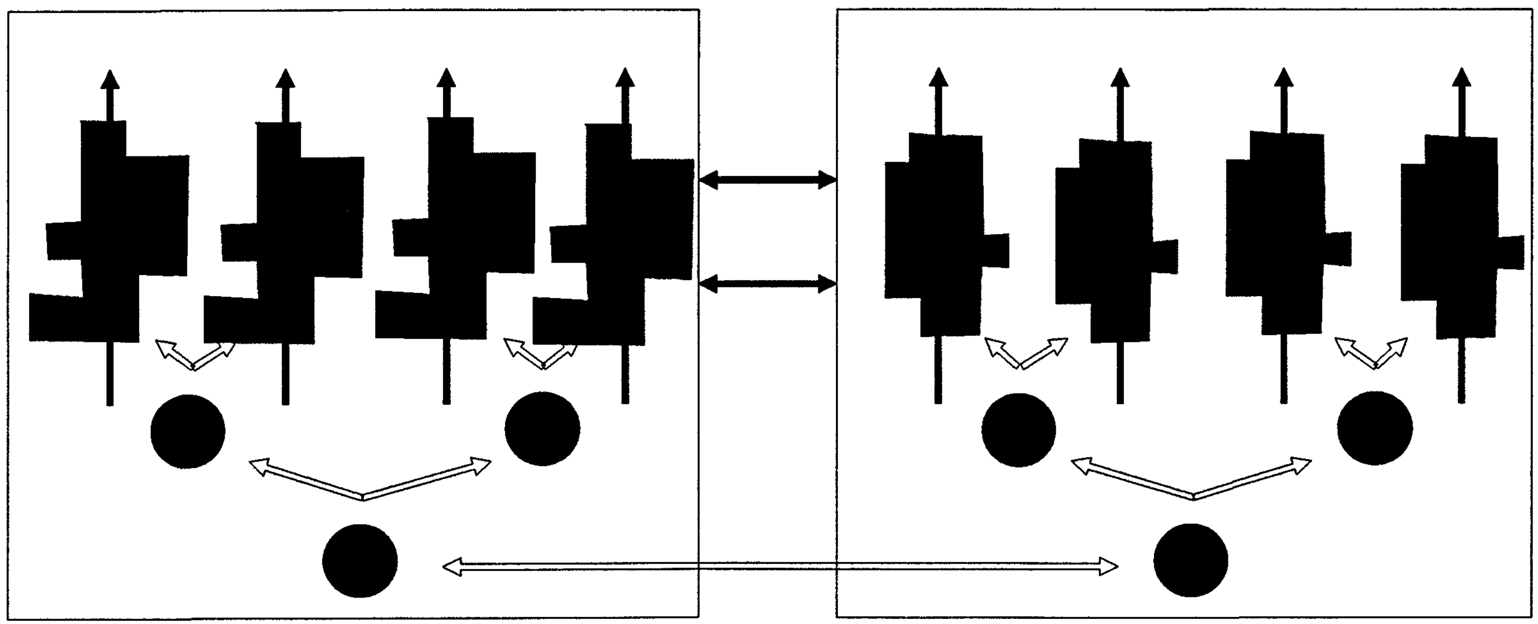
The following PBTs have been developed:

| | |
|---|---|
| PBT 1 | Functional department |
| PBT 2 | Manufacturing cell |
| PBT 3 | Flexibel Manufacturing System |
| PBT 4 | Multi-productline |
| PBT 5 | Flow dock |
| PBT 6 | Dock |

The following symbols are used in the schematic representations:



# PBT 1, Functional department

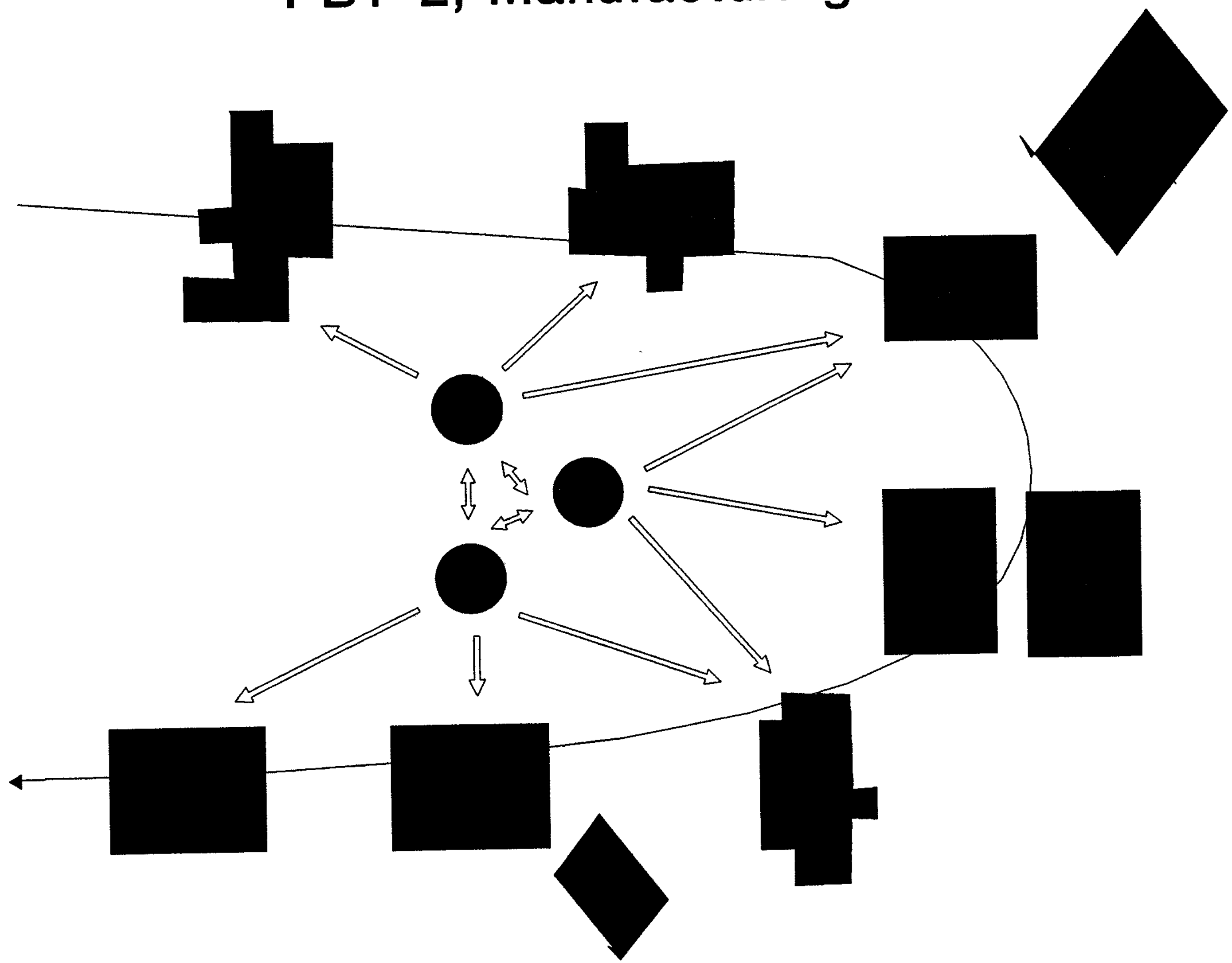


## PBT 1 FUNCTIONAL DEPARTMENT

*Description*
In a functional department, the work stations are connected in a parallel way and not specialised. The products follow variable routings, only passing one of the work stations in the department. On each work station, one task is executed. Every work station is operated by one operator; possibilities exist to operate a few work stations at the same time. All supporting processes are separated from the production process. Raw materials, products and tools are distributed to the department from a central point. Quality assurance and process planning have been centralised as well. Finally, coordination takes place from a central point also.

*Characterisation*
The structure described above is very flexible. The amount of work on each work station can be varied without influencing the other work stations. The specialisation on one task supports learning effects so that new and unknown products can be handled as well as changes in the product mix of existing products. However, some restrictions may be mentioned. Longer waiting and throughput times will occur if the amount of work in the departments increases. Therefore, this amount has to be controlled carefully. Furthermore, changes in the product mix require an intensive planning and balancing between departments because of the high number of possible routings. Another important aspect are the set up times that can occupy much capacity of the work stations. A functional department is coordinated centrally because an overview of the whole production flow can only be reached at this level. Coordination between departments is focused on the production sequence, the coordination in the departments is focused on the allocation of the jobs to the work stations. Supporting processes (process planning, quality assurance, tool management) have been centralised to achieve a better efficiency.

# PBT 2, Manufacturing cell

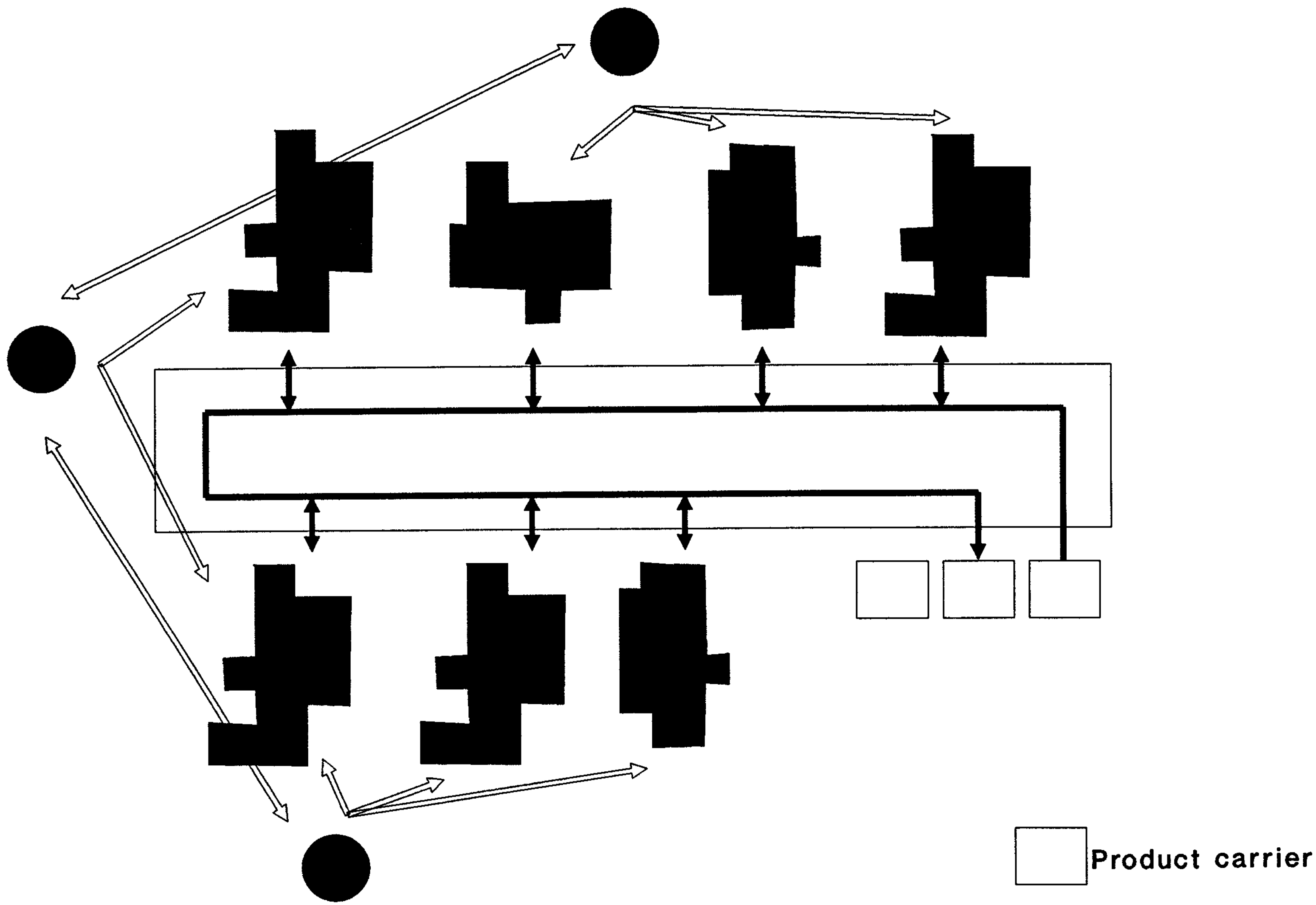


## PBT 2 MANUFACTURING CELL

*Description*
A manufacturing cell consists of a number of serial connected work stations. The products follow a fixed routing between the work stations. On every work station one task is executed; the work stations have been specialised for a specific group of products. Supporting processes like storage, internal transport, quality assurance, tool management, and process planning are executed in the cell. Coordination between the work stations is executed in the cell as well.

*Characterisation*
A manufacturing cell is structured to cope with a certain group of products; the structure and capacity of the work stations are specialised for this product group. Therefore, the variety of products that can be produced in a cell is more limited than for instance in a functional department. This variety may be increased by permitting products to pass by work stations or by permitting to vary the product routings. Fluctuations in mix and volume are more restricted as well. Capacity problems in a manufacturing cell can not always be solved by sending the products to other cells. A solution can be to install extra capacity in the cells. The manufacturing cell is responsible for the produced output. The overview over the production flow gives opportunities to coordinate the tasks in the cell decentrally. The work stations can work independent from each other to a certain extent because the work may continue on other work stations temporarily in case of disruptions. Supporting processes like process planning and quality assurance can be handled in the cell because enough overview over the processes exists. The specialisation of the cell for a product group provides the possibility to integrate tool management, storage and internal transport as well because redundancy of tools and parts is minimised.

# PBT 3, Flexible Manufacturing System (FMS)



## PBT 3 Flexible Manufacturing System (FMS)

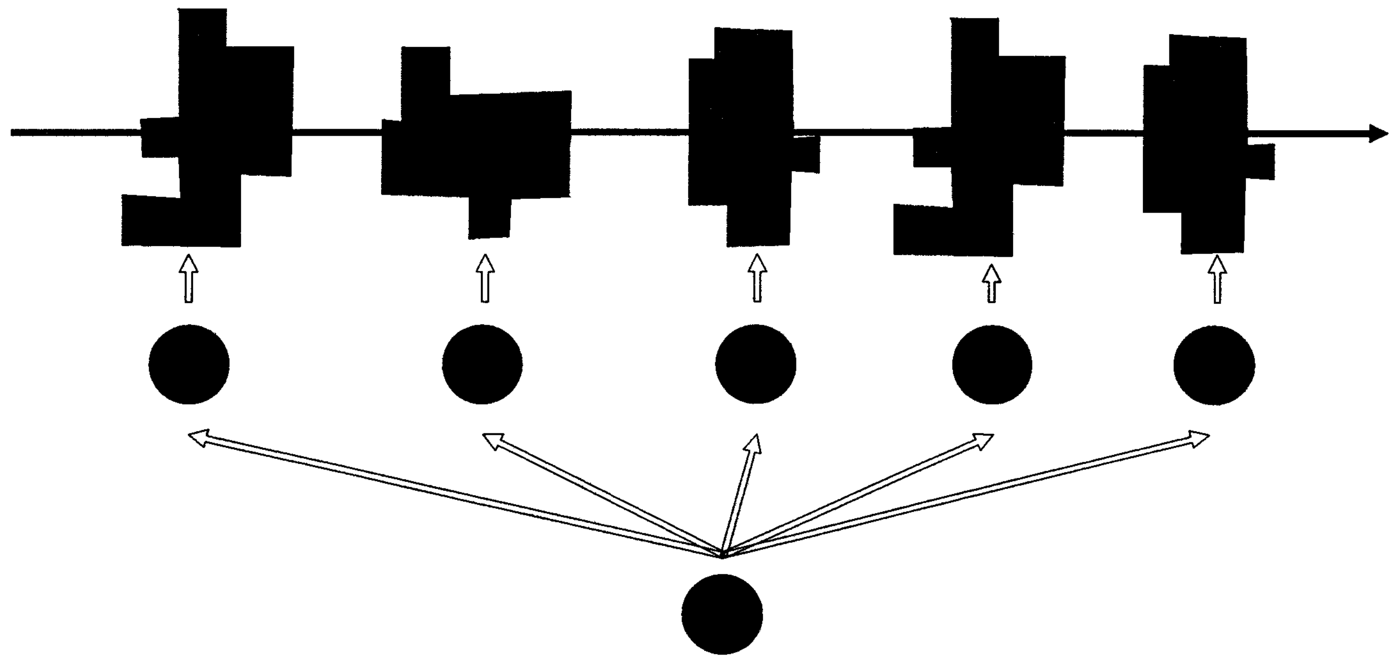
*Description*

In a Flexible Manufacturing System (FMS) the work stations are serial connected by an automated materials handling system. This system also serves as a buffer between the work stations in which products may be stored. The routing of the products between the work stations is variable. Tool management has been automated as well. Process planning is executed outside the FMS in a central department. Coordination of the activities and quality assurance take place internally in the department.

*Characterisation*

The most important characteristic of an FMS is the high level of automation. The initial investments in an FMS are high, not only for procurement of the hardware but even more for the necessary software. The production programme has to consist of high amounts of products and has to remain stable to earn these investments back. An advantage of the system is that an FMS can operate unmanned. The variety in the production programme is limited by the number of different product carriers and tools that can be placed in the work stations. The structure of the PBT does not restrict the fysical complexity of the handled products. The FMS is responsible for the produced output; the overview over the production process is clear enough to coordinate the work in the system. However, this work is limited because of the level of automation (in the most extreme case all the work has been automated).

# PBT 4, Multi-product line



## PBT 4 MULTI-PRODUCTLINE

*Description*

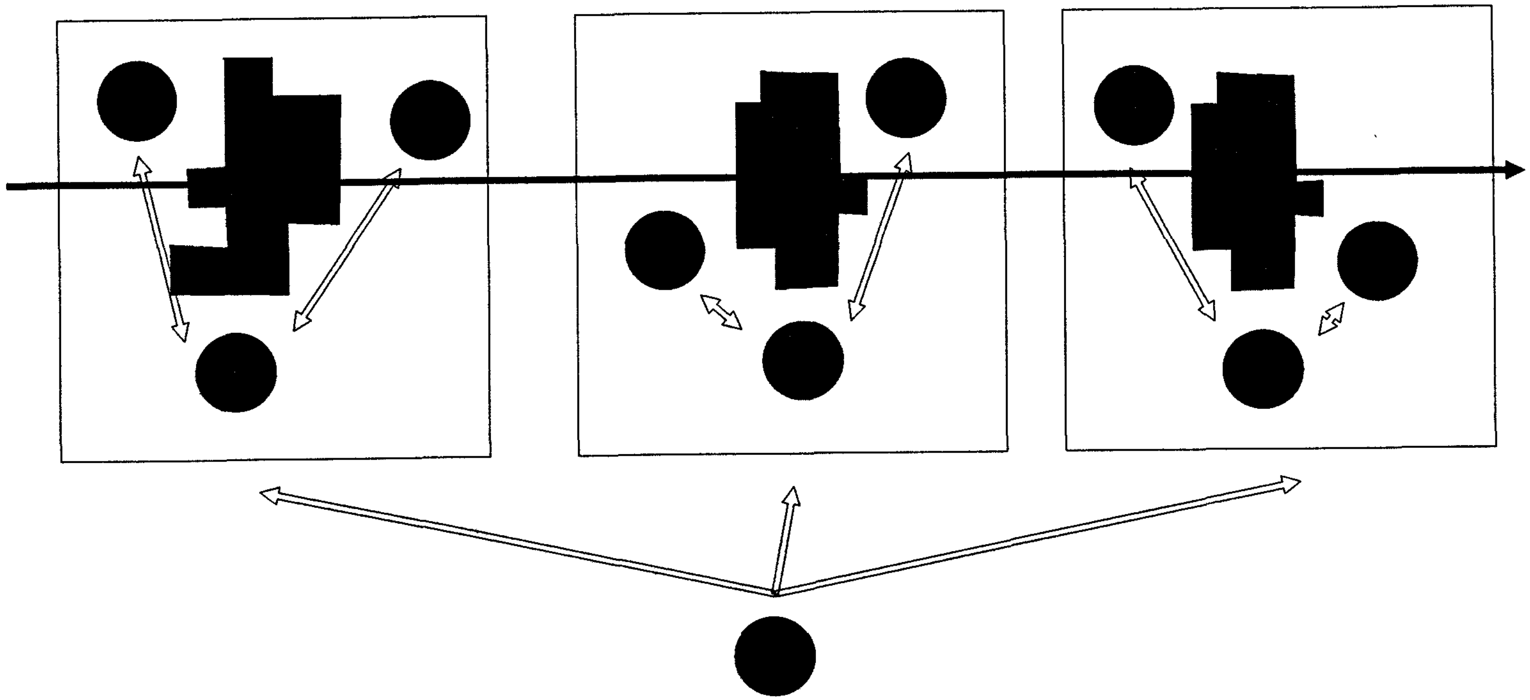
A multi-productline consists of a number of serial connected work stations with small buffers between them (or without buffers). The products follow a fixed routing between the work stations. On every work station one task is executed. The output per time period is equal for every work station. The work stations are specialised for the required production programme. Storage of parts takes place in the department. The other supporting processes (process planning, quality assurance, transport of parts and finished products, tool management) are executed in other departments separated from the production. Coordination of the activities takes place centrally.

*Characterisation*

The main characteristic of a multi-productline is the high interdependency between the work stations. The whole line stops if a disruption occurs at one of the work stations. If the work stations haven't been balanced, disruptions occur as well. Therefore, initial balancing of the line is important. Tasks that have to be executed and the structure of the work stations are determined and fixed before actual productions starts. Coordination of the activities takes place centrally because no overview of the process can be achieved on the individual work stations.

Relatively high amounts of products can be produced in a multi-productline if the line is balanced. However, fluctuations in mix and volume lead to disruptions in the production and have to be avoided as much as possible. The variety of products can be increased by permitting work stations to be passed but this will lead to a more complex balancing problem. Unknown of partly unknown products can not be produced because otherwise the line cannot be balanced.

# PBT 5, Flow dock



## PBT 5 Flow dock

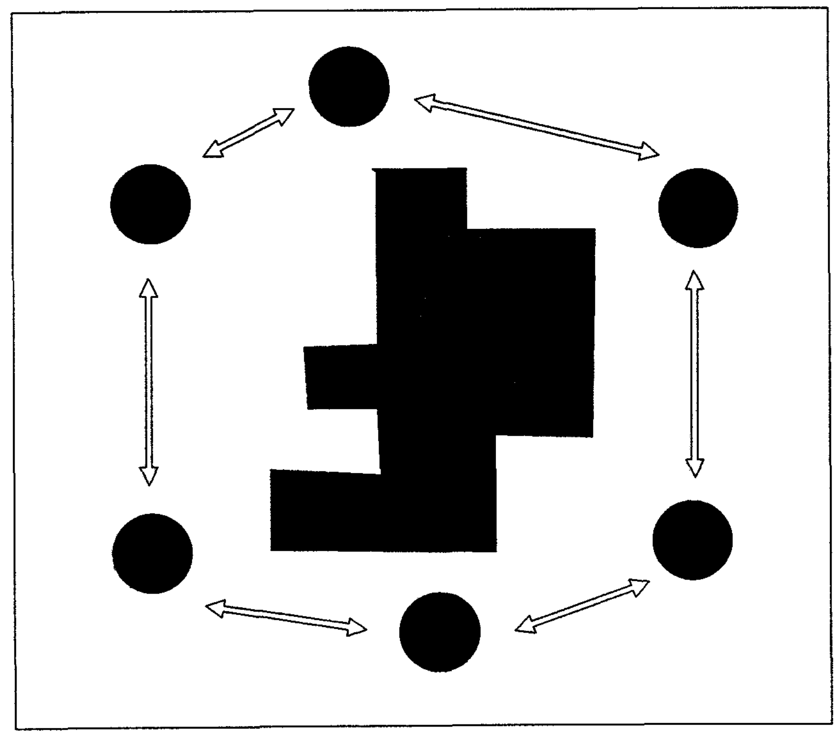
*Description*

In a flow dock, a number of work stations are connected serially. The products follow a fixed routing. On each work station, a number of tasks are executed parallelly on one product. The work stations are specialised for a certain group of products. The average output per time period of each work station has to be equal but the amount of work may vary by varying the number of parallel tasks. Storage, transport, tool management, process planning and quality assurance take place in the module. The flow dock is coordinated from a central point.

*Characterisation*

This structure is more flexible than the structure of a multi-productline. The work in a work station may vary to a certain extent without disrupting the production flow. However, after some time the whole line has to stop as well. In a work station, coordination of the activities is necessary. Tasks have to be divided and measures have to be taken so that the parallel activities do not disturb each other. More possibilities exist to change the work speed because this can be corrected in the other tasks in the work station. A flow dock is coordinated centrally because an overview of the whole production flow can be achieved on this level.
Fluctuation in the product mix can be handled by varying the number of tasks that are executed parallelly. The production volume has to stay rather constant because otherwise the whole line has to increase or decrease its speed.

# PBT 6, Dock



PBT 6 DOCK

*Description*
A dock consists of one integrated work station in which all activities are executed. These activities are coordinated in the dock. The dock is responsible for the output. Process planning takes place centrally. All other supporting processes take place in the module.

*Characterisation*
The most important characteristic of a dock is that the product remains in a fixed place and the people, materials and tools go to the product or are taken to the product. An advantage of this is that a good overview of the activities can be reached but the tasks have to be coordinated carefully. The risk of congestion ("traffic jam") exists if many tasks are executed parallelly. Docks need normally a relatively high amount of floor space, because the products are large. Combined with the long throughput times, the needed floor space makes the division of the available space to an important problem. Replacement of the product during the production process has to be avoided as much as possible. A dock is restructured after a product is finished so that new products can be handled easily.

## APPENDIX 2 SERVICE BASIC TYPES (SBTS)

The Service Basic Types (SBTs) give an overview of the possibilities to structure the supporting processes. A number of SBTs have been developed for each of the supporting processes. The elaboration and description of the SBTs have been done in the same way as the elaboration of the PBTs. A list of the developed SBT per supporting process is given below.

*Transport*

Occasional transport (OT)
Mechanical Transport (MT)
Continuous Transport (CT)
Automated Transport (AT)

*Storage*

Manual Central Store (MCS)
Manual Decentral Store (MDS)
Manual Buffer Store (MBS)
Automated Central Store (ACS)
Automated Decentral Store (ADS)
Automated Buffer Store (ABS)

*Production control*

Central Production Control (CPC)
Area Production Control (APC)
Coordinating Area Production Control (CAPC)

*Quality assurance*

Local Quality Assurance (LQA)
Central Quality Assurance (CQA)

*Process planning*

Local Process Planning (LPP)
Central Process Planning (CPP)

*Maintenance*

Local Maintenance (LM)
Overall Maintenance (OM)
External Maintenance (EM)

*Tool management*

Central Tool Management (CTM)
Self-Reliant Tool Management (SRTM)

*Waste disposal*

General Waste Disposal (GWD)
Specific Waste Disposal (SWD)
Central Waste Disposal (CWD)

## APPENDIX 3 SUITABILITY PROFILES OF THE PRODUCTION BASIC TYPES

Each Basic Type has certain advantages and disadvantages that influence the performance of the Basic Types in certain situations. The Basic Types can be compared mutually on their relative performance in relation to characteristics of the production programme. In this way an overview is created of the situations in which the Basic Types realise a better or worse performance. Such an overview is called a suitability profile of the Basic Type.

An overview of the suitability profiles for the PBTs is presented in table 1 of this appendix. In the following tables, an argumentation is provided for the suitability profiles of each PBT. The characteristics of the production programme that are used in the suitability profiles have been derived from the analysis of product characteristics that are produced in small batches (see section 4). The following definitions have been used:

- Quantity = Average number of products per time period
- Variety = Number of different products (types, variants) related to the total number of products per time period
- Organisational complexity = Required effort to coordinate the necessary tasks to produce a product
- Fysical complexity = Required effort to transform the raw materials into a finished product
- Fluctuations in product mix = Fluctuations in the numbers of products that have to be produced for each type
- Fluctuations in production volume = Fluctuations in the average number of products per time period
- Novelty = Percentage of the tasks for a products that are new of not fixed before the production starts

Table 1 Suitability profiles of the Production Basic Types

| Characteristic | Funct. dept. | Mfg. cell | FMS | Multi-prod. line | Flow dock | Dock |
|---|---|---|---|---|---|---|
| Quantity | +/- | +/- | + | + | +/- | - |
| Variety | + | - | +/- | - | + | + |
| Organisational complexity | - | + | - | + | + | +/- |
| Fysical complexity | - | + | + | +/- | + | + |
| Fluctuations in product mix | +/- | - | +/- | - | + | + |
| Fluctuations in production volume | + | - | - | - | +/- | +/- |
| Novelty | + | - | - | - | + | + |

Table 2 Suitability profile of PBT 1, Functional department

| Production programme characteristic | Value | Argumentation |
|---|---|---|
| Quantity | +/- | Specialisation in tasks; supporting processes separated from production; no parallel tasks on one product; inefficient coordination between work stations |
| Variety | + | Work stations are not specialised and independent from each other |
| Organisational complexity | - | Many parts cause complex routings and coordination problems |
| Fysical complexity | - | One task per department, many tasks cause complex routings and long throughput times |
| Fluctuations in product mix | +/- | Work stations are not specialised and independent from each other; each product can be produced on all work stations; change of mix asks intensive coordination and balancing |
| Fluctuations in production volume | + | Work stations are not specialised and independent from each other; capacity can be increased relatively simple |
| Novelty | + | Work stations are not specialised and independent from each other; each product can be produced on all work stations |

Table 3 Suitability profile of PBT 2, Manufacturing cell

| Production programme characteristic | Value | Argumentation |
|---|---|---|
| Quantity | +/- | Less learning effects; supporting tasks integrated in the cell |
| Variety | - | Fixed routing; specialised work stations |
| Organisational complexity | + | Overview of production process is possible because of the small size of the unit, the restricted variety, short throughput times and mutual coordination |
| Fysical complexity | + | |
| Fluctuations in product mix | - | Structure and capacity of the work stations are determined for a certain group of products; in a manufacturing cell more possibilities exist to cope with fluctuations than between cells |
| Fluctuations in production volume | - | |
| Novelty | - | |

Table 4 Suitability profile of PBT 3, Flexible Manufacturing System

| Production programme characteristic | Value | Argumentation |
|---|---|---|
| Quantity | + | Automated and standardised operations and supporting processes; unmanned operations |
| Variety | +/- | Variable routing; work stations are not specialised; restrictions by size and variety in tools and product carriers; in practice routing is not really variable most of the time |
| Organisational complexity | - | Automated supply of parts is complex and expensive |
| Fysical complexity | + | Variable routing, product can pass by as many work stations as desired |
| Fluctuations in product mix | +/- | In practice routing is not really variable most of the time, (control of) transport activities become complex |
| Fluctuations in production volume | - | High investments require high use of capacity, extension of available capacity is expensive; possibility of unmanned operations |
| Novelty | - | High investments to adapt software, tools and product carriers; a new variant within one product family can be added relatively easy |

Table 5 Suitability profile of PBT 4, Multi-productline

| Production programme characteristic | Value | Argumentation |
|---|---|---|
| Quantity | + | Work stations specialised and balanced; learning effects; if balance is disturbed loss of capacity and time |
| Variety | - | Coordination problems between work stations; complex balancing problem |
| Organisational complexity | + | Parts delivery spread along the line; no congestion problems |
| Fysical complexity | +/- | Number of work stations is not limited |
| Fluctuations in product mix | - | Coordination problems between work stations; complex balancing problem |
| Fluctuations in production volume | - | Coordination problems between work stations; all stations have to increase and decrease their speed |
| Novelty | - | All work stations specialised and balanced; whole line has to be adapted; If product is unknown, line can not be balanced |

Table 6 Suitability profile of PBT 5, Flow dock

| Production programme characteristic | Value | Argumentation |
|---|---|---|
| Quantity | +/- | Work stations are balanced, learning effects |
| Variety | + | Number of parallelly executed tasks can be varied |
| Organisational complexity | + | Parts delivery spread along the line; no congestion problems |
| Fysical complexity | + | Number of work stations not limited |
| Fluctuations in product mix | + | Parallel tasks may be varied without disrupting the balance |
| Fluctuations in production volume | +/- | Number of parallel tasks may be varied; if volume surpasses a certain maximum a new flow has to be created ->investments |
| Novelty | + | Work stations are not specialised, balancing is easier because of parallel tasks |

Table 7 Suitability profile of PBT 6, Dock

| Production programme characteristic | Value | Argumentation |
|---|---|---|
| Quantity | - | No specialisation, no learning effects |
| Variety | + | Work station not specialised; tasks may be varied |
| Organisational complexity | +/- | All parts to one site gives overview; congestion problems |
| Fysical complexity | + | Parallel tasks; coordination possibilities; overview |
| Fluctuations in product mix | + | Work stations not specialised |
| Fluctuations in production volume | +/- | Number of parallel tasks may be varied, but available space to work on the product is limited |
| Novelty | + | Work station is restructured each time a product is finished |

## APPENDIX 4 COMBINATION AND CONFIGURATION RULES FOR THE BASIC TYPES

The combination and configuration rules in the PDL give an overview of the possibilities for combinations and configurations of the Basic Types and the advantages and disadvantages given a required performance that has to be realised. In this appendix, the various parts of the rules are illustrated by means of examples of the guidelines.

In table 1, an overview is presented of the possible combinations of SBTs integrated in the PBTs. The table shows for each supporting process the possibilities (i.e. the possible SBTs) to integrate its activities in the PBT. If nothing has been filled in, the supporting process will not be integrated normally.

The tables 2 and 3 provide an overview of the activities that take place in the supporting processes transport and storage. These checklists are used to determine which activities are integrated and which activities not. Also the consequences of the integration of supporting processes are described.

Table 5 gives an overview of the possible configurations of PBTs and SBTs. Finally, in table 6 an overview is given of preferred configurations (including the argumentation) of the PBTs and SBTs if an optimalisation of throughput times and throughput reliability is strived for.

The used abbreviations are explained in the appendices 1 and 2.

Table 1 Possible combinations of integrated SBTs in the PBTs

| Supporting process | PBT | | | | | |
|---|---|---|---|---|---|---|
| | Functional department | Manufacturing cell | Flexible Manufacturing System | Multi-product-line | Flow dock | Dock |
| Storage | MBS, MSPS | (MCS), MBS, MSPS | MBS, ABS, ASPS | nothing (or MBS) | nothing or MBS (MCS) or ABS and MSPS | MCS, MSPS |
| Transport | OT | OT or MT | AT | OT or AT or CT | OT or MT or AT | OT |
| Production control | APC | CAPC | APC | APC | CAPC and APC | |
| Quality assurance | LQA or nothing | LQA | nothing | LQA or nothing | LQA | |
| Maintenance | LM or nothing | LM | nothing | nothing | nothing or LM | |
| Tool management | SRTM or nothing | SRTM | nothing | SRTM or nothing | nothing or SRTM | |
| Process planning | LPP or nothing | LPP | nothing | nothing | nothing or LPP | LPP |

Table 2 Activities in the supporting process Transport

| Activity | Integrated? | |
|---|---|---|
| | Yes | No |
| Long-term investment planning | | |
| Technology development | | |
| Organisation development | | |
| Personnel development | | |
| Method planning | | |
| Fundamental questions of work evaluation | | |
| Maxim questions of payment | | |
| Determination of overheads | | |
| Transport of employees | | |
| Transport of materials, products and production facilities | | |
| Transfer of parts from transport to storing | | |
| Commission | | |
| Intermediate storing on transport units | | |
| Control of transport units | | |
| Administration of transport orders (writing of transport papers, availability preparation of transport units and additional transport equipment | | |
| Organisation of transport units | | |
| Conformity check of goods data, transport papers and transport units | | |
| Check of transportability | | |
| Procurement of transport units | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Table 3 Activities in the supporting function Storage

| Activity | Integrated? | |
|---|---|---|
| | Yes | No |
| Long-term investment planning | | |
| Technology development | | |
| Organisation development | | |
| Personnel development | | |
| Method planning | | |
| Fundamental questions of work evaluation | | |
| Maxim questions of payment | | |
| Determination of overheads | | |
| Acceptance of goods | | |
| Incoming check | | |
| Formation of store units | | |
| Sorting of parts | | |
| Intermediate buffering | | |
| Identity check | | |
| Check of storing properties | | |
| Selection of storage area | | |
| Administration of storage areas | | |
| Inventory control | | |
| Release of orders | | |
| Check of store conditions | | |
| Transport organisation inside the store | | |
| Preparation of dislocation | | |
| Disposition and execution of dislocation | | |
| Updating of job instructions | | |
| Formation of transport units | | |
| Transport organisation | | |
| Delivery goods check of goods to be dispatched | | |

*Consequences of integration*

The integration of supporting processes signifies that supporting tasks will be executed by the people in the production. Production departments will be more independent from each other in this way. Besides some specific consequences per supporting process, the integration of supporting processes has two general consequences as well. They will be explained shortly.

*Consequences for capacity*

The integration of supporting processes signifies that the people in the production need time to perform the extra activities. A balance has to be found if this time is limited. The number of activities that will be integrated may be reduced. Furthermore, it may be checked if certain tasks can be carried out externally during peak periods. To analyse these consequences, the available time of the people is estimated first (total available time minus production time, set up time, and friction losses) followed by an estimation of the supporting tasks. Based on this information, a balance can be made between the execution of supporting activities by external people and the increase of available time of the production people (e.g. by permitting slack time at the work stations).

*Consequences for education*

If supporting activities are integrated in the production, attention has to be paid to the education of the production people so that they will be able to execute their new tasks. First a qualification profile of the people has to be made followed by a required profile. Education activities have to focus on the balancing of both profiles. The required effort to do this has to be compared to the estimated benefits of integration to determine the level of integration.

*Consequences for production control*

The information flow to control progress of the production is replaced by the own responsibility of the production groups of departments. Central departments are restricted to the determination and control of the delivery dates of finished products, Individual operations will not be controlled anymore. The coordination between the production and supporting modules will not be done centrally neither. Capacity levels and delivery dates remain the only decisions to be taken on the higher level.

*Consequences for process planning*

The integration of process planning activities may take place in two ways:

- Integration of routine tasks: e.g. the handling of order documents, programming of the machines and correction of the programmes. The integration to this extent relieves the central department but restricts the control capabilities of the production people.
- Full integration of short and medium term activities, i.e. all necessary activities to prepare the production of a certain order.

*Consequences for quality assurance*

The integration of quality tasks starts with the testing and measuring of parts and products. Dependent on the product complexity more tasks may be integrated. It is important to limit the number of checks as much as possible. Tests with special requirements (e.g. conditioned rooms) need special attention. They have to be executed as close to the production as possible.

*Consequences for tool management*

The more tools are available in a work station the faster set ups can be made. Standardisation of tools may reduce the duplication of tools and therefore the costs of integration. The process planning will have to be adapted to achieve this.

*Consequences for maintenance*

The main advantage of keeping the connection between production and maintenance as short as possible is that breakdown time will be reduced. The integration of maintenance activities will be restricted to simple tasks most of the time. Preventive as well as reactive maintenance has to be considered while discussing the integration of maintenance.

*Consequences for storage and transport*

Not only the internal transport in a module but also the transport between modules has to be considered. A decision has to be taken between a "push"-structure and a "pull"-structure.

Table 4 Configurations of PBTs and SBTs

| PBT | SBT | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Storage | | | | Transport | | | | Production control | | QA | Maintenance | | Tool mgmt |
| | MCS | ACS | MBS | ABS | OT | MT | AT | CT | CPC | APC | CQA | OM | LM | CTM |
| 1 | + | +/- | +/- | - | + | + | - | - | + | + | + | + | + | + |
| 2 | + | +/- | - | - | + | + | +/- | - | + | + | +/- | +/- | + | +/- |
| 3 | +/- | + | + | + | - | +/- | + | - | + | + | + | + | + | + |
| 4 | + | +/- | +/- | + | - | + | + | +/- | + | + | + | + | +/- | + |
| 5 | + | +/- | - | - | + | + | + | - | + | + | + | + | +/- | + |
| 6 | + | +/- | - | - | + | + | - | - | + | + | + | + | + | + |

\+ Fits good
+/- Possible configuration
\- Fits not

Table 5 Preferred configurations while optimising throughput time and throughput reliability

| PBT | SBT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transport | | | | Quality assurance | | Maintenance | | | Process planning | |
| | OT | MT | AT | CT | CQA | LQA | EM | OM | LM | CPP | LPP |
| 1 | 1 | 2 | - | - | 2 | 1 | 3 | 2 | 1 | 1 | 2 |
| 2 | 1 | 2 | 3 | - | 2 | 1 | 3 | 2 | 1 | 2 | 1 |
| 3 | - | 2 | 1 | - | 2 | 1 | 3 | 2 | 1 | 1 | 2 |
| 4 | - | 3 | 2 | 1 | 2 | 1 | 3 | 2 | 1 | 1 | 2 |
| 5 | 1 | 2 | 2 | - | 2 | 1 | 3 | 2 | 1 | 2 | 1 |
| 6 | 1 | 2 | - | - | 2 | 1 | 3 | 2 | 1 | 2 | 1 |

| PBT | SBT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Storage | | | | | | Production control | | | Tool mgmt. | |
| | MCS | ACS | MDS | ADS | MBS | ABS | CPC | APC | CAPC | CTM | SRTM |
| 1 | 5 | 4 | 3 | 2 | 1 | - | 1 | 2 | 3 | 2 | 1 |
| 2 | 4 | 3 | 2 | 1 | - | - | 3 | 2 | 1 | 2 | 1 |
| 3 | 6 | 5 | 4 | 3 | 2 | 1 | 3 | 1 | 2 | 2 | 1 |
| 4 | 2 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 1 |
| 5 | 2 | 2 | 1 | 1 | - | - | 3 | 2 | 1 | 2 | 1 |
| 6 | 2 | 2 | 1 | 1 | - | - | 3 | 2 | 1 | 2 | 1 |

*Argumentation*

*Transport*

The suitability of configurations with respect to throughput times and throughput reliability depends on the availability of transport possibilities at the moment a request for transport occurs. These possibilities depend on the availability of people as well as means of transport. Using OT, no means are necessary which increases the availability. If enough transport capacity is available, the performance of AT and MT will be better because higher speeds can be reached. Using CT, capacity is always available, so if it is possible to use CT (in a configuration with PBT 4), this option always will give the best result.

*Storage*

The most important criterium that has to be considered to determine the preferred Basic Type is the speed with which products can be taken out of their storage place. This speed is determined by the necessary handling and the distance to the work station. Based on this consideration, a buffer scores better than a decentralised store and a decentralised store scores better than a central store in its turn. For the same reasons the automated stores score a little bit better than the manual stores but this statement is very much dependent on the available capacity. The advantage of manual stores is that it will be easier to meet the requirements in the peak periods.

*Process planning*

In functional departments, process planning can better be centralised because no overview exists locally to reach an optimal process planning. In a Manufacturing cell it is possible to reach an overview and at this level it is easier to react to local circumstances (such as available capacity). In PBT 3 a central process planning is required to reach an optimal load for the work stations. In product lines, process planning takes place centrally to be able to balance the line. In flow docks and docks, adaptations to local circumstances can easier be made locally. The best approach can be chosen by mutual adjustment between the workers.

*Production control*

In PBT 1, the overview of the complex production flow in the organisation can not be seen in the departments. Therefore, it is necessary to coordinate the production centrally. In a compact Manufacturing cell, decentralisation of the control is possible and gives the most advantages. Central planning is favoured in an FMS because of the available knowledge of the product mix on this level. The coordination of tasks with respect to quality assurance and so on can be executed decentrally (CAPC). APC gives the best overview in a product line and gives the most opportunities to react if the line is getting out of balance. The distinction between CAPC and APC in a dock or a flow dock is small. In general, APC will be preferred in bigger units because in that case using APC will provide a better overview.

*Quality assurance*

LQA is preferred independent from the choice of PBTs. In all cases, CQA will lead to longer waiting times which has a negative influence on the performance on the chosen criteria.

*Maintenance*

Like for Quality Assurance, the preferred configurations are independent from the choice of PBTs. In general, reaction times of LM are shorter and will lead to a better performance. If enough capacity is available in OM, the difference with LM will be small. EM will lead to longer waiting times because of the fysical distance.

*Tool management*

The same argumentation can be followed as for quality assurance. Independent from the chosen PBT, SRTM will lead to shorter waiting times. However, this advantage will only occur if all the tools are stored in the work station. The more tools have to be fetched from the central store, the less the difference in waiting times with CTM (in which case the tools are brought to the work station) will be.

## APPENDIX 5 CHECKLIST FOR INFORMATION TO MAKE A PDL DESCRIPTION

### 1. GENERAL INFORMATION

- Give an overview of the production means (number of machines, main technologies, level of automation, number of people per machine).

- Give a layout of the production area. If possible, the position of the machines, the (most important) transportation routes, stores, and so on are marked in the layout.

- Give an organogram of the organisation with the number of people per department.

### 2. PROCESS STEPS

- Give a description of the various operations to produce the products and the way in which these operations are executed (manually, automated, ..) Make a drawing of the main flows.

- What are average throughput times for the different process steps?

- How are the operations executed, individually or in groups? How many people work in every process step?

### 3. STORES / STOCK AREAS

- Where are stocks of products located? Describe stores as well as buffers on the floor. Normally, a stock is present between every process step. What are the stock levels?

- Who is responsible for order picking, people from the store or production people? How many people are employed in the stores?

### 4. TRANSPORT

- How does transport take place between the process steps and between the process steps and the stores? Normally, transport takes place between every process step.

- Who is responsible for transportation: people from the stores, transport people or production people? How many people are employed in transport?

5. QUALITY ASSURANCE

- Where are test points located in the production? Does a special quality department exist?

- Who executes the test: production people or quality people?

- What happens with rejected products: waste, rework, ..? Who is responsible for rework?

6. PRODUCTION CONTROL AND PROCESS PLANNING

- How does the production control take place (which steps are followed)? Where is the CODP located? Does a central production planning department exist? If so, which tasks are executed there and what is the size of the department?

- Do group leaders or production leaders exist in the organisation? What are their tasks? How do they coordinate with the central production planning department?

7. MAINTENANCE

- How does maintenance take place? Curative, preventive? Does a special maintenance department exist?

8. TOOL MANAGEMENT

- How are tools exchanged and maintained? Does a special department for tool management exist?

## Appendix 6 An extended PDL description

In this section, three PDL descriptions (production relationships, control relationships, and information relationships) of the company Ets A & L Verhaegen SA/NV are presented. This company, one of the participants of the HOPE project, produces slatted boards and mattresses (trademarks: Lattoflex and Epeda) for consumer markets. In addition to the three descriptions of the relationships between production and production modules, three descriptions have been provided of the structure of the department "assembly Lattoflex" as well. The figures in the pictures refer to the explanations of the modules and relationships in the tables. Quantitative information has not been added to assure the confidentiality of this data. Furthermore, the description of the information relationships between the modules has been restricted to the information relationships of the department "assembly Lattoflex". The signification of the used terms and symbols are explained in section 6 of this report.

Production

Control

Informati-
on

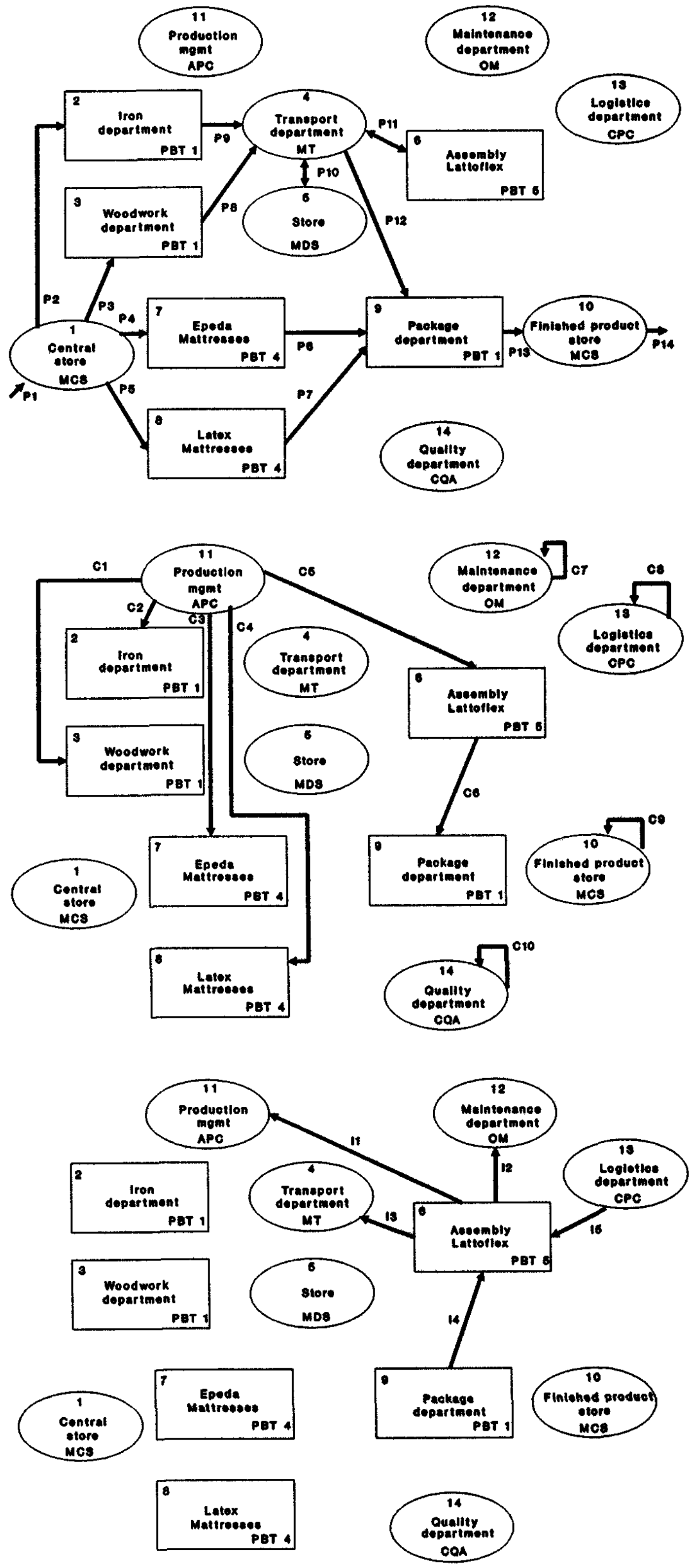



**Figure 1 Verhaegen, production and service modules**

In the tables below, the relationships are described that are shown in the pictures. Firstly, an overview of the production and supporting modules is given. Then, the starting point and the direction, the executor, and some additional information on the three types of relationships (production, control, and information) is presented. The tables complete the (qualitative) information on the production organisation that is collected with support of the PDL

| Organisation: Verhaegen | Production and supporting modules | |
|---|---|---|
| Production modules | | |
| Nr. | name | type |
| 2 | Iron department | PBT 1, functional department |
| 3 | Woodwork department | PBT 1, functional department |
| 6 | Assembly Lattoflex | PBT 5, flow dock |
| 7 | Epeda mattresses | PBT 4, multi-productline |
| 8 | Latex mattresses | PBT 4, multi-productline |
| 9 | Package department | PBT 1, functional department |

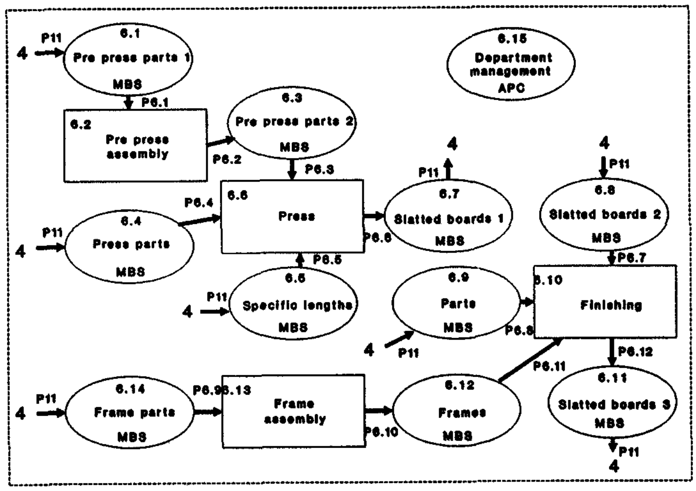
| Organisation: Verhaegen | Production and supporting modules | |
|---|---|---|
| Supporting modules | | |
| Nr. | name | type |
| 1 | Central store | MCS, Manual Central Store |
| 4 | Transport department | MT, Mechanised Transport |
| 5 | Store | MDS, Manual Decentral Store |
| 10 | Finished Product Store | MCS, Manual Central Store |
| 11 | Production management | APC, Area Production Control |
| 12 | Maintenance department | OM, Overall Maintenance |
| 13 | Logistics management | CPC, Central Production Control |
| 14 | Quality department | CQA, Central Quality Assurance |

| Organisation: Verhaegen | Production and supporting modules | | | |
|---|---|---|---|---|
| Production relationships | | | | |
| Nr | From | To | Who | What |
| P1 | External suppliers | Central store | External suppliers | Raw materials, components |
| P2 | Central store | Iron department | Store people | Raw materials, components |
| P3 | Central store | Woodwork department | Store people | Raw materials, components |
| P4 | Central store | Epeda mattresses | Store people | Raw materials, components |
| P5 | Central store | Latex mattresses | Store people | Raw materials, components |
| P6 | Epeda mattresses | Package department | Production people Epeda | Mattresses |
| P7 | Latex mattresses | Package department | Production people Latex | Mattresses |
| P8 | Woodwork department | Transport department | Transport people | Parts, parts specific lengths |
| P9 | Iron department | Transport department | Transport people | Metal parts |
| P10 | Transport department | Store | Transport people | Parts slatted boards |
| | Store | Transport department | Transport people | Parts slatted boards |
| P11 | Transport department | Assembly Lattoflex | Transport people | Parts slatted boards |
| | Assembly Lattoflex | Transport department | Transport people | Parts slatted boards |
| P12 | Transport department | Package department | Transport people | Slatted boards |
| P13 | Package department | Finished Product store | Distribution people | Slatted boards, mattresses |
| P14 | Finished Product store | Customers | Distribution people | Slatted boards, mattresses |

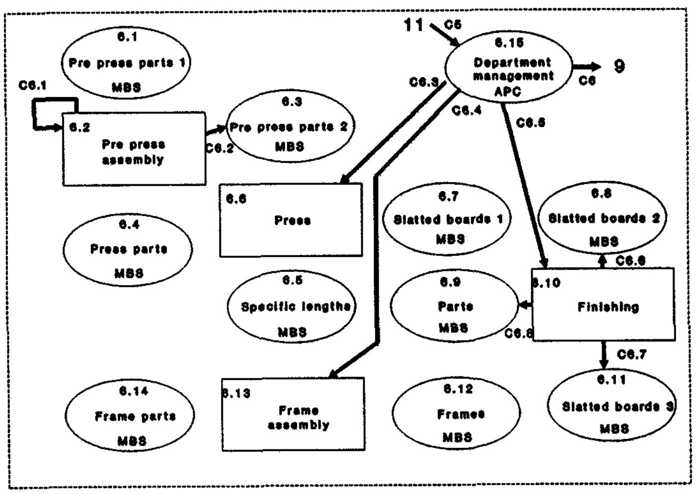
| Organisation: Verhaegen | | Production and supporting modules | |
|---|---|---|---|
| Control relationships | | | |
| Nr. | Who coordinates | who | What |
| C1 | Production management | Woodwork department | Overall responsibility |
| C2 | Production management | Iron department | Overall responsibility |
| C3 | Production management | Epeda mattresses | Overall responsibility |
| C4 | Production management | Latex mattresses | Overall responsibility |
| C5 | Production management | Assembly Lattoflex | Overall responsibility |
| C6 | Assembly Lattoflex | Package department | Output Lattoflex determines activities packaging |
| C7 | Maintenance | Maintenance | Self-reliant responsability |
| C8 | Logistics management | Logistics department | Self-reliant responsability |
| C9 | Finished Product store | Finished Product store | Self-reliant responsability |
| C10 | Quality department | Quality department | Self-reliant responsability |

| Organisation: Verhaegen | | Production and supporting modules | | |
|---|---|---|---|---|
| Information relationships | | | | |
| Nr. | Sender | Receiver | Aim | Type |
| I1 | Assembly Lattoflex | Production management | Information on progress | Signal |
| I2 | Assembly Lattoflex | Maintenance | Request for assistance | Signal |
| I3 | Assembly Lattoflex | Transport department | Request for transport<br>Removal of buffer | Signal<br>Signal |
| I4 | Package department | Assembly Lattoflex | Information on progress | Signal |
| I5 | Logistics management | Assembly Lattoflex | Production orders | Document |

Production




Control




Informati-
on

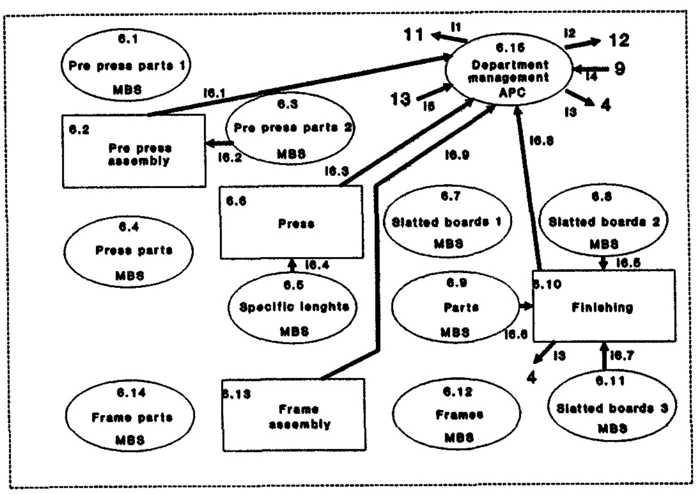



**Figure 2, Verhaegen, Assembly Lattoflex**

The tables with production and supporting work stations and their production, control and information relationships in the department Assembly Lattoflex are given below in the same order as has been done for the overall picture of Verhaegen.

| Organisation: Verhaegen | Module: 6. Assembly Lattoflex | |
|---|---|---|
| Work stations production | | |
| Nr. | Name | |
| 6.2 | Pre press assembly | |
| 6.6 | Press | |
| 6.10 | Finishing | |
| 6.13 | Frame assembly | |

| Organisation: Verhaegen | Module: 6. Assembly Lattoflex | |
|---|---|---|
| Supporting work stations | | |
| Nr. | Name | Type |
| 6.1 | Buffer pre press parts 1 | MBS, Manual Buffer Store |
| 6.3 | Buffer pre press parts 2 | MBS, Manual Buffer Store |
| 6.4 | Buffer press parts | MBS, Manual Buffer Store |
| 6.5 | Buffer specific lengths | MBS, Manual Buffer Store |
| 6.7 | Buffer slatted boards 1 | MBS, Manual Buffer Store |
| 6.8 | Buffer slatted boards 2 | MBS, Manual Buffer Store |
| 6.9 | Buffer parts | MBS, Manual Buffer Store |
| 6.11 | Buffer slatted boards 3 | MBS, Manual Buffer Store |
| 6.12 | Buffer frames | MBS, Manual Buffer Store |
| 6.14 | Buffer frame parts | MBS, Manual Buffer Store |
| 6.15 | Department management | APC, Area Production Control |

| Organisation: Verhaegen | Module: 6. Assembly Lattoflex | | | |
|---|---|---|---|---|
| Production relationships | | | | |
| Nr. | From | To | Who | What |
| P11 | Transport department | Buffer pre press parts 1 | Transport people | Pre press parts |
| | Transport department | Buffer press parts | Transport people | Press parts |
| | Transport department | Buffer specific lengths | Transport people | Specific lengths parts |
| | Transport department | Buffer slatted boards 2 | Transport people | Slatted boards |
| | Transport department | Buffer parts | Transport people | Slatted boards parts |
| | Transport department | Buffer frame parts | Transport people | Frame parts |
| | Buffer slatted boards 1 | Transport department | Transport people | Slatted boards |
| | Buffer slatted boards 3 | Transport department | Transport people | Slatted boards |
| P6.1 | Buffer pre press parts 1 | Pre press assembly | Operator pre press assembly | Pre press parts |
| P6.2 | Pre press assembly | Buffer pre press parts 2 | Operator pre press assembly | Pre press parts |
| P6.3 | Buffer pre press parts 2 | Press | Operators press | Pre press parts |
| P6.4 | Buffer press parts | Press | Operators press | Press parts |
| P6.5 | Buffer specific lenghts | Press | Operators press | Specific lengths parts |
| P6.6 | Press | Buffer slatted boards 1 | Operators press | Slatted boards |
| P6.7 | Buffer slatted boards 2 | Finishing | Operators finishing | Slatted boards |
| P6.8 | Buffer parts | Finishing | Operators finishing | Parts |
| P6.9 | Buffer frame parts | Frame assembly | Operators frame assembly | Frame parts |

| Organisation: Verhaegen | | Module: 6. Assembly Lattoflex | | |
|---|---|---|---|---|
| Production relationships | | | | |
| Nr. | From | To | Who | What |
| P6.10 | Frame assembly | Buffer frames | Operators frame assembly | Frames |
| P6.11 | Buffer frames | Finishing | Operators finishing | Frames |
| P6.12 | Finishing | Buffer slatted boards 3 | Operators finishing | Slatted boards |

| Organisation: Verhaegen | | Module: 6. Assembly Lattoflex | |
|---|---|---|---|
| Control relationships | | | |
| Nr. | Who coordinates | Who | What |
| C5 | Production management | Department management | Overall responsibility |
| C6 | Department management | Package department | Output Lattoflex determines activities packaging |
| C6.1 | Operator pre press assembly | Operator pre press assembly | Determination of production sequence |
| C6.2 | Operator pre press assembly | Buffer pre press parts 2 | Responsibility for stock level |
| C6.3 | Department management | Operators press | Determination of production sequence |
| C6.4 | Department management | Operators frame assembly | Determination of production sequence |
| C6.5 | Department management | Operators finishing | Determination of production sequence |
| C6.6 | Operators finishing | Buffer slatted boards 2 | Responsibility for emptying buffer and requesting new stock |
| C6.7 | Operators finishing | Buffer slatted boards 3 | Signal full buffer |
| C6.8 | Operators finishing | Buffer parts | Responsibility for stock level |

| Organisation: Verhaegen | Module: 6. Assembly Lattoflex | | | |
|---|---|---|---|---|
| Information relationships | | | | |
| Nr. | Sender | Receiver | Aim | Type |
| I1 | Department management | Production management | Information on progress | signal |
| I2 | Department management | Maintenance | Request for assistance | signal |
| I3 | Department management | Transport department | Request for transport | signal |
| | Operators finishing | Transport department | Request for transport | signal |
| I4 | Operators Package department | Department management | Information on progress | signal |
| I5 | Logistics management | Department management | Production orders | document |
| I6.1 | Operator pre press assembly | Department management | Information on progress | signal |
| I6.2 | Buffer pre press parts 1 | Operator pre press assembly | Information on stock levels | signal |
| I6.3 | Operators press | Department management | Information on progress<br>Request for new parts | signal<br>document |
| I6.4 | Buffer specific lenghts | Operators press | Information on production specific lengths | signal |
| I6.5 | Buffer slatted boards 2 | Operators finishing | Information on production | signal |
| I6.6 | Buffer parts | Operators finishing | Information on stock levels | signal |
| I6.7 | Buffer slatted boards 3 | Operators finishing | Information on stock levels | signal |
| I6.8 | Operators finishing | Department management | Information on progress | signal |
| I6.9 | Operators frame assembly | Department management | Information on progress | signal |

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