A REFERENCE MODEL FOR PRODUCTION PLANNING IN METALS INDUSTRY

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Abstract

Metals industry is strongly customer oriented, where the major part of the business is make-to-order and partially make-to-stock, especially for semifinished goods. The multi-level product structure is totally different from usual engineering type convergent bills of material. In a characteristic divergent structure, multiple end-product items are derived from a single initial raw material (e.g. steel, alluminum). Products and semifinished goods are described and identified by characteristics (e.g. grade, coating, thickness, width) and tracking of individual pieces instead of batches is needed (e.g. reels, coils, slabs). One of the main production scheduling problems is the setup time optimization.
Objective of this paper is to study and evaluate a reference process model for production planning/scheduling in metals industry which acts as a set of design specs for an Advanced Planning and Scheduling (APS) system. While most data processing oriented reference models are based on structured analysis and diagramming techniques, this study concentrates on two aspects of business process modelling which mostly support decision making orientation, i.e. simulation and activity based costing.
Keywords: *Metals industry, production planning, simulation, activity based costing*

1. Modelling and simulating a Rolling Mill

This modelling and simulation study concerns the production of a rolling mill. The objective is the analysis of the impact of changing the production plan. This process has been proven to be a critical business process. Therefore, the production itself has been modeled in order to analyse the consequences of the decisions in the production planning department. This simulation model has been built using the simulation tool FEMOS (ZUELCH, 1996, 1998, RINN, 1998) .

The first step of a simulation analysis is usually the modelling of the existing system. On this basis, the planner can easily compare future modifications of the production system using the simulation tool.

Figure 1 gives an overview of the production system which has been modelled in the described simulation study. It consists of one steel plant with two mini mills, two casting units and two rolling mills. Additionally, one furnace is installed in front of each rolling mill. The products of the steel plant are billets in different qualities, which are the input for both rolling mills.

During previous studies the planning of rolling mill 1 of this production system proved to be a critical business process. This rolling mill consists of 14 stands which form the material during the rolling process. The shape and the size of the rolls form the bars to the final style. Furthermore, sheers have to cut the bars at different stages of length for technical reasons. At the end of the rolling mill the bars have to be cooled before transferring them into stock. The equipment of rolling mill 1 has been directly modelled using the simulation tool FEMOS. This detailed modelling of the single stands is necessary for the further analysis of the different set-up activities.

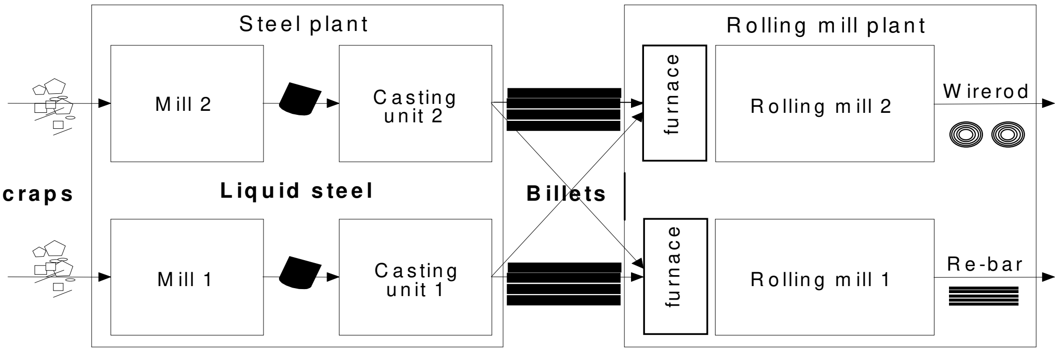

Figure 1: Scheme of the global production system

The billets are rolled sequentially through the whole rolling mill which means through all stands. This is independent from the different diameters, lengths etc. From the point of view of a FEMOS activity network, all diameters have the same processing sequence. The only parameter which is dependent on the diameter during the production is the duration of every process. This duration is directly linked with the speed of the rolls. Based on the different rolling speeds, the average output for the single diameters is also different.

The used stands and installed rolls depend on the chosen diameter. For every diameter, it is fixed which stand is set-up with which roll. The rolls are characterised by form and size. Figure 2 demonstrates the needed rolls for different diameters. The table is based on diameter 10 mm as starting situation. Therefore, the graphic explains which stand has to be exchanged if it follows diameter 10 mm. For example, for the change from diameter 10 mm to 12 mm all stands from line 7 to line 14 have to be exchanged.

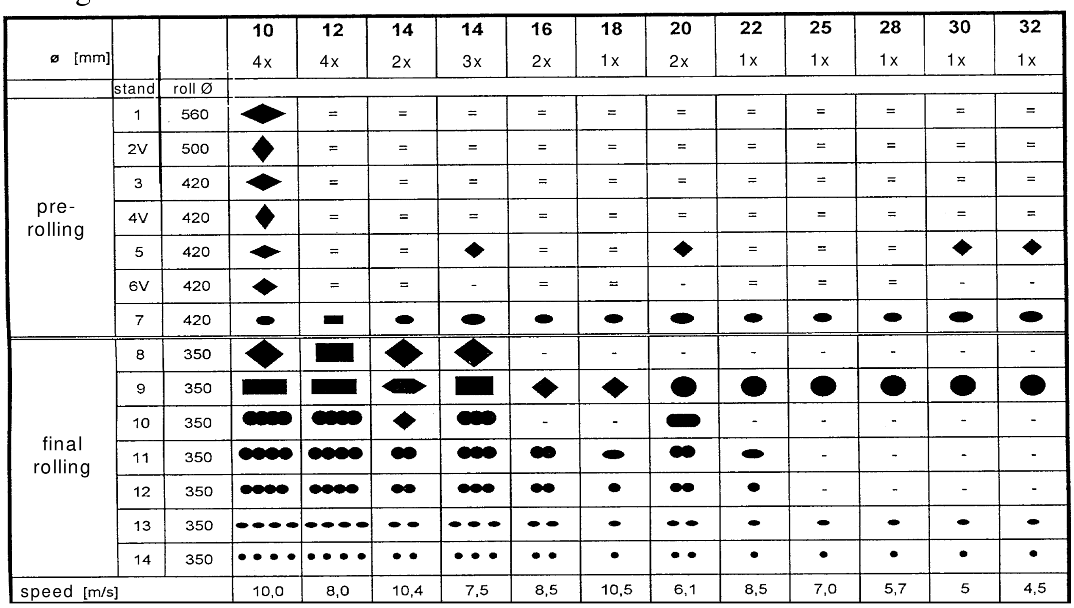

Figure 2: Graphical description of the needed stands for the different diameters

Additionally, Figure 2 shows that the bars are slit depending on the diameter. For example, diameter 10 mm and 12 mm are slit into four lines, while e.g. diameter 32 mm is kept in one line. If a diameter change is linked with a change in the number of slit lines three looping tables between the stands 11, 12, 13 and 14 have also to changed. This causes additional set-up efforts.

On this basis, an initial rolling sequence for rolling mill 1 has been developed based on experience. This sequence is developed from experience of the technical management of the rolling mill. It is expected as an optimal rolling sequence concerning the total set-up efforts for all diameters, starting for example with 12 mm and ending again with 12 mm. It is based on the existing technical and available human resources. Figure 3 shows this sequence with the different set-up times which are dependent on the number of stands which have to be exchanged and the therefore needed time.

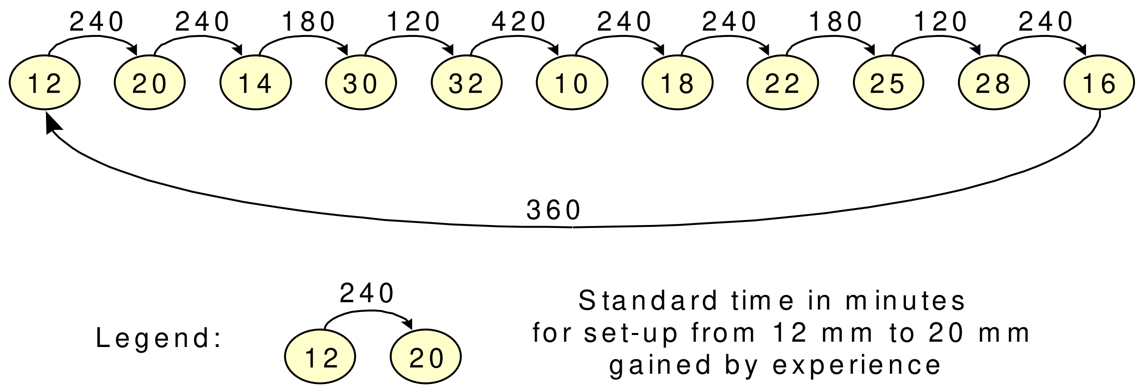

Figure 3: Existing rolling sequence and the related set-up times

After modeling the described resources and activities with the simulation tool FEMOS the production program of three months were simulated and validated by the real production results. The simulation model produced the same amount of each type of product during theses three months, so that the simulation module could be regarded as valid.

The simulation runs are visualised through Gantt-Charts. Figure 4 shows the Gantt-Chart of a one day simulation run. The graph represents the different activities linked with the individual resources of the production system. During the first four hours, the stands of the rolling mill are prepared for a new diameter. This can be identified on the irregular processing for the different stands. The bars in the Gantt-Chart represent the different activities for changing and preparing the stands. Both mills of the steel plant are producing continuously in parallel, which can be seen in the first two lines.

Based on the Gantt-Chart, a first analysis of the production system during the simulation can be peformed. In parallel, all events concerning the technical and human resources as well as the material and the orders are stored in the results database of FEMOS. With this database several evaluations of the simulation run concerning logistical and financial key figures can be done ex-post. Figure 5 shows i.e. the utilisation of the different production units and the stock turnover in tons of scrap, steel and billets. It is obvious that only approximately one third of the billets are taken from stock. This is because of the not modeled big rolling mill which consumes twice as much billets as the modeled rolling mill.

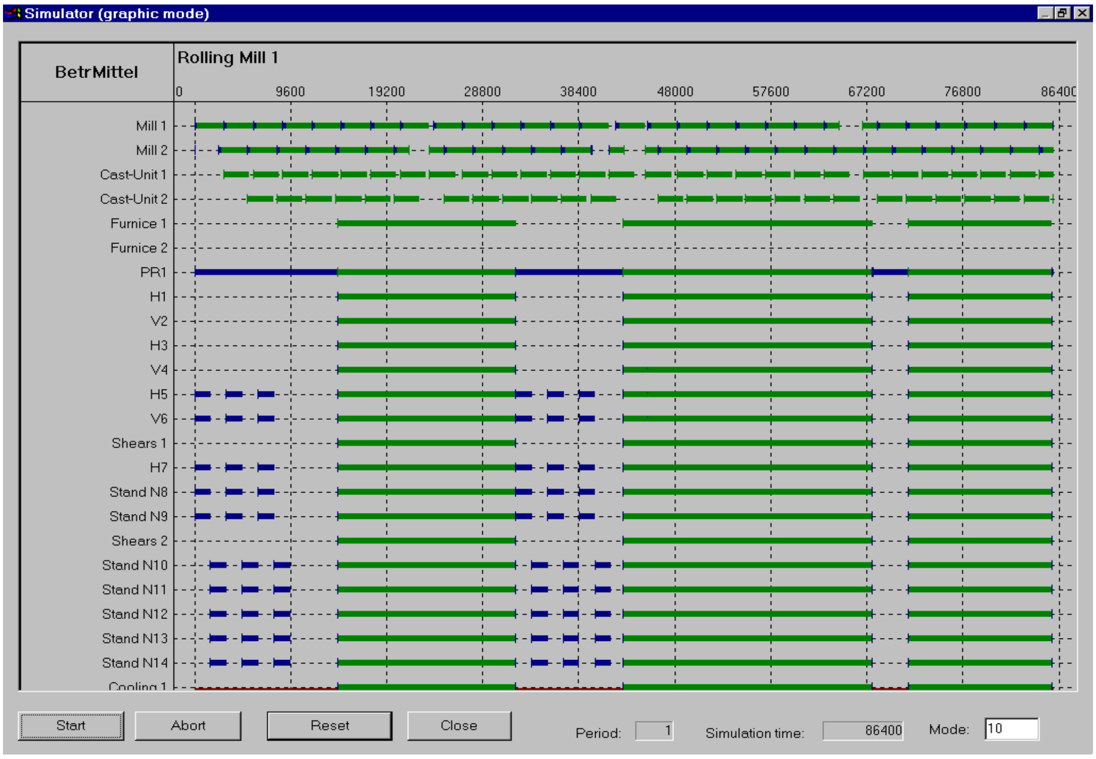

Figure 4: Simulation run of one day of the rolling mill

Based on the online animation and on the evaluation tool of the simulation system FEMOS, the user is able to analyse in detail the existing production system as well as possible future modifications. During the simulation study, several ideas for potential improvements arose. The most important improvement field was the optimisation of the diameter sequence. As a result of the study, the improvement possibilities are described as follows:

The set-up activities are strongly influenced by the organisation and planning of the set-ups. As already described before, the sequence of rolling the different diameters has been developed by the rolling mill management through experience. The aim of the rolling mill management is to integrate existing customer orders into this fixed rolling sequence as efficiently as possible.

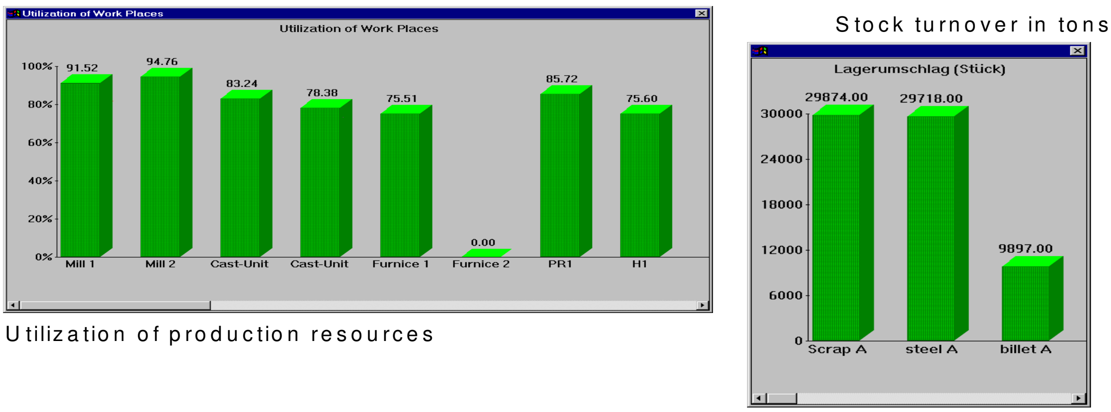

Figure 5: Evaluation of the production resources utilisation and the stock turnover

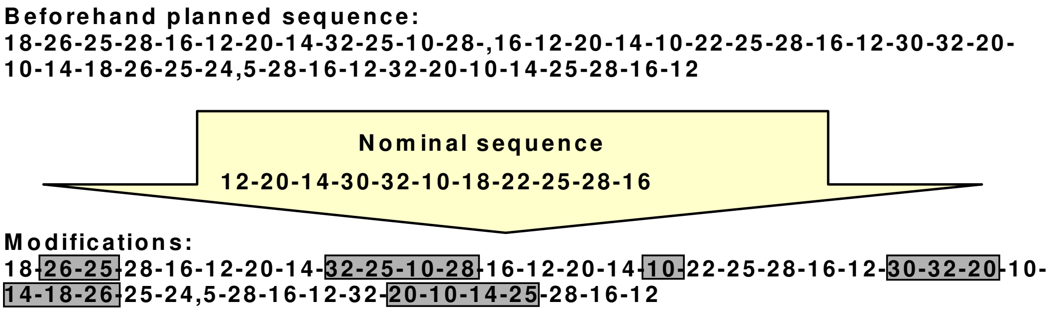

Figure 6: Monthly adaptations of the rolling sequence (3 months)

This example demonstrates that even if the developed sequence leads to minimal set-up efforts the continuous modifications on a monthly, weekly and daily basis cause additional set-up efforts which are usually not optimised by the support of a production planning tool.

To optimise the set-up efforts in any situation, all possible set-up combinations have to be analysed in detail. This means, a set-up matrix must be created containing all times for changes from diameter x to diameter y. Due to the complexity of this study which is strongly connected with the field of Operations Research (OR), the following description is only a global one.

Based on the chosen OR-algorithm (Travelling Salesman Problem, cf. e.g. NEUMANN, MORLOCK 1993) an optimal solution can be achieved. Furthermore, additionally planned adaptations can be integrated in this optimisation process.

The solutions of the statical optimisation of the rolling sequences with the OR-algorithm were transferred to the simulation tool FEMOS. On this basis, the dynamic influences on the optimised production system could be studied, and when necessary, modifications on the statically optimised production sequence can be done. Table 1 shows the achievement by optimising the rolling mill.

	Statically calculated set-up time in min/month	**Total output in t/month**	**Δ Output in t/month**
Actual sequence	2920	39966	-
Optimised sequence	2580	40165	199

Table 1: Simulated achievements of rolling sequence optimisation

It demonstrates that the dynamic analysis recommends the planner to use another rolling sequence instead of the previously defined optimal sequence. By doing this, nearly 200 tons more can be produced per month.

2. Application of Activity Based Costing

The following example of the steel company concerns the study of the setup process that is needed in order to change production from one product to another.

2.1. Methodology of Setup Calculations

Two distinct aspects of setup have an influence on production decision-making. The first aspect concerns the loss of capacity and therefore the ability to satisfy demand. The second one deals with the cost implications of setup. This latter aspect is most frequently encountered when dealing with lot size calculations (e.g. the economic order quantity or EOQ). In the following paragraphs we shall focus on the capacity aspect of setup.

The capacity of a factory is finite. As a result, this capacity is consumed by demands such as production, maintenance, idle time and setup time. There is an inverse relationship between setup time and capacity availability. The more time is spent for setup, the less time is available to meet the other demands placed on capacity. On the contrary, the less time is used for setup, the more capacity is available to meet the other demands.

A classical definition of setup is the following: Setup is the amount of time that it takes to change a machine or work centre to go from the last part of a production lot to the first consistently good part of the next production lot. With this notion of setup, one setup does not end until the company is able to produce parts meeting their specifications. In other words, any parts which are rejected because they do not meet the defined specifications are considered to be part of setup.

An Activity Based Costing approach needs to analyse the activities carried out every time a setup occurs. The activities identified in most cases are the following:

- Review of the specifications and processing information for the part to be next produced,
- location of the necessary tooling and verification that tooling is usable (in a good condition),
- physically tear down the previous setup and rebuilt the equipment by inserting new tooling so that it can produce the necessary items,
- position the parts and ensure that the items will be produced correctly, and
- adjust.

Taking the above activities into account, the following parameters of setup costs should be considered:

- Labour cost (for any activity),
- Administrative cost (supervision),
- machine maintenance,
- tool maintenance,
- share of depreciation, and
- other facility costs

The sum of the above costs can generate the total yearly cost for setups in the factory. The next step is to calculate the number of setups in each year. An even better approach should be to calculate the total setup hours getting an hourly overhead rate. Finally one of the following performance indicators could be calculated:

$$\boxed{\textbf{\textit{Cost of one setup}} \quad \text{or} \quad \textbf{\textit{Cost of one setup hour}}}$$

The above cost can be calculated for the different product families produced in BSW. In the case of the German company, the following action plan was followed:

Recognition of activities performed during the setup
The following list was used as a blueprint. The activities which were not relevant were erased, and, if other activities were performed, these were written down.

Activities	Exist ?
Review of the specifications and processing information for the part to be next produced	YES/NO
Location of the necessary tooling and verification that tooling is usable (in a good condition)	YES/NO
Physically tear down the previous setup and rebuilt the equipment by inserting new tooling so that it can produce the necessary items	YES/NO
Position the parts and ensure that the items will be produced correctly	YES/NO
Adjust	YES/NO
Add Other Activities	YES

Table 2: Search for relevant activities

Cost information connected with the recognised activities
The necessary data were provided by the company for a selected number of the following cost categories:

Cost category	**Cost (in DM)**
Labour	
Supervision	
Tool & Machine Maintenance	
Depreciation	
Other Facility Costs	
Total Cost	

Table 3: Needed cost data

Calculation of the yearly setup hours or the number of setups

Cost Driver	**Value**
Number of Setups	
Setup Hours	

Table 4: Cost drivers

Calculation of the cost of one setup or of the cost of one setup hour
The above process was followed for every product family which will be analysed. The outcome of the above ABC analysis was the recognition of the overhead rate due to the setup activity in the different product families.

2.2 ABC Analysis Results

The identified setup activities were the following:

- To prepare the stands (this was finally chosen not to be analysed),
- to stop the machines,
- to replace the stands,
- to build new stand,
- to adjust, and
- to run new stand.

Figure 7 presents the inputs and outputs of the activities.

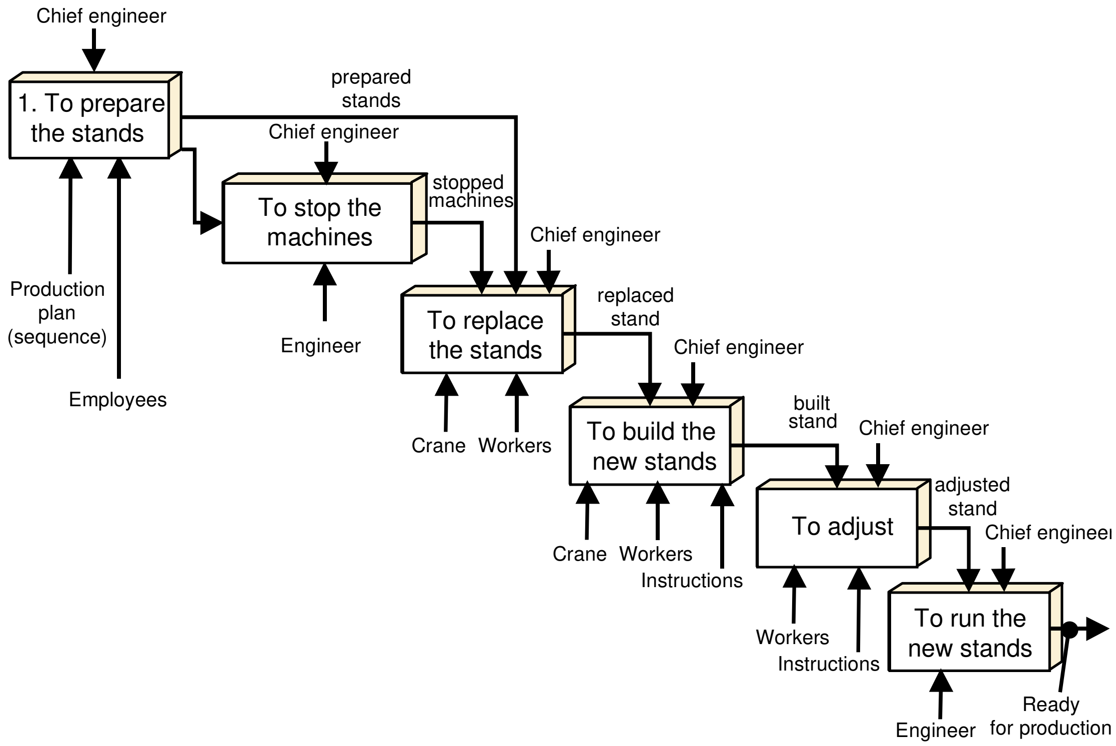

Figure 7: Inputs and outputs of the analysed activities

The cost categories that were used in the analysis are:

- Labour,
- supervision, and
- opportunity cost (cost because of lost production).

The selected cost driver for each activity was the time needed for the corresponding activity.

- The model which was constructed for each product family is seen in the following page.
- This analysis was applied for all the recognised product families of the company, in two different cases:
  - In the situation before Business Process Re-engineering
  - In the new situation, after the completion of the re-engineering process.

Examining the summary results of the old and the new situation, it was found that a cost reduction of 245,000 DM or 122,500 ECU was realised after the introduction of a new way of performing the setups.

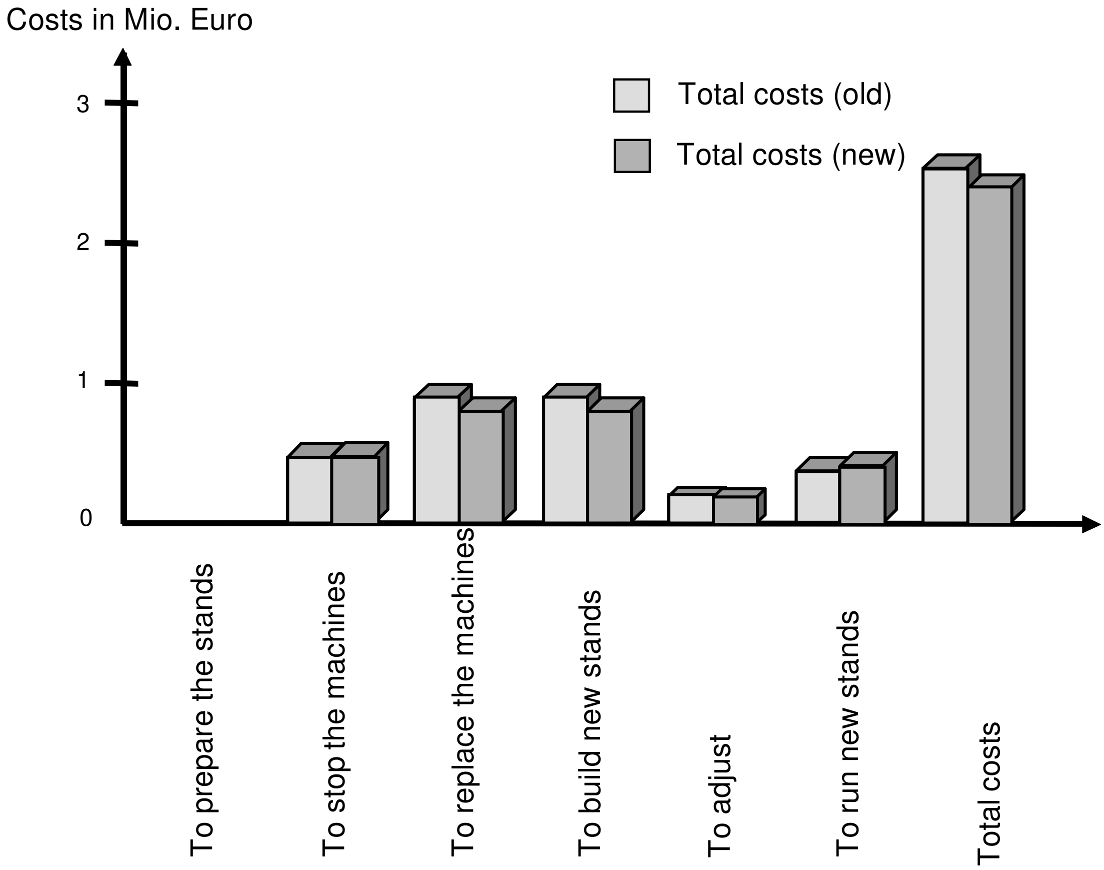

Figure 8: Set-up cost comparison

This cost reduction resulted taking into account basically the parameter of cost of lost production. This means that every minute saved by the setup can be used for the production of different products.

The above analysis allowed the evaluation of the re-engineering results by providing an internal benchmarking approach which compared the cost of setups in the old situation with the one in the new situation.

AA	Activity	Labour cost	Supervision cost	Cost of lost production	Total cost
1	To prepare the stands				
2	To stop the machines	5,255	263	24,5	30,018
3	To replace machines	23,650	1,182	110,25	135,082
4	to build the new stands	23,650	1,182	110,25	135,082
5	To adjust	3,504	175	16,333	20,012
6	To run the new stand	7,007	350	32,667	40,024
	Total costs	63,066	3,153	294,000	360,219

Table 5: Existing situation for diameter 12 mm

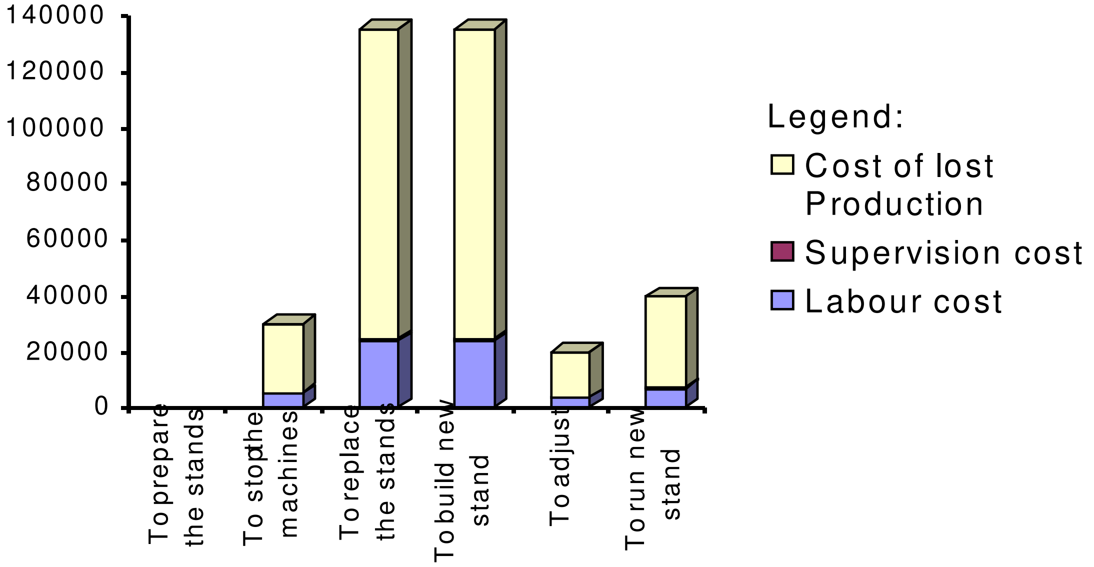

Figure 9: Detailed costs for a set-up activity

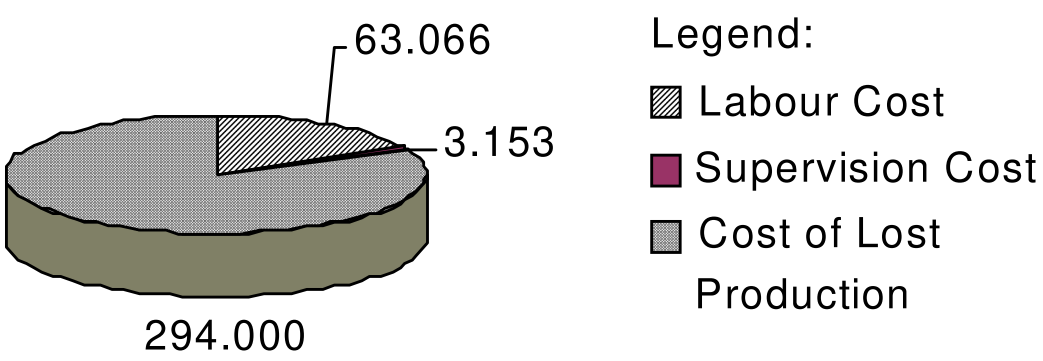

Figure 10: Distribution of the costs for a set-up activity

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