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Simulation Aided Planning of Work Structures

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Abstract

This paper discusses a simulation aided planning game in the field of re-designing work structures. The game deals with a bicycle production and mainly covers the following three aspects: to enhance the understanding of problems and solving in the field of work structuring, to enable teamwork practise and to awake interest in using simulation tools for analysis of production systems. The planning game is supported by a guideline of work structuring for a suitable procedure and the simulation system FEMOS for dynamical analysis of planned systems.

The planning game is part of the European wide seminar program *Simulation Aided Management Training SAM*, which is granted by the COMETT program of the European Community. Aim of the seminar program is the training of managers and students in the use of simulation tools in production and logistics.

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1. INTRODUCTION

In recent years remarkable changes have taken place in industry. Markets switched from producer-orientation to customer-orientation, the quantity of units per order decreased and customers demanded for shorter product life cycles in accordance with reduced lead times. So, industrial enterprises became aware that changes have to be made in the production system to remain competitive in the market. In this context, concepts like segmentation, lean production or process orientation are under discussion. A common essence of this new sight of production systems is the human centered approach under organizational concepts.

J. O. Riis (ed.), *Simulation Games and Learning in Production Management*

These influences of market, as well as technology, law and society require a change of work structures. In addition to the technical and economical point of view, human aspects have to be considered to create new work systems with high productivity and flexibility.

In order to give the possibility to see the effects of new forms of work structures (e.g. group work) and principles of work structuring (e.g. job enrichment, job enlargement and job rotation), this course focuses on aspects of the interlinkage between abilities and assignments of personnel and functional requirements.

2. WORK STRUCTURING IN PRODUCTION SYSTEMS

The design of economic and human work systems require a reciprocal adaptation of man and work (Figure 1). On one hand man with their different skills, claims and expectations could be prepared for work with measures like ability analysis, training, instruction and motivation. On the other hand there are demands of the work, influenced for example by the kind of work places, the work contents and the environment. In order to ensure that working man could fulfill their assigned tasks correctly, the correspondence between the abilities of man and the demand of the work have to be ensured.

Due to the fact that in general there is no exact overlapping of the abilities and demands, we need work structuring as a process of adaptation. On the work side the basic conditions, i.e., the ergonomical and environmental conditions, should be ensured. On the other side it is necessary to know the suitability of man for an assigned task. Other adaptation processes could be started by the introduction of new techniques or automation which should be accompanied by measurements for the concerned man like special training and instruction.

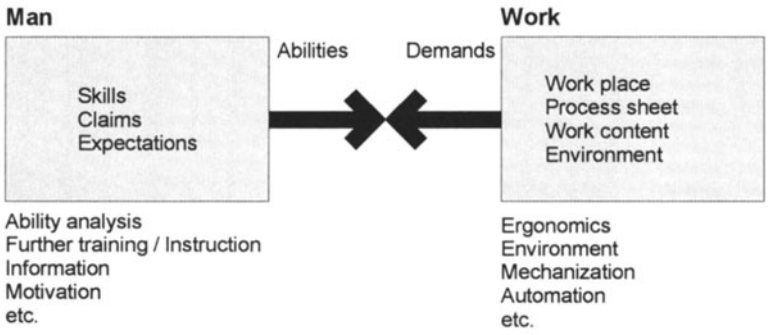

Figure 1. Work structuring as the reciprocal adaptation of man and work [2]

In addition to this aspect of micro designing, work structuring can also have the dimension of macro designing. For the re-engineering of a production system it is necessary to optimize not only a single work place but the whole system.

Therefore, flow principles have to be fixed and new forms of work like group work should be taken into consideration.

In order to achieve a suitable solution, the planning of work structures can be supported by a guideline (Figure 2). The guideline is the essence of many work structuring projects in industrial practice [3] and was published by Grob and Haffner [2]. Zülch enlarged this guideline with additional steps he gained through experiences with simulation studies [7, 8]. The enlarged guideline was the starting point for the definition of a simulation aided planning game in the field of work structuring.

The main topics of the guideline for work structuring is the planning of different variants and a dual evaluation. In order to achieve a good solution, it is necessary to plan several variants based on different organizational concepts [3]. Thereby, it is possible to consider different levels of automation, abilities of staff and limitation of investment. A dual evaluation allows to consider an economical analysis on one hand and a rating of scores for the non-monetary benefits on the other hand.

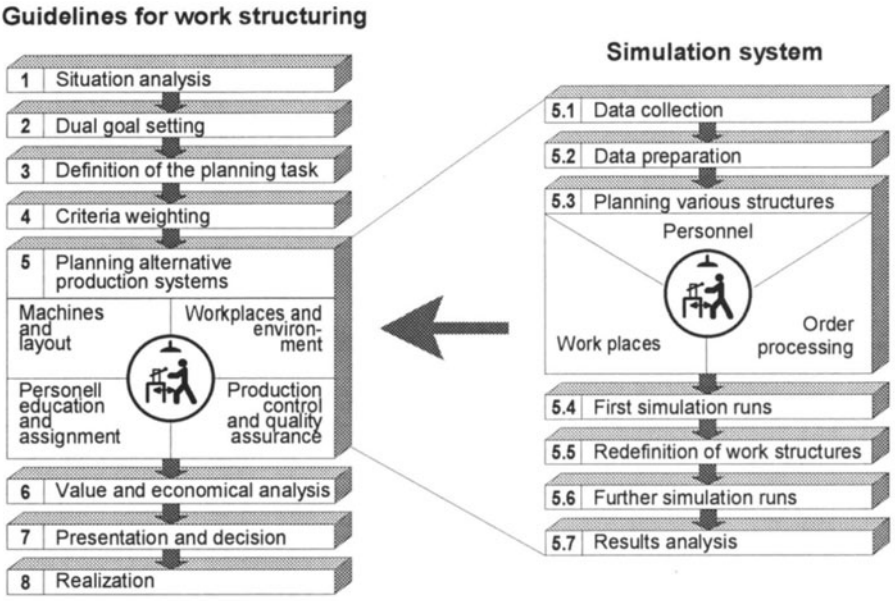

Figure 2. Guidelines for planning work structures enlarged by simulation [7, 8]

For the quantification of the effects this planning procedure is enlarged by simulation runs in order to evaluate the dynamic characteristics of the planned solutions.

3. DYNAMICAL ANALYSIS OF WORK STRUCTURES WITH THE SIMULATION TOOL FEMOS

For the evaluation of planned work structures a personnel-oriented simulation is needed. The simulation program FEMOS, which is being developed since 1988 at the ifab-institute in Karlsruhe, is normally applied in the areas of research and industrial projects ([10];for the suitability of simulations tools see [9]). The open concept and its user-interfaces with windows-technique allows to use this tool also for this seminar. In spite of this, there was the need for changes in the program to simplify the modeling and the evaluation for unskilled users. Furthermore, the interfaces of the simulation tool and the representations of the evaluation module were translated into English.

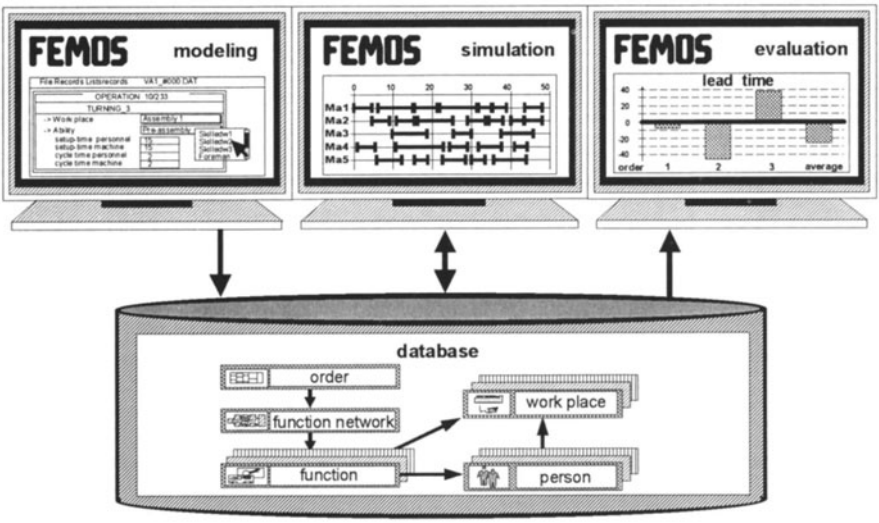

Figure 3. Components of the simulation tool FEMOS [4, 1]

FEMOS consists of three modules (Figure 3): a tool for the input of the model data, the simulation module with several possibilities of an on-line animation and the evaluation tool for the calculation of the key data. A system can easily be modeled in form of a database as a logical description of the production system by filling out the masks of the modeling tool. Thereby, the work system is modeled by the following elements:

- Personnel with abilities and competence for a set of work places
- Working hours
- Work places with feasibility for a set of tasks
- Materials inclusive inventories
- Operations with processing times

- Function networks
- Orders with due dates

The simulation itself is the imitation of the processing of operations, initiated by the winding-up of orders. This process is dominated by a competition of orders on restricted production capacities. The dynamical performance of the system is influenced by the kind of working. For instance, work in a production line leads to a loss of adjustment of the line work places. This effects the key data like utilization or lead time. In opposite a group work place, where a whole product has to be assembled, the staging of the needed materials has repercussions e.g. on the inventory.

Special psychological effects of work like group dynamical aspects cannot be simulated by a computer program. Also individual behaviour is not the aim of the simulation investigation. Furthermore, the planning of work structures is a designing of work and therefore it should be apt in general and not only for the momentary staff configuration. For these reasons and with the background of experiences with simulation studies it can be stated, that dynamical analysis of different work systems with a simulation tool is a great opportunity to compare solutions relative to their dynamical characteristics by means of key data. Further aspects like the satisfaction of the employees must be considered in the non-monetary benefits analysis or should be treated in another kind of simulation game like the *work flow game* [6] with its simulation of group work in a board game.

4. DESCRIPTION OF THE GAME

The seminar on "Simulation Aided Planning of Work Structures" can be carried out in a three days version with a complete planning game and in an intensive version of one day with the essentials of work structuring and a reduced version of the planning game. The participants of the planning game redesign the work structure of a bicycle production in teamwork. Supported by a guideline and by the simulation tool FEMOS, the teams are able to find a suitable solution. Normally the planning procedure is done manually. Instead of this classical planning process, this course uses a simulation tool for the analysis of the dynamical system behaviour. Thereby, rapid feedback between planning ideas and their effects could be evaluated. The planning game is carried out in several steps with the background of the described guideline.

4.1 Steps of the seminar

The planning game starts with an introduction to the basics of planning work structures dealing predominately with work systems, principles of planning and structuring.

Before starting with the planning of a system, the participants are clubbed up in teams, but no specialized roles are given beforehand. During the planning process the teams will segregate their roles themselves.

Introduction into the initial planning situation

To familiarize the participants with the bicycle production, the initial situation is described through materials like pictures of the produced bicycles or a rough layout of the system (Figure 4). In order to get a start of the planning process, the participants are confronted with a situation analysis which shows a more or less poorly run factory. For example it is not possible to fulfill the increasing demand of the market, the quote of scrap and rework is too high and the worker's council complains the missing of a suitable recreation area.

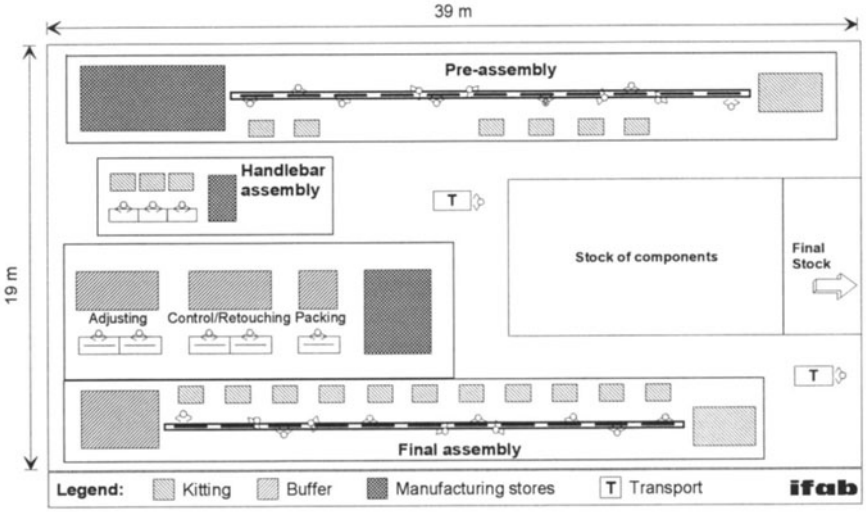

Figure 4. Layout of the initial situation showing mainly line assemblies [1]

Setting of the non-monetary criteria

The dual evaluation consists of a calculation of investment and a rating of scores of a non-monetary benefits analysis. For the dual evaluation of the planning alternatives, non-monetary criteria like "Improvement of the work content" had to be defined. The criteria are worked out with the background of a given situation analysis and should work like a "red line" during the planning process. By means of the defined criteria the planning results will be evaluated at the end of the seminar.

Weighting of the criteria

The criteria of the benefits analysis are weighted in the way of comparison by pairs. This process is supported by using a matrix of criteria in order to ease calculations of scores. The weight of the criteria implies the necessity of the goals to be fulfilled.

The process of weighting is done in a common discussion with all participants after a combination of criteria which the teams developed before separately.

Planning of the work system

- *Choosing a principle structure*
  With the support of a morphological scheme the teams have to choose a principle structure. Hereby they can decide on separation into assembly blocks, on production oriented segmentation with regard to the three bicycle types, on flow principles like line production or complete assembly work places and on work organization like group work or division of work.
- *Allocation of operations to work places*
  On behalf of the principle structure the operation had to be allocated to work places. Therefore, a precedence diagram with a logical description of the operations is used.
- *Capacity requirements planning*
  With due considerations to the scheduled order program, the required capacity (respectively the quantity of employees and work places), must be calculated.
- *Qualification and wage rate of staff*
  With regard to the work structures, the teams can decide on principles of structuring like job rotation, job enrichment and job enlargement. Therefore, the needed abilities of the employees and their wage rate must be determined.
- *Organization of transport*
  The teams can also decide on the transport system. For example the transport can be organized by dedicated personnel or by members of a work group.
- *Capacity of stocks and buffers*
  Dependent on the chosen work structure the capacity of stocks and buffers between segments or single work places must be determined.
- *Quality assurance*
  Aspects of quality assurance could be part of work enlargement measurements. Therefore, tasks like adjusting and rework could be integrated into the groups.

Simulation and optimization

After the teams reach a state where their data is apt to be transferred into the simulation system, the model of the initial situation of the bicycle production is altered. After modeling a new solution bottlenecks can be located by an on-line animation during the simulation and the following evaluation of key data. Using the simulation tool the configuration of the planned system can be optimized step by step.

Evaluation of the work system

After finishing of the simulation run, the calculation of investment and the evaluation of the system by means of the criteria had to be done.

Presentation of the solutions and final discussion

The last step of the planning game is the presentation of the planning results by the teams. Therefore, each team has to prepare some flip charts with the goals and characteristics, the investment calculation, results of the simulation and a rough layout of their new bicycle factory. By means of the charts the teams have to explain their goals, ideas, their strategies and results in front of a so-called "board of advisors". That should give the participants the feeling of selling their ideas to the responsible departments and the top management of the company.

4.2 Materials and documents for planning

For the planning process the teams receive the following materials and documents for the planning process:

- description of the initial situation (jobs with cycle time, network plan, parts data, etc.),
- problem analysis,
- objectives of the management,
- prepared forms for the support of the planning process,
- data for calculation of the efficiency (personnel costs, store costs, etc.) and a
- manual for the use of the simulation program.

Playing the planning game several times gives the experience, that it is more effective to give the participants the needed initial data already at the start of the game. Then the teams are supported with additional information continuously during the game course by handing out prepared forms. So they have all the required information available for the overview and on the other hand they have the red line to fulfill the planning tasks in the right way by the sequential supply of additional forms.

4.3 Characteristics of the game

During the Workshop on Games in Production there has been a discussion on how planning games can be classified. Based on the two-dimensional characteristic of games with axis of the pedagogical objectives and the number of predefined jobs, published by Riis, Johansen and Mikkelsen in 1993 [5], the form of the classification scheme has been enlarged by an additional axis for the level of system innovation.

The attempt to map this planning game in the two dimensions, give by the authors leads to the realization that a single place cannot be pointed out (to the problem of placing games in the map see also [5]). Because the game covers different aspects on every axis it could be better characterized by a cube (Figure 5).

The pedagogical objective of this game is mainly the *understanding* of the problems and the mechanisms of redesigning of work structures. Additionally, the game should *aware* the participants of the possibilities by involving a simulation tool in a planning process. Furthermore, the *know how* of practising teamwork should be trained during the game.

With respect to the level of system innovation, the course is mainly dedicated in the *design* of new work structures. But due to the fact that the first step of a design process is an analysis study, the participants are also involved in an *analysis* phase. Of course the implementation of new work structures could not be fulfilled by the planning teams but they have to take aspects of *implementation* into consideration during the planning game.

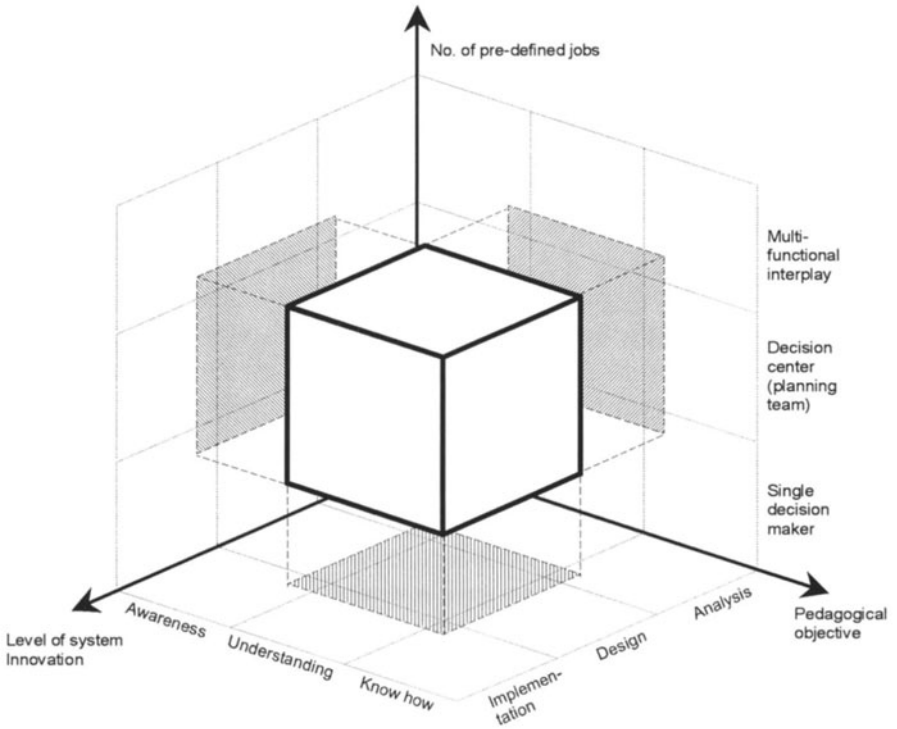

Figure 5. Characteristics of the planning game
(following [5]; discussion paper from the "Workshop of Games in Production Management")

Concerning the characteristic of number of pre-defined jobs the planning game is mainly based in the field of a *decision center,* because the planning process has to be done in teamwork. But it is up to the team to either have a division of work with several jobs or not. In that case it could be useful that some decisions are done by a *single decision maker.* On the other hand the planning game covers a wide range of aspects with a lot of different tasks which could not be carried out by one participant alone, so it could also be described by a *multi-functional interplay.*

5. EXPERIENCES WITH THE SEMINAR

The seminar has been offered in two versions: a three days version with a complete planning game and an intensive version of one day, covering the essentials of work structuring and a reduced version of the planning game. The three days seminar have been enriched by additional lectures on basics of simulation of production systems and simulation studies in industry. During the one day seminar it was not possible to play the entire planning game to every detail. But with a little more support and hints by the moderator of the game the teams were also able to develop a new work structure and to run simulations. Restrictions to the three day course mainly amount to the optimization and the presentation of the solutions. In addition, there was not enough time to have a detailed investment calculation and to discuss the non-monetary benefits analysis more profoundly at the end of the game. But nevertheless it was possible to give the participants an impression and the main topics of planning new work structures and the use of a simulation tool during the planning process.

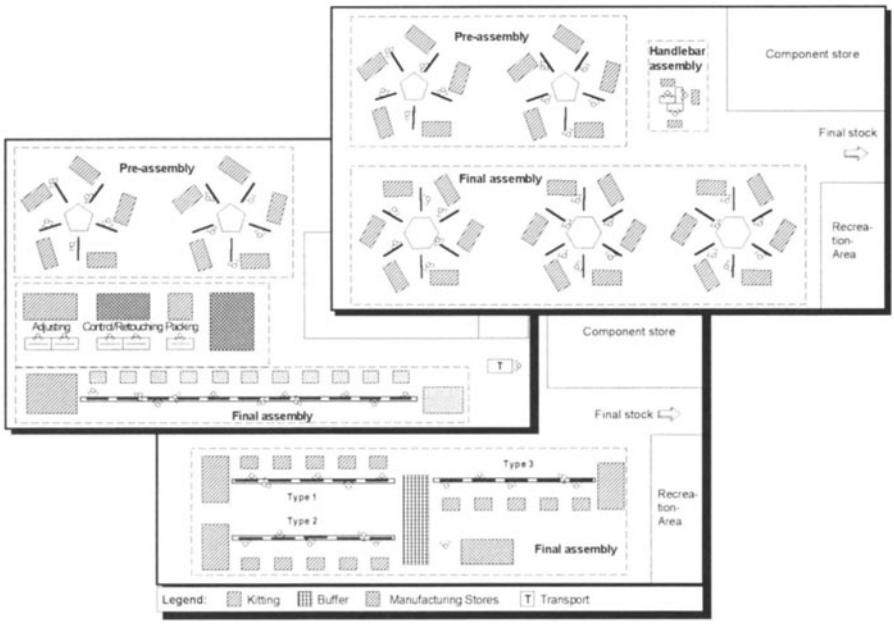

Figure 6. Layout examples of the bicycle production as result of the planning process of different teams

So far the seminar has been held six times at five different European locations in four different countries. The experiences with the seminar are really good. The participants are rather enthusiastic about planning new work structures with

the help of a simulation tool. Furthermore, they liked to get practice in teamwork and presentation of results and the English language as a common communication basis.

Playing the game with different participants of several European countries gives the chance to compare the problem solving strategies. Remarkably interesting results were noticed in the problem solving techniques of the various teams and their diverse approaches (see for example Figure 6). Of course, the results are influenced by the coaching of the moderator, but according to the different backgrounds of education and society there are different strategies. Some groups try to solve the problem of capacity planning by exact calculations. Other groups estimated the need of capacity. This inexact calculating way sometimes consider the dynamical effects better than the "exact" way, so that they do not need so many simulation runs for optimization. At the end, all strategies lead to a more or less good planning result. But it is remarkable that the solutions are very individualistic.

Perhaps it would be a good idea in the future to record the different strategies of the teams during the carrying-out of the planning game in order to have an evaluation of the strategies with respect to the background of the participants. Additionally, the results of the simulation runs of the planned system can be used for a quantitative comparison.

6. CONTEXT OF THE GAME

So far the game has been used in the seminar program *Simulation Aided Management Training SAM*. The SAM-project originally was initiated by the "West-European Group of University Teachers for Industrial Management". The courses of SAM have been granted by the COMETT-program of the European Community. All courses took place in every location of the partners who came from University of Ghent in Belgium, Universities of Karlsruhe and Dortmund in Germany, Technical University of Lyngby in Denmark and University of Zaragoza in Spain.

The subjects of the program are from the field of planning and running productions systems with the topics Management by Projects, Integrated Factory planning, Planning of Work Structures, a game concerning Euro Distribution, Productions Planning and Control and a Business Logistics Game.

7. FURTHER DEVELOPMENTS

The rich experiences with the planning game of work structuring based on a simulation aided concept lead to the idea to enlarge its topics and to transfer other planning games to the model of the bicycle production.

The partners of the COMETT-project SAM wish to use their experience by defining a new kind of a planning game (Figure 7): a Modular and Integrated Business Game in Logistics and Production (MOBIL with SAM), which includes all aspects of planning and control of a company during the whole life cycle of a

product. Thus, by the positive experiences with a bicycle factory as a field for gaming, it is planned to use the described bicycle production as a common example. The benefits of using a common example for several seminars are the following synergetic effects:

- The introduction into the example is only needed once.
- General tasks like analysis studies or definition of goals are only needed once for the whole program.
- The modules of the whole seminar program could be mixed.
- The duration of the course is more flexible.

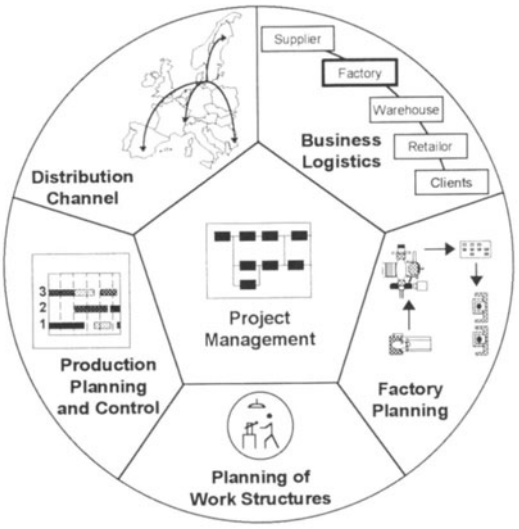

Figure 7. Modules of MOBIL with SAM

The definition of an integrated version of a planning game which includes aspects of production planning and control, project management and work structuring in a production string and aspects of market and business structures in a logistic string, is the aim of a new circle of games of the COMETT-partners.

8. SUMMARY

With the help of suitable guidelines, the participants of this seminar should be able to design new forms of work structures. This planning procedure is enlarged by simulation runs to evaluate the dynamic characteristics of the planned solutions, so that the planning teams will get a rapid feedback of the effects of their ideas. For that purpose, the simulation system FEMOS is used.

In order to demonstrate the the effects of new work structures, a suitable example had to be defined. On one hand it should be complex enough to see the effects of new work structures. On the other hand the participants should be able to change the simulation model themselves. Therefore, it was decided to use a bicycle factory, because bicycles are well known and the production system is not too complex. In order to build up a model of a realistic factory based on real data, two bicycle factories in Germany were visited. This data was used to build up an initial situation.

After an introduction into the basics of planning work structures, the guideline and the principles of a dual evaluation, the participants of the seminar start to plan new work structures of the bicycle production. Initially, the teams are confronted with a badly situated factory. This initial situation is described by simulation results and a situation analysis. During the planning game the participants have to improve the situation by developing new forms of work structures.

At first, after teams of three to five participants are formed, they have to work out the objectives for the dual evaluation. The next step is the definition of a principle solution. Thereby, it is for example possible to plan a segmentation of production in bicycle types or an installation of group work. The teams could also decide on flow principles, staff configuration, level of qualification and payment, work places, flow of material and investment. For the evaluation of their planning results they have to change the simulation model of the initial situation. With the help of the simulation runs the teams are able to evaluate the dynamical characteristics of the planned solutions. Thereby, they get a fast feedback of the effects of their ideas. Using the evaluation tool and the on-line animation of FEMOS, the teams locate bottlenecks and optimize the staff configuration of their solution.

After the simulation runs the teams have to work out further details of their solution. For example the investment and the time of amortization must be calculated. For the final presentation the teams also have to prepare some charts like the rough layout of the workshop, results of the simulation and the characteristics of their solution.

At the end of the seminar the teams have to explain their different solutions by means of charts. Thereby, the teams get the opportunity to demonstrate their ideas to improve the poor situation of the factory and to show the results of their planning process. Afterwards the scores of the non-monetary benefits analysis of the variants are defined in an open discussion with all participants. Within a final discussion usually a decision on the best solution is made and principle advantages of the different work structures are discussed.

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