

# SIMULATION OF GROUP WORK PROCESSES IN MANUFACTURING

Willi Bernhard  
Axel Schilling

Basle Institute of Technology  
CIM-Zentrum Muttentz  
CH-4132 Muttentz, SWITZERLAND

## ABSTRACT

This article describes how a manufacturing system with working people can be modeled and simulated, wherein the focus is on the organizational processes of the people itself. Explanations are based on a real model, which was made for a Swiss Company producing weaving machines. The model described includes the assembly part where seven people with different qualifications have to organise their work on more than 15 different assembly stations. The software "MASTER" was used for building the model, whereas the simulation model itself runs under the discrete-event simulation language SIMSCRIPT. The modeling concept can be applied to any other simulation package which shows a certain modeling flexibility.

## 1 INTRODUCTION

The realization of group work processes is getting more and more interesting for small and medium-sized enterprises. Improvement of efficiency, flexibility and motivation of the working people involved are reasons for that. As companies will undertake changes in the organizational structure only if economic advantages can be expected, simulation can help to support the decision process.

## 2 ASPECTS OF GROUP WORK

Various forms of working methods exist in the manufacturing business. In the earlier days, the man-machine combination was traditional. A more flexible form can be achieved when a foreman divides the daily tasks into jobs, which he assigns to the workmen available. Possibly the most flexible method is that of group work, where a group of workers organise their work independently from a foreman. Every worker can

make use of his personal qualifications, which improves his motivation at work.

## 3 A PRACTICAL EXAMPLE

The well known Swiss Company "Sulzer Rütli" was chosen as a "System under test." Sulzer Rütli is known as a traditional manufacturer of weaving machines. In order to improve flexibility, they considered implementing group work in the assembly area. One goal was to experiment with the model in order to find out the impact of the workers' qualifications on throughput and production time for different weaving machines.

## 4 MODELING OF GROUP WORK PROCESSES

The simulation of material flow within manufacturing processes is a well known and widespread application of discrete-event simulation. A standard way of taking workers into account is to model them as resources. Although most simulation packages provide the resource concept, the resource element is limited in its application for modeling active human behavior. In the case of modeling human behavior in group work processes, it is unnecessary to include psychological aspects. It would be very hard or even impossible to include more than the working capacity of people and the allocation to the work itself. Within our model, every worker is modeled as a self-running process which controls a worker-entity and owns data as well as certain rules for doing the work. All process-data are based upon interviews with employees of the Company.

## 5 MODELING ELEMENTS

Figure 1 shows the elements which are necessary in

order to define a process-network. A process can do anything from a simple time-delay to a complex decision-based action. Every process has a process-description which has to be described in the simulation language SIMSCRIPT.

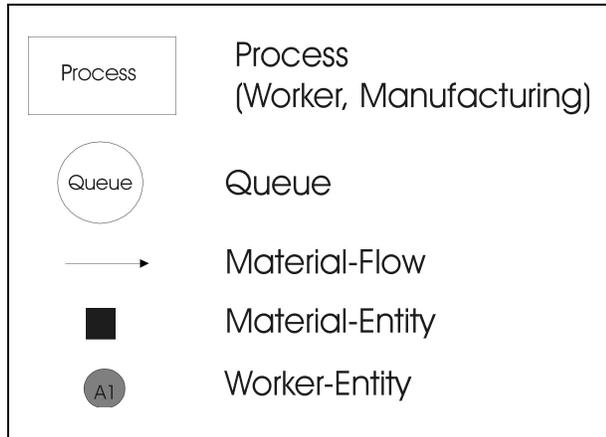


Figure 1 : Process-Network Elements for Building the Model

A queue can be used for holding entities. Like a process, a queue can have a specific description which defines what happens if an entity enters the queue (time-delay statements are not allowed within a queue process-description).

The arrow defines the material flow, while the material-entity is a dynamic object which is shown as a moving entity in the animation. Worker-entities are also dynamic entities but with a different shape. Every worker-entity has its own process which controls its worker-entity.

Figure 2 shows how workers can take action and exert influence on manufacturing processes. A worker on the right side of the manufacturing-process (here called 6103) initiates the manufacturing process. There are as many workers allowed as defined for the specific process. A worker who is not fully qualified for the manufacturing process but qualified to support a fully qualified worker (who is always shown on the right side of the process) is shown on the left side of the process.

As already mentioned, every worker is modeled as a process which controls a worker-entity. The process takes the decisions on where the worker has to work based on his qualifications and the system state of the manufacturing processes. As soon as the worker-process has made his decision for the next task, it sends out a worker-entity (which can be seen in the animation) to the corresponding manufacturing-process. It is important to have an animated model in order to understand the behavior implemented. It also helps in the verification

and validation phase of the model. Every worker owns a qualification for each manufacturing process (Figure 3.)

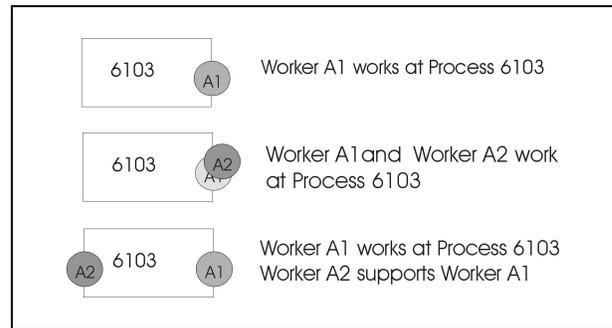


Figure 2 : Interaction of Workers with a Manufacturing Process

| Worker | Work-Processes |            |      |      |      |
|--------|----------------|------------|------|------|------|
|        | Standard Prod. | Lean-Prod. |      |      |      |
|        | 6103           | 6103       | 6204 | 6101 | 1301 |
|        | 6104           | 6104       | 6211 | 6102 | 1302 |
|        | 6117           | 6117       | 6213 | 6120 | 1303 |
|        |                |            |      |      | 1305 |
|        |                |            |      |      | 1306 |
| A1     | X              | X          | X    | X    | X    |
| A2     | O              |            |      |      | X    |
| A3     | O              | O          | O    |      | X    |
| A4     | X              | X          | O    | X    |      |
| A5     | X              | X          |      | X    | X    |
| A6     | X              | X          |      | X    |      |
| A7     |                |            |      | O    |      |

Figure 3 : Qualification Table which are Used for the Workers A1 to A7. An X Indicates Full Qualification for this Process, whereas O Indicates only the Qualification for the Ability to Support an already Present Worker

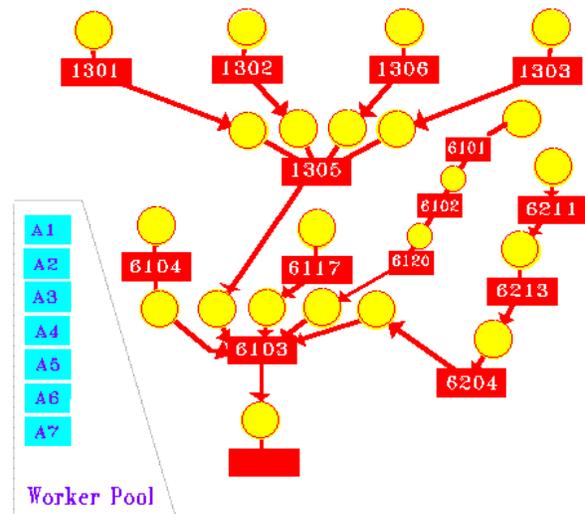


Figure 4 : Process-Network Model. The Seven Worker Processes are Placed on the Left Side

Figure 4 shows the process-network of the assembly system. The worker processes are placed on the left side. Every manufacturing-process has a corresponding workplace-number.

### 6 DECISION-LOGIC OF WORKER PROCESSES

When a worker has completed his task, possibly in conjunction with other workers, he has to make a decision where to work next. First, he has to check every process (which he is qualified to execute) according to its priority. The following conditions for the checked manufacturing-process must be true, in order to undertake it:

- a certain amount of material must be ready in the Queue(s) in front of the checked manufacturing-process.
- the maximum number of fully qualified workers has not reached a predefined limit for the checked manufacturing-process.

If none of these conditions is true, the worker has to do the same for all processes for which he is not fully qualified but still can support another worker already working there. When a worker supports another worker (qualified or not) the remaining manufacturing-process time will be reduced.

### 7 RUNNING THE MODEL

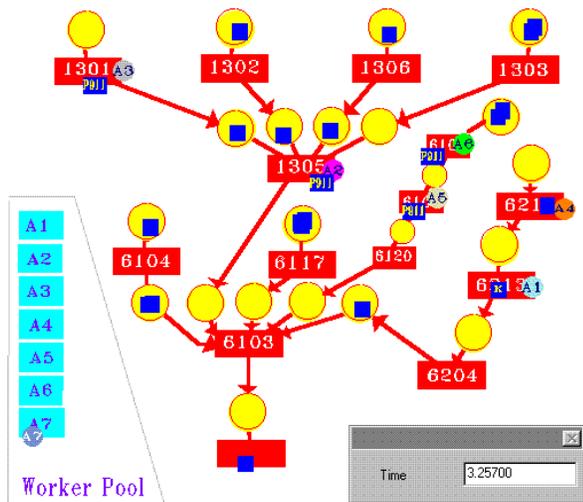


Figure 5 : Animation Screen-Shot of a Running Model

Figure 5 shows a screen-shot of a running model. Worker A2 is just checking for his next work while other workers are still working. By watching the animation, it is easy to understand what happens in the model. Therefore, the model can also be used as a training tool for employees.

### 8 OVERVIEW OF SULZER RÜTI STUDY

A major goal of the study was to improve the throughput of weaving machines just by changing the mode of operation as well as the qualifications of the workers. The work processes are all different (see Figure 4). The processes 1305 and 6103 are assembly stations where the rest is mainly for the manufacturing of driving shafts, loading bars and linkage gear. It was intended to let the workers do experimental simulation runs in order to find out further possibilities to improve their individual qualifications.

### 9 RESULTS AND BENEFITS OF THE STUDY

Experimental simulation runs were done together with people from Sulzer Rüti and later also with students of the Basle Institute of Technology. Figure 3 shows the initial qualifications at the moment when the first experiment started. Figure 7 shows the throughput of weaving machines as well as the waiting times for the workers. Waiting time occurs when the worker cannot find a work process where he is qualified for it. Figure 6 shows wise changes in qualifications, these changes can improve the throughput from 348 to 491 weaving machines, which makes about 41% of improvement. Almost the same throughput (497) occurs, when all workers are qualified for all work processes. But this at a higher cost for the company.

| Worker | Work-Processes |            |      |      |      |
|--------|----------------|------------|------|------|------|
|        | Standard Prod. | Lean-Prod. | 6204 | 6101 | 1301 |
|        | 6103           | 6103       | 6204 | 6101 | 1302 |
|        | 6104           | 6104       | 6211 | 6102 | 1303 |
|        | 6117           | 6117       | 6213 | 6120 | 1305 |
|        |                |            |      |      | 1306 |
| A1     | X              | X          | X    | X    | X    |
| A2     | X              | X          |      | O    | X    |
| A3     | O              | O          | O    |      | X    |
| A4     | X              | X          | X    | X    |      |
| A5     | X              | X          |      | X    | X    |
| A6     | X              | X          |      | X    |      |
| A7     | O              | O          | O    | O    |      |

Figure 6 : Qualification Table for the Workers which Improves the Throughput More than 41%. The Grey Fields Shows the Changes in Qualifications Regarding to Figure 3

| Worker   | Qualified according to Figure 3  | All workers are fully qualified for every process | Qualified according to Figure 6 |
|--|--|---|---------------------------------|
|  | Waiting time of the workers according to their qualification for the work (in % of worktime) |   |                                 |
| A1   | 0 %  | 2.3 %   | 0.8 %                           |
| A2   | 38 %   | 3.1 %   | 1.4 %                           |
| A3   | 19 %   | 2.6 %   | 3.8 %                           |
| A4   | 10 %   | 2.3 %   | 3.8 %                           |
| A5   | 18 %   | 2.5 %   | 1.9 %                           |
| A6   | 22 %   | 2.5 %   | 3.7 %                           |
| A7   | 16 %   | 2.8 %   | 1.8 %                           |
| Mean waiting time of A1..A7                        | 20 %   | 2.6 %   | 2.5 %                           |
| Through-put of the assembly system within 3 months | 348 Weaving machines   | 497 Weaving machines                              | 491 Weaving machines            |

Figure 7 : Throughput of Weaving Machines and Waiting Times of the Workers According to Their Qualifications

## 10 CONCLUSIONS

The project of Sulzer Rütli has shown that it is possible to successfully model and simulate group work behavior in manufacturing. Some programming effort on the decision logic as well as the conditional control of processes are a must for modeling group work processes. We think that although group work based simulation models of this kind are still rarely to be found in the industrial world, they will play an increasingly important role in the future. People within the management level are nowadays becoming more conscious of this important aspect of their labor-force.

As the budget for further training is limited in every company, we have to invest them where it seems to be necessary and at the same time keep those people motivated that can not benefit from the training budget.

## REFERENCES

- Antoni, C. 1994. *Gruppenarbeit in Unternehmen*. Beltz Psychologie Verlags Union, Weinheim.
- Bernhard, W. and M.C. Bettoni. 1993. "General Purpose Enterprise Simulation with MASTER." In *Proceedings of the 1993 Winter Simulation Conference* (Los Angeles, CA, Dec. 12-15), Evans, Mollaghasemi, Rusell, Biles. The Society for Computer Simulation, International, San Diego, CA. 1290-1295.
- Binkelmann, P., H.J. Braczyk, and R. Seltz. 1993. *Entwicklung der Gruppenarbeit in Deutschland*. Campus Verlag, Frankfurt / New York.
- Hackman, J.R., and G.R. Oldham. 1976. Motivation through the design of work: Test a theory. *Organizational Behavior and Human Performance*, 16, 250-279.
- Russell, E. 1992. *Building Simulation Models with SIMSCRIPT II.5*. CACI Products Company.

## AUTHOR BIOGRAPHIES

**WILLI BERNHARD** is a Professor at the CIM Center at the Basle Institute of Technology. He teaches Simulation and Modeling and is responsible for the research and consultancy work in the area of enterprise simulation. He is leading the nation-wide research and development project "Simulation of Enterprises." His research interests are in modeling and simulation of enterprise systems, cost-optimization and simulation-education. He is a member of SCS, ASIM, SGL, and ESLA.

**AXEL SCHILLING** is a lecturer at the CIM-Center MuttENZ (CZM) at the Basle Institute of Technology. He teaches "Industrial and Organizational Psychology" and "Implementation of Group Work." Dr. Schilling researches human communication processes in integrated manufacturing systems and in problem areas of group work. He consults enterprises on questions of leadership and internal communication and implementing different kinds of work design.