Proceedings of the 1991 Winter Simulation Conference
Barry L. Nelson, W. David Kelton, Gordon M. Clark (eds.)

A SURVEY OF VARIED PRODUCTION SYSTEMS AND DIFFERENT ASPECTS USING COMPUTERSIMULATION

K.HEINZ WEIGL

Institute of Manufacturing Engineering
Technical University Vienna
A-1040 Vienna, Austria

ABSTRACT

The purpose of this paper is to present different problems conducting simulation projects of a wide range of production systems. The presentation will provide some insight in the variety of the initial conditions and illustrates different situations for the modeler. Especially "historically grown " systems e.g. in the metal industry with a very low level of automation and poor controlled materialflow are very difficult to analyse and to develop the functional specification. This paper will also point out unpredictable benefits for the production engineer during the simulation process.

1. INTRODUCTION

The competitive business situation especially in the manufacturing area forces engineers to use new techniques in order to reduce project life cycles and to maximize systems performance. This situation has a great impact on the innovation of the manufacturing industry. All companies should be aware that CIM is essential to their survival in tomorrows market place. Many of the important advances in the manufacturing area have occurred in the last five years. Most European companies are devoting enormous efforts to restructuring their production environment, with the hope to gain more competiveness. Due to the high financial risk caused by this changes, the modeling and analysis of manufacturing systems has become an important role.

There is currently an explosion of the interest in computer aided planning tools and has challenged many researchers. One of todays most established computer aided planning tools with the greatest success is computer simulation. In hundreds of publications computer simulation based approaches are described. Most of the approaches are concerned with a small class of manufacturing systems namely Flexible Manufacturing Systems due their increasing popularity. It seems to me that these class of systems are more "hypothetical "due their tremendous volume of costs and basic layout requirements. Most manufacturing systems today have a very low level of automation with constraints in terms of layout design, material flow, transportation and human education.

There is also in some manufacturing engineers mind that the use of simulation technology can automatically solve problems with a minimum of effort and system knowledge. At this point it should be mentioned, that the simulation process is a knowledge integrating process of both,- the client and the simulist.

In most cases the aid of simulation technology is the last " straw" production engineers are catching at, after trying a lot of other techniques in order to solve their problems. This fact implies for the simulation specialist a lack of time for a successful simulation study, resulting in unacceptable results. The traditional view of simulation encompasses the use of a simplyfied model to mimic the behavior of the real system in order to gain insight into the integration effects and performance of that system.
However, experience gained in the last view years has resulted in a wider view of simulation in which such other elements as production scheduling activities, complex material flow logic, databases and knowledge based systems play a role in an integrated manufacturing environment. According the so called " C technologies " namely CIM, CAP and CAM we can transfer this philosophy into the Simulation world and use the acronyms SAS for Simulation Aided Scheduling, SAP for Simulation Aided Planning and SAM for Simulation Aided Manufacturing.

Most attention has to be paid on the simulation process life cycle, demonstrating that a simulation study is multifaceted and multidisciplinary. The ever increasing complexity of systems being simulated can only be managed by a structured approach to conducting the simulation study; see Balci (1990).

The purpose of this paper is to address a wide range of manufacturing systems providing insight during the simulation process into various problems in terms of defining, analysing, formalizing and structuring the system problem. The objectives and required detail of all manufacturing systems are different. The only common characteristic is, that all systems are under operation. In the first case of the AGV system, the model was used to determine the number of AGVs in order to meet the required throughput. In the second case study the designers of a Flexible Manufacturing System were not shure whether their already developed control strategies will work properly in order to meet the resource capacity the customer specified. In the third and fourth case we are going to measure the impact of new layout configurations and simplification of the material flow in terms of system performance, like utilization of resources, minimizing number of operators and troughput time. In the last two cases the project still remains in the functional specification phase,- a model development phase has not started yet. All finished projects discribed in this paper used SIMAN/CINEMA for model development.

2 HISTORY AND COMMON ASPECTS USING SIMULATION

Simulation is not new and we can not claim this technique as a invention of our century. The roots lie about 500 years ago, when a well known artist, sculptur and scientist,- Leonardo da Vinci used models to learn about dynamic behavour of a system,- he was simulating. Since the first simulation languages were developed 30 years ago, simulation has evolved into a technique which is extremely useful to predict systems performance under a variety of circumstances. Due to the lack of suitable computers and graphics, simulation lost credibility and popularity; see Pegden (1990). At this time developers focused principal the development of modeling concepts for materials handling.

In the 80's when graphical animation and Personal Computers became available, there was a tremendous impact on the use of simulation. Compared with the manufacturing requirements 10 years ago, simulation was mainly concerned with simple material flow applications. The innovation forced changes in production systems, since simulation become more accepted by decision makers. Today numerous simulation tools for the design and analysis are available. Most attention is paid by developers to simplify the simulation process, but there is still a lack of a tool to decompose in a guided way the structure of the system to be simulated accordingly the goals we have defined. Is the simplification and reduction of the simulation process compatible with the increase of complexity of systems ?

Beside flexible Simulation languages like SIMAN/CINEMA special purpose simulators such as XCELL or GRAFSIM are available. The analyst has only to change few parameters using a predifined model structure without programming effort describing the structure of the real system. These template packages are very convenient, but in most cases of real world problems today it is impossible to cover customized circumstances.

I will compare the simulation process with the olympic competition decathlon. The decathlon competitor never can win a competition leaving out one of them. During the simulation process there is a unknown potential of unpredictable benefits for the production manager as long he is involved in the simulation process. Simulation today is a multifaceted discipline and its nature enables building a symbiosis with other areas like knowledge based systems, promising to deliver important benefits.

Simulation is an art and only an expert can profit by the flexibility of a simulation language and is aware about limitations and constraints; see Shannon 1990. The experience of the last 5 years teaches us, that simulation is more than just developing a model.

Focusing different articles in the simulation area, most of them are concentrated on simple, idealized high automated systems assuming all phases of the simulation study life cycle had already successfully conducted. The majority of applications of simulation are towards the simpler ends of the model complexity and focuse mainly the applications on machine/cell/shop level.

We have today powerful simulation systems like SIMAN, SLAM etc. on hand, but there is currently a lack of tools analysing and structuring a manufacturing problem in the right way. There is a need to move towards more complex simulation and control of manufacturing environment, but the difficulty of modelling a given situation is compounded by the dynamic nature and the specific topic.

3 THE SIMULATION PROCESS IS A KNOWLEDGE INTEGRATION PROCESS

For a successful simulation study a multifaceted and multidisciplinary knowledge and experience are required. At the start of a simulation process the most important tasks for the engineers is the description and decomposition of the manufacturing environment in terms of appropriate layouts, system characteristics, shop floor devices, material flow, control and process logic mechanisms and scheduling algorithms.

We cannot assume, that the decision maker in the manufacturing industry is aware of all available solution techniques and the effort being required using a simulation tool.

In my opinion, one of the most essential tasks of the simulation specialist is to develop a colloborative responsibility and integration for the success of the simulation study. There is a need of the knowledge integration during the simulation process. At the start of every simulation study we recognize the inability identifying of tangible benefits and justifying the expense.

A successful simulation study requires a cooperation between the analyst and the user. The software developer tend to simplify simulation tools for the user in order to shorten the simulation process. Many developments aim a certain facilitation for a specific user, but this tends to a lack of the educational process. We should be in future aware of that. Today most attention is paid using Artificial Intelligence tools in the manufacturing world, but have not to forget that simulation is a powerful tool towards "PRACTICAL INTELLIGENCE". Real systems gets more and more complicated and due the integration of high automated resources on one hand and the randomness of human influence during the manufacturing process on the other hand we are confronted with different levels defining the problem for effective simulation studies.

4 DIFFERENT SITUATIONS IN THE MANUFACTURING AREA

The nature of simulation and modeling is such that it can be applied to any situation where the problems, material flow control, process logic and performance measures are understood; see Pegden 1990. Simulation modeling gets more important and the interest of the manufacturing industry in Austria is in the moment exploding with the popular fallacy simulation can automatically solve every problems with a minimum of effort.

Computer Integrated Manufacturing (CIM) as a promissing key philosophy is sometimes appearing as a euphorical vision and forces production engineers to take advantage of new computer aided tools like computer simulation. Numerous papers and research work address computer integrated manufacturing environments as well as control strategies for CIM systems. The trend of the manufacturing industry is towards modular architectures in terms of hardware and software. The ideal manufacturing company of this decade is quite different to the traditional manufacturing environments. As a result, modularity and flexibility is essential to the requirements of the market demands. The situation for the manufacturing industry are different. Opportunities for new plant startups are rare, because of the high investments, existing historically grown facilities and layoutconstraints. The majority of manufacturers face the challange of achieving CIM within existing facilities, step by step. One of these basic steps towards achieving CIM, is the reorganization of large, complex manufacturing operations into focused, simplified, manageable cells.

This trend is supported by the dramatic reductions in the costs of computer hardware and software. The unsatisfied goals in recent years are generating an untapped potential for the exploitation of simulation in the manufacturing environment. As a result, simulation of manufacturing systems is being increasingly used for reconfiguration and performance measure in the planning stage.

In the moment the main constraints to further applications are requirements like:

- the level of computer and research skills necessary to build effective simulation models.
- the time taken to build models
- the relationship between the model builder and the decision maker
- the balance between the model complexity necessary and the degree of sophistication employed by the model builder
- A structured, decomposition approach operating in different hierarchical levels in order to analyse in a guided way the real system and to develop the functional specification; see Wichmann (1991).

In order to gain the basic knowledge for using simulation correctly, R.Shannon (1986) pointed out that a practioner is required to put in 1 man years effort. There is a tendency in the manufacturing world, that simulation can solve every problem as a tool of the last choice and many companies are frequently asking : "Is our production suitable to be simulated ?" Most of the companies at the start are not aware about their special circumstances, like limited knowledge about materialflow control or bad defined datas. There is also a common tendency to aim for too much detail in the simulation modell in order to get "realistic" results; see Sadowski (1989). We can classify the nature of manufacturing processes from different perspectives, like quantity of products, location of resources, type of material handling and for instance mathematical,-organizational view of control. The procedure for conducting a successful simulation project is well known, the development of the functional specification, and problem formulation depends on the nature of the real world problem. The situations in the manufacturing world we are confronted with, are different and most simulation studies presented today are simple or idealized in order to demonstrate the need of simulation tools. Real world manufacturing problems cover a wide range of different categories in terms of productiontyp like assembly line-, transfer line-, or shop floor production. The following pages provides an overview of different applications with different degrees of automation and human impact in the manufacturing area. Especially the problems in historically grown systems with constrained space, high degree of human employment and random activities of operators. The following pages are a short survey over different, already existing manufacturing systems which naturally require a higher level of detail. All systems are quite different in nature, degree of automation and simulation project level. Some companies just want to know about the effort required developing a functional specification and the feasibility using a certain type of simulation system.

4.1 AGV Modeling in the Automotive Industry

The flexible assembly system which forms the basis of the simulation model produces 4 and 6 cylinder engines and consists of manual and automatic work stations with part and subassembly movement between them carried out by AGVs. Figure 1 and 2 shows the layout of this final assembly area which for the purposes of both physical and control requirements is split into three subsystems. Assembly area I is mainly used to finish engine type M40 and is controlled by 2 subsystems MC1 and MC2.

Assembly area I consists of:

- 1 loading station including standby (or buffer) station
- 2 kitting stations
- 2 inspection stations
- 3 rework/repair stations
- 1 unloading station with buffer
- 1 in/out feeding station
- 4 automatic stations with buffer
- 4 battery recharge stations
- 23 manual working stations

Assembly areas II and III are controlled by the subsystem MC3 and can only operate together. Assembly area II consists of 12 manual working stations. Assembly area III consists of:-

- 1 loading station with buffer
- 1 kitting station
- 2 inspection stations
- 2 rework/repair stations
- 1 unloading station including buffer
- 3 battery recharge stations
- 12 manual working stations

Each of these 3 physical subsystems is characterised by a closed circuit AGV loop and is controlled by its own Master controller (MC) as well as a Layout controller (LC).

Allocation of resources and associated routes for the AGVs are automatically changed according to the requirements of the production schedule and the existing status of the plant so that bottlenecks can are avoided.

However there are some rules as to which engine can be assembled in which area for example engine type M40 and M50 can be assembled in areas I or III and assembly area II can be utilised for either or both at the same time. The AGVs used are Digitron Robomatic vehicles.

There are as many as 30 different strategies that can be used to assemble each type of engine. These are used to call and to send AGVs to and from stations during the routing of the engine inside each assembly area. Each motor type has specified routes and these are allocated dynamically as the motor is assembled so moving them between individual working cells. Each working cell can be accessed from the main AGV loop. Engines are delivered to the assembly system by conveyors and are then mounted onto special pallets or carriers. An empty AGV is then called from the main track or, if necessary, from the battery charging stations.

The pallets can be loaded automatically onto the AGV at a special station, however, in case of breakdown, a standby or buffer station can used to manually load the pallet. After loading the base engine the AGV is routed to the kitting stations where parts to be added to the engine are loaded and then, according to the strategy in force, the AGV is routed to the first operation and so on. Each work station has a by-pass loop to allow for breakdowns. After completion of the assembly process the AGV is automatically unloaded and the pallet returned to the loading station.

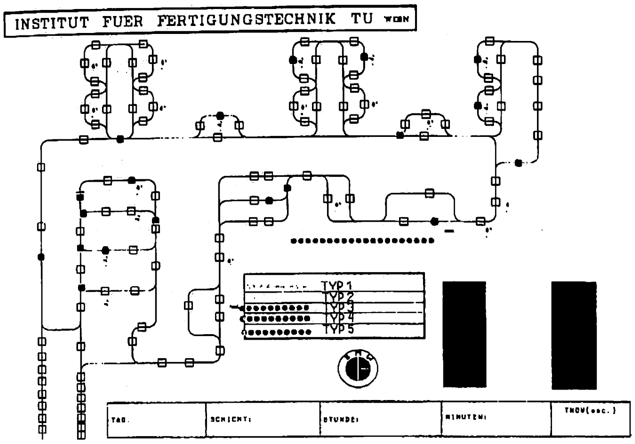

Figure 1: Assembly area I

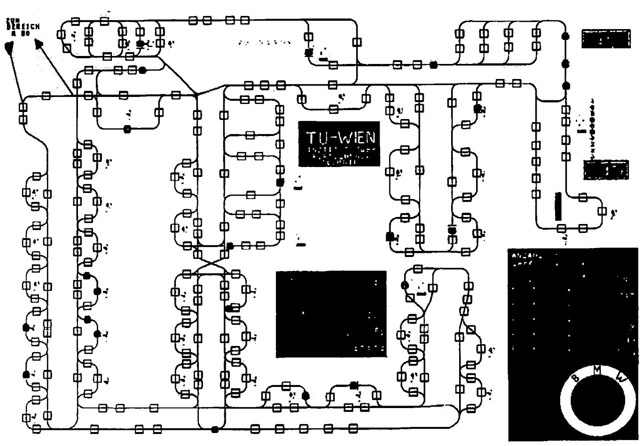

Figure 2: Assembly area II

The goal of the simulation project was to produce a tool which could be used by the plant manager to determine the resources needed (workstations, AGVs etc.) to achieve the required engine throughput rate and analyse the sensitivity of the system to breakdowns. For example if the required throughput rate was one engine per minute in each shift and the product mix was say 60/40 M50/M40, what was the required number of AGVs in the system using the operating strategies available, and where were bottlenecks likely to appear.

The tasks to be carried were:-

- build the simulation model to the required operational specification
- verify operational characteristics against the real system using the animation and OUTPUT processor to generate statistical results on sample runs (approx. 500 runs were carried out),
- sensitivity anaysis of the system to breakdowns and resultant evaluation of system flexibility,
- verification of operational criteria under breakdown circumstances,
- validation of new production schedules,
- performance analysis of different loading or capacity profiles,
- utilisation of battery charging stations,
- analysis of layout efficiency.

In order to complete these tasks it was necessary to build a very flexible and accurate model as well as collect detailed operational data. A very high level of detail was required in order to compare system performance of the simulation model to the real system. The simulation process took about 5 month and is now followed by other simulation studies because of the great success.

4.2 Flexible Manufacturing System with 4 Turning Centres

In this case an Austrian machinetool manufacturer was in the design phase installing their first FMS. The had before only experience gained from single machine tools. The customer of this FMS was a famous manufacturer of extruding and moulding machines in Austria. The machine tool manufacturer had to supply four turning centres, automated workpiece and tool transfer by an AGV, tool supply area, centralised coolant system and hard- and software. In the middle of the software development phase the tool manufacturer decided to use a simulation model in order to predict integration effects of the real system and to examine the operation of the system under different conditions to reveal bottlenecks and weaknesses prior installation. Due the progress of the control software development phase, the machinetool manufacturer had developed already an accurate definition of the control logic for the model. The functional specification was only concerned with the definition of the simulation objectives and the detail of complexity. There was a large amount of datas available, stored on a VAX. Most attention had to be paid on the right definition of the schedule for each machine. Altough the user was aware about the complexity of the system, the functional specification served as an educational process. The following parts of this section will give a short overview of the characteristic features of the FMS.

The FMS consists of 4 FMS 530 turning centres served with palletised parts and tools by an AGV Transportrobot H1000 of the German Company Bleichert. Each turning centre has ist own gantry robot system for parts loading/unloading, chuck changing, tool loading/unloading and monitoring (figure 3). The four turning centres are machining 19 families of parts involving chucking and shaft work for 115 parts for plastics, extruding and moulding machines (figure 4,5 and 6). The workpieces range in diameter from 30 to 340 mm, in lenght from 31 to 1334 mm and in weight from 1,3 to 442 kg.

The order of delivery of parts and tools to the machines by the single AGV is determined by each machine schedule which was read into the simulation model from a DEC Micro VAX 11/VMS. Each machine has 30 "loads" for a 15 shift run with batch times between 30 and 300 min. On-line facilities were provided, such that the progress of each machine through ist schedule could be monitored. In addition user menus were also attached in order to change interactively datas, like number of pallets, number of bufferpositions in the storage system, velocities of the AGV, time for operations and distributions. The company created different production mixes in order to cover most of the realistic situations in the real plant and to fix bottlenecks. There are 70 types of operation and 5 types of pallets with different capacities depending on part type to be loaded.

Parts are taken on pallets after loaded by the operator to the input NC shuttle picked up by the AGV. The AGV moves than to the a free machine input shuttle of the right machine and the parts are loaded by a gantry robot into the machine. The gantry robot can only load and unload light parts. Two of the machines were equipped with manually operated overhead cranes, which are used by an operator to load/unload heavy parts.

Tools are inspected, setted and loaded on pallets in the tool supply area for the next batch of components. The new tool pallet is picked up by the AGV for delivering to the machine input tool shuttle. Most concentration was on the definition and modeling of the control logic of the operators. There are two different types of operators in the system,- tool and FMS operators varying duties and capacities during the 3 shift system. One of the simulation study most important objectives was to carry out performance measures of these resources. Operators have different duties which vary in importance as follows:

Group I 1. Attend to machines breakdowns
2. load/unload heavy parts using overhead cranes
3. carry out part measurement during part m/c cycle

Group II 1. carry out machine set up

Group III 1. Unload finished or semi finished parts from pallets
2. Load new parts or semi finished parts on pallets

The interrupt rules were very complex and under most conditions a higher group job could preempt a lower one but interrupts were not allowed within a group. The second complex task was the modeling of the control logic of the AGV, because this could become a bottleneck of the system. There are different priority control strategies implemented:

- go to the nearest recharge station (two are in the system)
- if battery charge is below 20% discharge level. The charging/discharging process was written in a FORTRAN subroutine and was quite complex because of the non linearity of the discharging/charging time constant in the lower range of the battery.
- Go to the machine if pallet is ready for unload and put pallet in free unload station, otherwise in buffer.
- Take loaded pallet to machine if space available, but look for correct pallet in system buffer first, accept system buffer is to be filled up for unmanned shift.
- Take any pallets with finished parts or worn tools to the unload buffer station if free.
- Load pallets to the systembuffer from loading stations
- Top up battery at the nearest charging station if AGV is idle

Considerable time was spent in the development and validation of the model. During the validation process under different production schedules numerous logical errors were discovered. We examined hundreds of simulation runs with different loading schedules not only to get a large number of observations for the statistical analysis, but also to make shure that the system works properly under different conditions. The experimentation also showed, that the control logic originally defined by the machine tool manufacturer did not work as it was expected. This experience forced the control software and hardware designer to make some modifications of the control system running on the DEC VAX controller. The experiments were mainly carried out to test different scheduling strategies. After successful installation and testing procedures of the real plant, the performance measures of the simulation study were confirmed with a deviation of +/- 3 percent.

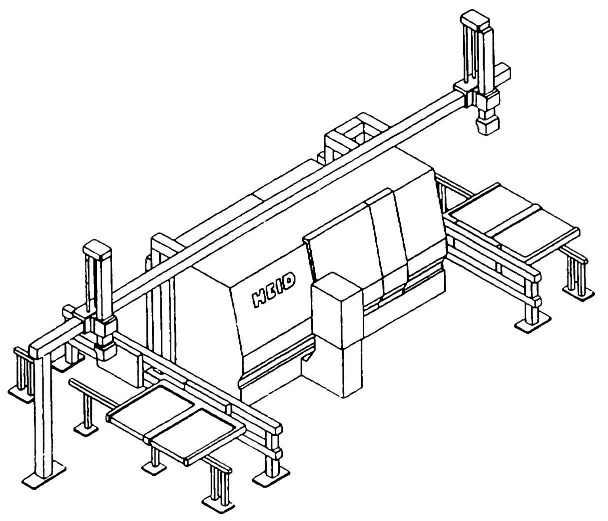

Figure 3: Single turning centre with NC shuttle and gantry robot

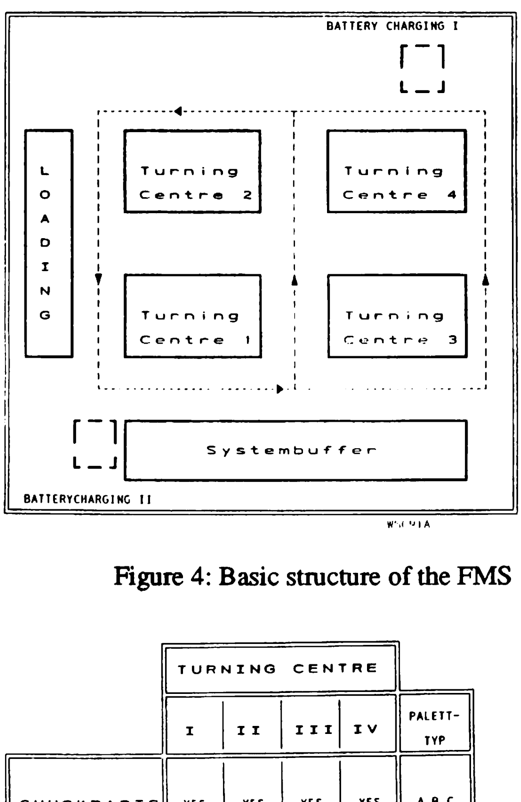

Figure 4: Basic structure of the FMS

	TURNING CENTRE				
	I	II	III	IV	PALETT-TYP
CHUCKPARTS	YES	YES	YES	YES	A.B.C
SHAFTPARTS	YES	YES	NO	NO	D
HEAVYPARTS	YES	YES	NO	NO	E

Figure 5 : Assignment parts to turning centres

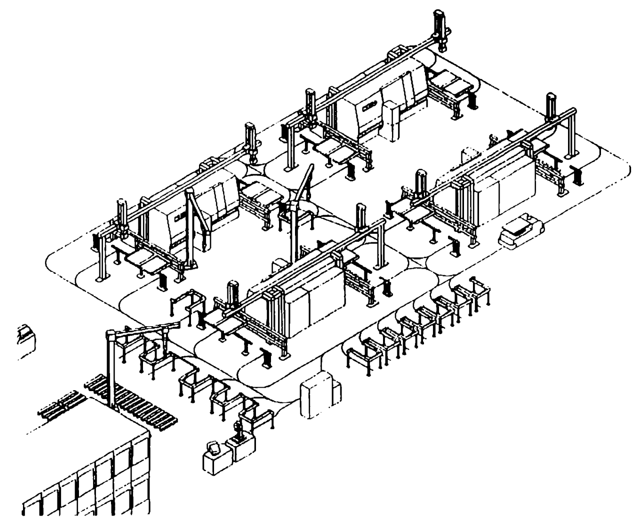

Figure 6 : Total view of the FMS

4.3 Industrial Knive and Guideways Work

The production engineers of a medium sized company in Austria want to know whether simulation is an appropriate tool for solving their problems and helping to achieve operational goals like low WIP, minimum queue times, short lead times and maximum production throughput. The utilization of NC and conventional machines are not satisfactory. These disadvantages should be largely eliminated by replacing the machines, simplifying the materialflow, if possible and installing a data collection system after justifying through simulation performance measure. All planned, desired future activities are limited by the existent layout configuration of the plant. The production engineers are aware that a simulation model can give them a lot of insights into the structure and dynamic behavoir of the system.

Finally the user focused the usage of a simulation model as a day to day on-line decision- and diagnosis tool assisting in production planning or scheduling. Fast data aquisition equipment linked directly to the simulation model in order to take a snapshot of the factory datas, some operational characteristics in future time like completion- and delivery date should be predicted with the aid of a simulation run. These aspects are very important for the production engineers in order to gain a high level of system utilization and to fulfill customers requirements.

In this specific case we were confronted with a very low degree of automation on the shop/cell level. The wide product range in terms of size and weight permit a high degree of automation and the transport of batches is handled manually with the aid of cranes and trolleys. The lack of documented procedures of the logic employed by human operators complicates the development of a functional specification. This situation causes also in most cases low machine utilization and high WIP.

And we have to manage about 30- 35 operations each batch with difficult, process cycles like annealing and tempering.
There are 5 main product groups like industrial knives for the metal-, wood-, plastic- and textilindustry, guideways and gliding elements for machine tools and all kind of machinery, tool steel, strip steel, cold rolled in coils or bars. About 300 tons are work in progress and 400 batches a month.

In our specific case we had to a hig amount of datas. We had about 4000 different production plans and the size of the products ranges from 4,5 mm to 6000 mm which are complicating a desired automatical transport handling. The factory layout is determined by the geographical situation of the work and there is nearly no possibility for major layout design changes. The second problem is the very low degree of automation, most processes are carried out on conventional machine tools and the transport is conducted by operators. There are no scheduling or sequencing rules with certain strategies available, the production is chaotic.

About 100 operators are involved in the production process and 50 working places are on the shop floor. Compared with a flexible manufacturing system it is very hard to develop a functional specification, defining the control logic and carrying out the data aquisition. Especially the materialflow logic is hard to define due to their random nature. Operators just take orders independent of the need of the next resource. One of the main question was how detailled should be the human interactions to be modelled and what is feasible. The production managers wish to test the system with different worklists, different batch and buffer sizes (input and output) at each work station on the overall throughput time, value of work in progress and utilization of people and machines. One of the major questions is the sensitivity of the heat treatment process and the impact on the system performance.

In order to evaluate the use of simulation for this sensitive system it was decided to get insight into the system through a " iterative step concept " with different levels of sophistication in order to indentify what system components will be modelled and what new issues has to be incorporated into the final simulation model. Major discussions took place between the modeler and the production manager to identify the problems and the impact of human influence on the system performance. In this stage a rough model should enable the modeler to describe some of the important relationships of the real system without excessive detail to be abstracted. The next step is to prove the operation of the plant under a wide range of idealized operational rules instead of randomly based rules underlying the human actions and to find out how best to operate the shop floor. Beside throughput time one of the key performance measure is the input/output buffer utilization of machineresources.

In the next stage more attention should be paid on the realistic materialflow and distances and the knowledge of the dynamic behavior gained from the simple model should be used for the development of a more detailed model. The location of process inventories in this system are not stationary and this circumstance made the functional specification difficult.

The transport time between workplaces was proposed on triangular distributions with fixed paths. The main purpose of this stage is to help employees and production engeineers to get more insight into the dynamic behavour and the structure of the system and to demonstrate system performance under different conditions. At a later stage the model will be used as a daily planning tool in order to justify different loading patterns in order to meet customers requirements.

4.4 Cold Rolling Mill Plant

This example is similar to the previous one and has nearly the same characteristic in terms of human impact. This plant use basically the same processes but with different operating characteristics, machinery details methods of operation and weight (sometimes tons) of batches. One major difference is the supply of material via cranes and electric trucks and the weights of material, which can have tons. The materialhandling is done by 15 cranes, 2 RGVs and 5 electric trucks. The main purpose of this study is to evaluate the use of simulation as a tool justifying major layout design changes in order to optimize materialflow resource allocation. Against most cases we have a huge amount of accurate datas which make the collection procedure in terms of filtering very complex. In our example we speak about 48000 data sets. Although we are aware that process times, load and unload times, transport and other material handling times are greatly following certain distributions, the production engineers did not admit a simplyfication in this form. His argument was, that such a simulation model is not accurate enough to gain information about the dynamic behavior of the real system in order to use the results justifying major layout designs. Although we explained the customer that the goal of a simulation study is not to mimic reality precisely but to capture the essence of the real system without including unnecessary detail. Our proposal was to develop a model of the existent real system with some approximation, idealizing the logic employed by operators and cranes and performing the validation. We also explained that it would be more useful for the customer, having in mind lack of available time developing a model with a high level of detail incorporated, to develop a simpler model. The big advantage of this procedure would be the larger amount of time for running the simulation model under different conditions like major layout designs changes. A significant amount of time has been spent in meetings with the production engineers providing expertise to them and explaining the goals of this simulation study. Because of this unsatisfactory situation the simulation process was interrupted. Nevertheless, one of the greatest benefits the customer gained during the functional specification process was a better understanding of his production process. Hoping that these people will change their mind and carry on with the unfortunately interrupted simulation process and become a future simulation user.

5 CONCLUDING REMARKS

Compared with the interest of Austrian companies 5 years ago, many production managers discover simulation now as a powerful decision tool. One of the major recognitions is the practical experience gained through the simulation process in each step. Most production managers are surprised about the unpredictable and unknown educational benefits and it quickly became apparent that simulation is a tool which leads to " practical Intelligence" for all educational levels in the organization. It is essential that in order to meet international competitive pressures, a regenerating of the manufacturing industry is required. The regeneration requires increasing levels of investment and education to achieve higher productivity and quality. The last two examples are studies in order to demonstrate the production engineers the effort has to put in conducting a successful simulation project and the flexible capabilities of a modern Simulation language like SIMAN.

REFERENCES

Balci O. 1990. *Guidelines for successful Simulation Studies*. In the Proceedings of the 1990 Winter Simulation Conference, eds. O.Balci, R.P Sadowsky, R. E. Nance, Department of Computer Science, Blacksburg, Virginia.

Katalinic, B. 1990. *Industrieroboter und flexible Fertigungssysteme für Drehteile*. VDI.

Novels M.D., Weigl K.H. 1989. *Graphical Simulation as a CAPM decision support tool*. In Proceedings 5th. International Conference Simulation in Manufacturing, 61-72. Chippenham, UK and Vienna, Austria.

Sadowski R. P. 1989. *The Simulation Process: Avoiding the Problems and Pitfalls*. In proceedings of the 1989 Winter Simulation Conference, eds E.A. MacNair, K.J. Musselman, P. Heidelberger, 72- 79. Systems Modeling Corporation, Sewickley.

Thesen A., Travis L.E.1990. *Introduction to simulation*. In proceedings of the 1990 Winter Simulation Conference, eds O. Balci, R. P. Sadowski and R. E. Nance, 14- 21. Department of Industrial Engineering, University of Wisconsin, Madison.

Weigl K.H. 1991. *The Multifarious Applicability of Simulation and its Role in CIM*. In Proceedings of the 1991 European Simulation Multiconference 438- 442. Institute of Manufacturing Engineering, Vienna, Austria.

Wichmann, K.E.,Bergsson K. 1991. *Why use structured development methods in a simulation study*. Proceedings of the 1991 European Simulation Multiconference, Copenhagen.

AUTHOR BIOGRAPHY

K.HEINZ WEIGL is a Research Assistent in the Institute of Manufacturing Engineering at the Technical University of Vienna. He received his degree in Electrical Engineering in 1980 from the Technical University of Vienna. Before joining the Technical University he was employed by Siemens in Germany for 5 years in the high voltage machine division and was designing high voltage motors and generators. His research interests include simulation applications and a number of research activities relating to simulation methodologies. He is an active member of the Society of Computersimulation in Europe.