2. BACKGROUND OF THE SIMMEK RESEARCH PROGRAMME

At NTH/SINTEF the depth research in the field of simulation in manufacturing started in the first half of the 1980s. It emerged from the production management field, and was mainly seen as a tool for evaluation and analysis of consequences of plans and schedules. The work was performed mainly by Jarle Aaram, and the research is reported in Aaram [6].

The work that was done, was theoretical basic research considering areas of applications for computer simulation within production management. Little work was done on making specifications or applications that could be used in real life cases. The obvious reason being the lack of tools. Existing tools were not user-friendly, they needed programming in each case, and their intended use were in factory planning.

Despite the lack of good tools, the suggestive conclusion from this research was that simulation seemed to be an appropriate assistance tool in production management. But it was also concluded that the software tools available at that time were far from good enough to be applied in production management. A proposal was made to launch a research programme within the area of manufacturing simulation.

2.1 The SIMMEK research programme

A large research programme was launched in 1985. It was set-up as a programme originally for five years, later prolonged to the end of 1990. The programme was financially supported by the Norwegian Council for Scientific and Industrial Research, NTNF. A steering committee was appointed to the programme. This committee was made up of representatives from Norwegian industrial companies. For the first years this membership in the steering committee was the only way industrial companies participated in the programme.

The research programme was called SIMulering i MEKanisk industri, Simulation in Mechanical Industry, abbreviated to SIMMEK. Its main goals were to investigate and improve existing computer tools or develop new tools for performing analysis of manufacturing systems, based on simulation techniques. Another stated goal was to establish manufacturing simulation as a field of competence at SINTEF Production Engineering. The ultimate goal was to improve Norwegian industrial companies competitiveness by giving them the benefits of using simulation as a decision support tool.

In the early stages of the programme, the research was not limited to discrete event simulation. Continuous and combined simulation were also studied until the end of 1986. From that time the scope was limited to discrete event simulation, as this was considered as the appropriate tool for use in discrete manufacturing. The limited budget was the main reason for not also covering simulation of manufacturing in process industries.

About the same time it was decided to start the development of a new computer tool based on discrete event simulation. It was stressed by the main responsible in that period, Dr.ing. Einar Ramsli and Siv.ing. Per Aage Nyen, that the prototype should be a multi-purpose simulation tool. By this is meant that the tool should as far as possible be useful both in factory planning/automation as one extreme and evaluating weekly schedules as another.

The specification and implementation of the system started as a project within the programme at the beginning of 1987. Late 1988 a first prototype of the simulator was launched. This prototype has been continually developed until the release of the first commercial version in March 1991.

Although stated to be multi-purpose, it is clear to see today that the first specifications of this prototype were more suited for use in factory planning-like situations, than in production management. This has to do mainly with three facts. First, most simulation tools in this field are for factory planning/automation purposes. Although these tools were considered not good enough, it was sought to pick up the best ideas from these tools. Secondly, there were not many publications or presentations that stated that use of simulation in production management was going to be the future of simulation in manufacturing. Thirdly, it was expected that implementing simulation as a decision support tool in a company would be done in two steps; first using a stand-alone tool for strategic purposes, then making it an operative tool in planning.

But since the first prototype was operative in 1989, it became obvious that the further development should focus on operative use of the tool. Again a number of reasons can be referred to behind this decision.

The existing tools were already pretty good for use in factory automation/layout planning (today some excellent tools are available for this purpose). There was no point in using a lot of resources trying to make something that already was available. From this follows that the area of use where a lot of research was left to be done, was the operative one.

To be able to implement a simulator as a module in a computerised production management system (as a part of a CIM-system), it is necessary to control the way the information is imported and exported from the simulator, and also how the simulation itself is conducted. This can only be controlled when the source code of the system is available.

Some key information about the programme is given in the table below.

Name	SIMMEK
Financed by	NTNF, The Norwegian Council for Scientific and Technical Research, SINTEF Production Engineering
Start	1985
End	1990
Budget	NOK 9,8 MILL.
Programme managers	85-87 Dr. ing. Einar Ramsli 88-89 Siv.ing. Per Aage Nyen 89-90 Siv.ing. Jan Ola Strandhagen
Pilot installations	GLAMOX AS NORWESCO AS RAUFOSS AS
Reports and publications	See reference list

Table 2.1 The SIMMEK research programme

2.2 Informal surveys

2.2.1 The use of DES tools in Norwegian industry

During the first years of the programme, a number of computer tools available for performing discrete event simulation experiments was examined. Programming languages, both general purpose programming languages and simulation languages, were examined. At that time there were not as many simulators on the market as there are today, but the most well known ones were examined. These were both general simulators, but mainly special purpose (manufacturing) simulators. The tools were both for PCs and mainframe systems. Some of these tools were tested in the laboratory, others were tested in real life in Norwegian companies.

Although the structure of the industrial companies in Norway may be somewhat different from the rest of the industrialised world, there are many indications on that what we found is applicable outside the Norwegian border.

Despite the number of tools available, and the willingness to look into new techniques, we found that simulation was often rejected as a method for performing analysis of manufacturing systems. This finding was not a surprise to us. During our research work in production management and control, within a large number of industrial companies, very few of them ever considered simulation as a tool for this purpose.

During these tests mentioned, the following questions were sought to be answered both by the researchers and representatives from the industry. It must be stressed that these questions are answered through meetings and talks with industrial representatives, and not through formal questionnaires.

> *What are the potentials of performing analysis of manufacturing with computer based discrete event simulation tools?*

First of all it must be pointed out that in the majority of companies they had not heard about simulation of this type at all. But we found that the need for analysis tools was large; a lot of investments and changes is implemented without proper analysis being done, and these changes are often crucial for the survival of a company.

The typical example is when investing in new machinery is considered. Many production managers said that they had to rely on figures presented to them by the salesman from the company delivering the machines, with no possibility to check them. Some companies delivering equipment even presented results from simulation studies, but it was not possible to check them either, because the models were only represented in complex program code. Thus it was not possible without a lot of work and time spent on verification and validation of these models.

The conclusion was that there is a need and a large potential for simulation tools.

It is evident that since the typical situation where simulation is thought of as a useful aid is in machine investment/automation, it is also this type of use that most simulation tools are developed for. Although this was not the case when the survey was performed (see next question), simulation tools for this purpose are really excellent.

> *What were the reasons why simulation was not widely used in industrial companies despite of the potentials?*

The main reason was that the availability of most of the existing or known tools were limited. Programming and simulation expertise were necessary. For most companies the only way to do simulation experiments was to hire a simulation expert from a consultant company for the job. This meant that the experiments were extremely cost expensive. And it took too long time to get

the job started; the right consultant company must be found, contracts written and signed and so on. Simulation is often considered as the "method to use if everything else fails", and at that situation, time is the limited resource. This is not a fact that is limited to Norwegian companies [11].

The alternative to hire simulation experts is to run the experiment yourself. But when you are in a situation that you have to decide next week, you do not feel good about having to learn how to do programming in a simulation language.

This lead to the conclusion that what was wanted, was manufacturing simulators, where time consuming programming tasks were banned.

How should a simulation tool, or preferably a simulator, work to be used in a larger scale in industrial companies?

The tool must use advanced facilities in user interaction, i.e., windowing and graphical facilities, so that it will be easy to use and easy to learn to use. No programming should be needed, and manufacturing terms should be used in the modelling of manufacturing systems. The result presentation must be complete, and graphical presentation facilities available.

The need for economical analysis facilities was pointed out by all the industrial managers. It is very nice to have short throughput times and small stocks, but what really impresses the managers are production cost savings compared to investment needed for performing the change.

In what other area than the design/change in layout can simulation be used?

A surprisingly large percentage of the production managers pointed out that simulation in the future may also be used at the operational level. By this was meant using simulation to get the best out of your existing plant. This means evaluation and feasibility tests of short term plans and schedules.

All the answers we found to these four important questions made it obvious to us that a project should be initiated. The main goal should be to develop a simulation tool with all these facilities available.

As stated earlier, it also lead to the conclusion that it was in the semi-operational and operational areas of use that most of the research was left to be done, see Section 1.5.2.

2.2.2 A survey performed among students at NTH

Another informal survey was performed as a part of my lectures/exercises in a course given at the Department of Production and Quality Engineering at NTH; Computer Based Production Management Systems.

As a part of the lectures (6 hours of 45 minutes each) the students were introduced to manufacturing simulation and the prototype of SIMMEK, with its graphical model building facilities and manufacturing oriented screens. The functionality of the tool was only described in words, and the tool itself was presented on a video screen. The students themselves did not operate the tool, but some effects (lot sizes and capacity) were demonstrated through a model.

As a part of the exercises the students were introduced to another simulator with an inbuilt model. The exercise was performed as a hands-on study on PCs with groups of two or three students. The students were asked to change some central parameters (lot sizes and initial buffer sizes). The model was presented through some handed out papers, but not on the computer. The purpose was to simulate and hence illustrate the effect the change in parameters had on throughput times and other performance indicators.

After both these sessions were completed, the students were given a questionnaire to fill in. They were asked what the benefits of the two different sessions were.

The majority found that the demonstration of the SIMMEK tool was useful, but only as an introduction to what simulation can do in a company. Since they were not able to use the tool themselves, they did not learn how to use it, and they also did not learn anything from the examples.

The exercise with the other simulator was by all (approx. 40) but two students considered as not of any use. The main reason being that since they did not build the model themselves, they never really understood what they were doing. They also did not have much faith in the results. In fact many of them compared what they were doing (changing parameters and measuring indicators) with throwing dices.

This survey was performed in the autumn of 1990. The major learning from this survey is the following.

The time to learn to understand what a simulation system is, was again longer than expected. This is often the case when the users are not familiar with simulation.

The use and effect of statistical distributions to model parameters are the most difficult step to climb when trying to understand simulation.

When the models as such are not presented to the user, the users do not understand what is happening, and they do not believe in the results.

2.3 The UK Simulation Market Report

There is a recent study performed by the Simulation Study Group in the UK; Simulation in the UK Manufacturing Industry [11]. The study was performed in 1991, and was therefore obviously not influencing the start-up nor the work within the SIMMEK Programme. But the results from this study are very interesting, and support the informal survey performed in the programme.

The study remit was, “to evaluate the extent and nature of the use of simulation in UK manufacturing industry, the value and potential value of the approach to this industry and the market failures which have influenced its wider use.”

The study group consisted of industrial users, consultants and people from academia.

In the report there is a set of proposals on how to gain more benefits of simulation in the UK manufacturing industry. I will not refer to them, but will concentrate on the actual findings from the study.

1. The estimated lost opportunity within the SME Sector for not applying simulation is £ 300 million per year

2. Of 431 manufacturing sites in the study
   192 were unaware of simulation
   174 were aware, but not users
   48 were users
   12 were ex users
   5 no answer

   showing that only 55 % are aware of simulation at all, and that only 11 % are users

3. Those using simulation listed the following applications for use

Plant layout and utilisation	77 %	
Analysing material control rules	66 %	
Analysing required manning levels	65 %	
Short term scheduling and loading	60 %	
Capital equipment analysis		52 %
Line balancing	51 %	
Inventory evaluation and control	49 %	
Information flow analysis	40 %	
Process definition and analysis	35 %	

4. Benefits named by these users (prompted)

Risk reduction	80 %	
Greater understanding	75 %	
Operating costs	72 %	
Lead time reduction		72 %

5. Of those using simulation, only 57 % set objectives for the project, and out of these 92 % met the objectives, reflecting a high level of satisfaction with the technique

6. Concerning education, 100 courses around in the UK, undergraduate and postgraduate covered (partly) discrete event simulation, varying from 2 to 72 hours of teaching

7. The main obstacle in teaching is said to be “Computer packages play an essential role in the teaching of simulation, but are difficult to absorb”

Table 2.2 Findings from The UK Simulation Study Group

The findings of this study are very much in the line of our informal study in Norwegian industry, but I think the percentage of users is much lower in Norway. Of the 11 % claimed users, the study tells that many of them were not able to name the computer package they were using. Another fact was that it was not the cost of purchasing the packages (between £ 1 000 and £ 20 000), but the costs of usage that prevented those not using simulation to day from using it.

It is also interesting that even though the “famous” and well known packages SIMAN/Cinema and Witness were the two most used packages in education, it was still stated that the main obstacle was the time required to learn to use them properly.

Another problem is that there is very little research and development in the field of simulation compared to other, comparable areas. As an example, out of 530 ESPRIT, IMT/BRITE-EURAM, and EUREKA projects investigated, only 4 of them dealt with discrete event simulation.

2.4 Future research area of DES in manufacturing

The question in the heading of this section indicates that there is still a lot of unsolved questions in this area. It is important to remember that simulation is still unknown to the majority of industrial companies. Another large number of companies know of simulation as a possible aid in production management, but have found the tools not applicable in their situation.

In addition to the conclusion from Sections 2.1 and 2.2 we see the following topics as the ones that effort should be put into to enlarge the number of companies and situations where simulation may come to use.

*	Improving facilities of existing tools
*	More integration facilities
*	More automated/computerised functions
*	Speed up the learning, modelling and simulation time

Table 2.3 Future general research areas of DES in manufacturing

It must be stressed that these topics are chosen for the purpose to make better tools for the users, and not for the reason of making the tools easier to promote from a commercial point of view. To explain what is meant by this we can take the example of animation. Concerning this topic there are numbers of tools available with excellent animation facilities (SIMAN/CINEMA, Witness, etc.). The animation facilities in these tools are more than good enough for use in real cases; visualisation and verification/validation. Any improvement here may make the tools easier to promote, but will not necessarily make the tools any better in use.

Giving a little more elaboration on these points, we have the following table;

Improving facilities of existing tools	
*	Closer to manufacturing and production management in modelling
*	Covering more manufacturing planning and control phenomena
*	Easier modelling/updating of sequences of parameters
*	Covering human behaviour (learning curves, peak performance, etc.)
*	Guided and reliable use of statistics

* Facilities to model with uncertain specifications,
  i.e., One-of-a Kind production

More integration facilities

* Accepting input from:
  - Process plans
  - Production plans (Master Production Schedule and schedules)
  - Sales
  - Costs accounting
  - Data acquisition facilities
* Transformation of values to statistical parameters/distributions
* Giving output as suggestive plan/schedule iterations
* Facilities to import uncertain specifications,
  i.e., One-of-a Kind production

More automated/computerised functions

* Transformation of values to statistical par./distributions (as above)
* Automated use of replications/long runs for improved reliability

Speed up the learning, modelling and simulation time

* Use of tutorials in learning
* Easier modelling (see above)
* Faster computer processing (parallel, more true object orientation, etc.)

Table 2.4 Future detailed research areas of DES in manufacturing

There is no room for elaboration on each point. Much of what is mentioned concerning integration and automation is relevant in our work and is partly covered in later sections. Some of the points made on improving existing tools are covered in Section 8, Knowledge Based Systems in Manufacturing Simulation. See also Sections 3 and 7.

One of the most interesting development areas is the possible integrated use of scheduling and simulation systems. Section 7 will give a description of some ideas in this direction.

2.5 Follow-up project of SIMMEK

In 1992, there was launched a follow-up project of SIMMEK. This project was also funded by Norwegian Council for Scientific and Industrial Research, NTNF. Main partners were Technology Institute, Kongsberg, Stavanger EDB (a software company), and SINTEF.

The main goals of this project were.

*	Move SIMMEK from Macintosh to a MS-DOS platform
*	Integrate with an MRP II based system
*	Improve some of the modelling and model change functions

Table 2.5 Main goals of follow-up project of the SIMMEK programme

The project is now in its finishing period. There is now a version of SIMMEK-II running on PC under MS-DOS. This version can import data from an MRP II system through an Excel spreadsheet. And there have been major improvements in the modelling functions. See also Section 3.

As I have only been supervising this project, the work completed within this project is not reported here. More details on this work can be found in Borgen [12].

The possibilities of using a simulation tool as an operative tool in evaluating detailed production plans/schedules are very promising. This research will be followed by several research tasks within our research group at NTH and SINTEF.