5. RESULT PRESENTATION AND ANALYSIS

In Section 1.1.2, it was distinguished three major tasks in a simulation experiment, extracting information from the experiment being one of them. Extracting is here used in its widest meaning, including printing of the numbers in one extreme corner, statistical analysis in another, and human interpretation in the third. Result presentation and result analysis will always be the part of the process that gives most information about how the system being modelled is going to perform.

This is not the same as neglecting the learning effects of the modelling and simulation process, which are important results on their own. In fact simulation experiments have been called off during the conceptual modelling because it has already become clear to the analysts what the solution to the problem might be. But this is certainly not a normal and recommendable approach in most cases.

Referring to the simulation process designed by Law [2], and shown in Section 1, the results in a simulation experiment are used for two main purposes (with reference to simulation process step);

*   As an aid in model verification/validation - Steps 4 and 5

*   For result analysis (testing, comparisons, predictions) - Step 9

Referring to Figure 4.1, we see model validation as a task that is performed during the entire experiment, and not as a separated activity that is phased in and out. To use the case presented in the next section as an example, an informal validation was here performed even at the final presentation of the results.

In Section 1.3 and Table 1.3 three out of five success factors of simulation were concerning result analysis.

5.1 Critical factors of result analysis

For both of these purposes mentioned there are at least four critical factors that influence how useful the results are. The factors refer to facilities that should be available in a manufacturing simulator.

1	The calculation methods and accuracy of the results
2	What types of results are calculated and how detailed and complete they are
3	The presentation method and format
4	Whether the results can easily be post processed and integrated

Table 5.1 Critical success factors in result presentation

Some further explanation of these factors are needed, specially since some of them may be misunderstood. Factors 2, 3 and 4 will be explained within the presentation of how this is done

in SIMMEK, while the first will be specially treated in the next section. It is also necessary to repeat that the success of any experiment is continually dependent on the skills of the persons performing the experiment. These skills and knowledge concern factors of Table 5.2.

1	The knowledge about the actual system being modelled (or the ability to extract information from those who know)
2	Insight and knowledge about how discrete event simulation works
3	Insight and knowledge about how the chosen simulator works

Table 5.2 Skill factors

5.1.1 The correctness and accuracy of the results

The calculation methods and accuracy of the results are, of course, important parts of the validation story, but it must not be interpreted as the validation itself. I will use an example to show the difference in this area.

Consider a repetitive manufacturing system where one of the standard products is called PA. A production order of PA is released every month, and the lot size is different from month to month dependent on the estimated demand. The product goes through three operations; two machining operations and between them a heating process. In the first operation the whole lot is finished before it is moved to the oven and also heated as a whole. After the final operation the PAs are put into boxes of ten, and transported to the finished goods store or shipped directly. The highlighted question in this assumed simulation experiment is; what is the throughput time of PA ?

A valid model in this example is a model that can handle the varying lot sizes, that calculates the heating time independent from the number of parts in the lot, and that allows the splitting into ten and ten parts after the final operation. In short; a model that operates the same way as the system itself.

Then there is the question of how to calculate the throughput times. This depends heavily on how the start-up times and finishing times are measured. There are several alternatives, which are all correct, but have different accuracy. The key criteria for deciding on the accuracy level is what is used (if measured) in the real system, and what gives the most meaningful information.

In the following table is given some alternatives for calculating the throughput time. Finding the throughput time for PA over the year can be done by weighed or not weighed averages over the lots. Again different results dependent on the method, but all are correct.

Start time	Finishing time	Throughput time
For the lot (first started part)	For the lot (the latest finished part)	For the lot
For the lot	For the packing lot (of ten)	For the packing lot (of ten)
For each part	For each part	For each part

For a randomly picked part	For the same part	For the lot (as an indicator)
(Combinations of these methods are also possible)		

Table 5.3 Calculations of throughput time

The following advice should be followed in this matter;

   * The results should be calculated in as much as possible the
         same way it is measured in the real system being simulated

   * If differences can not be avoided, make sure that everyone
         involved is aware of these differences

Accuracy in the sense of the number of reliable digits behind comma is a different question. This accuracy may be split into two different meanings;

   * The accuracy and round off rules of the result calculation methods

   * The chosen accuracy considering the accuracy of the input

The first of these should not really be of any practical concern. Any commercial simulation system available can be relied on in this matter. And any difference in round off rules will not affect the results substantially.

The second thing is not a very clear topic. I include here problems like replacing distributions with other distributions, as well as rounding off input values.

The reason that one distribution is replaced with another distribution is mainly the speed of the simulation itself. A small example will illustrate this. Consider a job shop model with lot sizes of 1000 for a particular type of product given as a uniform distribution between 3 and 4 minutes. From the law of great numbers we know that this may be replaced by a normal distribution which it is possible to find the mean and deviation for. But what if the lot of 1000 is split into smaller batches of 10 in each for this operation? Can we now replace the uniform distribution by a normal distribution for this batch size?

This trade off between simulation speed and accuracy is a difficult one. In the SIMMEK system we have settled for a solution that compromises between statistical accuracy and computer speed, by using average times for small batches.

We are not completely satisfied with this solution. This is an area for future research, testing the different approaches and their effects on a number of cases.

5.2 Presentation of results with SIMMEK

This section will explain how the results are presented and how they can be post processed. Section 5.3 will give a complete description of the results available in SIMMEK. The monitor function of SIMMEK will be described in Section 5.4. Section 5.5 will give some further comments on result presentation.

In Figure 5.1 the two formats used for result presentation in SIMMEK is shown. These are results concerning the products in a simulation experiment.
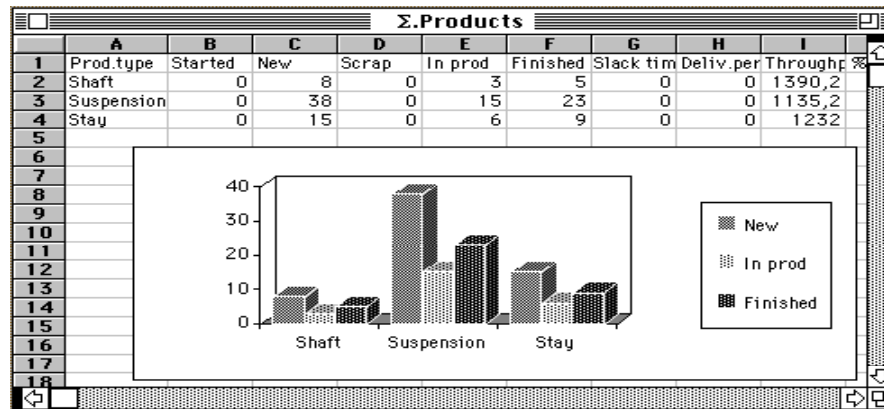

	A	B	C	D	E	F	G	H	I
1	Prod.type	Started	New	Scrap	In prod	Finished	Slack tim	Deliv.per	Throughp %
2	Shaft	0	8	0	3	5	0	0	1390,2
3	Suspension	0	38	0	15	23	0	0	1135,2
4	Stay	0	15	0	6	9	0	0	1232

Figure 5.1 Example of EXCEL spreadsheet with product type results

5.2.1 Using the Excel spreadsheet for result presentation

Apart from the trace, all results produced by SIMMEK are in the Excel spreadsheet format. It is also available in the Cricket Graph and Statworks format. But Excel now has most of the facilities of these two programs. The Excel spreadsheet format was chosen for a number of reasons listed in Table 5.4.

1	It is a well known format for presenting information (tables)
2	The formats can be easily changed for printing purposes
3	It has graphical facilities
4	The results can be post processed (relations, macros and programs)
5	It can be integrated
6	It is available on other hardware platforms than Macintosh

Table 5.4 Using Excel spreadsheet for result presentation

Some comments on this are necessary. Spreadsheets are the second most used type of application used on personal computers. This means that most people using a PC is familiar with spreadsheets. With the facilities of changing formats, types, etc., and its graphical facilities, it is possible to create reports that are easy to read, nice to look at and still give a lot of valuable information.

The possibilities of post processing the results are also important. The results generated in SIMMEK are detailed and separated. One example is that the throughput times (TPT) for two components used in one final product are given separately. The reason for this is that in one company this is how the TPTs are evaluated. In another company the TPTs for the components are included in the TPT for the final product. The problem is that this inclusion may be done in several ways; Adding the average TPT for the components to the TPT of the final product, adding the maximum TPT of the two or more components to the TPT of the final product, etc.

We have chosen a solution where this aggregation is done with macros and by creating mathematical relations between the cells in the result spreadsheets. It is also possible to write small computer programs if more complicated calculations have to be made. But normally the macros and relations are more than sufficient for this purpose.

5.3 Available results in SIMMEK

This section will explain the structure of the results available in SIMMEK. It will also list and explain all result types available.

5.3.1 Results along different axis

The results in SIMMEK are organised along two axes; one axis giving the different categories of results, the other giving what could be called the time scope of the results.

Along the first axis we have results in four categories;

1	Economical and market service results for the total model (Ex; Net profit, value of WIP, delivery performance)
2	Product results. Per production order or per product type (Ex; Throughput time, no of pieces in stock, turnover)
3	Resource results (Ex; Utilisation rate, queue)
4	Experimental facts (Ex; Simulation time, warm up time)

Table 5.5   Results along the category axis

Along the second axis there are five major points. These factors concern the simulation time span over which they are captured, as well as the degree of detail of the results.

1	Estimated expected values These "results" are calculated before the simulation Resources; It shows the expected load for the resources Products; The minimum TPT (if no queues anywhere)
2	Average results/values from one replication This is the most used type of results. It is exemplified in Figure 5.1, averaged over one replication

<div style="border:1px solid black">

3   Detailed results/values from one replication
         Gives a more detailed and also chronological picture of
         one replication for some of the results concerning
         resources and products
         (Ex; Every TPT measured, the utilisation *profile* for the
         resources)

4   Average results from many replications
         All the results from 2, averaged over more than one
replication

5   A trace of all events from a selected period of one replication

</div>

Table 5.6   Results along the time scope axis

The format of this report does not allow a full description of all possible interpretations of all the results available in SIMMEK. This can be found in SIMMEK User Manual. But to give some insight in why SIMMEK is different from other simulation systems, and how closely related to manufacturing it is, quite some details are needed.

What will be explained in most detail is what average results are available from one replication. That is point 2 of the second axis, for all points of the first axis. These results are the ones most frequently used. That is at least our own experience from numerous experiments. These results are also the same that is found in point 4 of the second axis, but then averaged over all replications.

5.3.2 Average results from one replication

The results are split into the four above mentioned categories; economical and market service results, products, resources, and experimental facts. The following tables give an overview and explanation of these results. The first part, Economical and market service results, is split in two. The first part gives the total results for the whole model, 5.3.2.1, while the other part shows detailed economical and market service results for each product type, 5.3.2.2.

5.3.2.1 Economical and market service results. Model totals

Table 5.7 shows the economical results for the model aggregated over all resources and products. In the SIMMEK system this is called the Model totals. It can be seen as a rough account for the factory for the simulated period.

Result type	Unit	Explanation

Fixed running costs for
   Machines
   Transport units
   Stores/buffers
   Operators
   Requisites
	Currency	Fixed running costs, not allocated to the products, for the whole simulation period. For the five types of resources shown in the left column. It is decided in the model input whether the costs are allocated to the products or not

Sum of fixed running costs	Currency	The total fixed running costs for all resources over the simulated period. Sum of the five above rows
Product costs	Currency	Sum of all other costs (other than fixed)running costs, raw material, components, etc.
Total running costs	Currency	Sum of the two rows above
Interest cost; WIP and finished products (FP)	Currency	The calculated interest cost of all WIP, finished components and finished products
Deficits	Currency	The calculated deficits over the simulation period
Total costs	Currency	Sum of all costs over the period
Sales income	Currency	Aggregated over all products over the period
Net income	Currency	Difference between sales income and total costs
Earning power		The ratio income/total costs
Change in WIP and FP	Currency	The difference in value of (WIP + FP) at the start and at end of the simulation period
Adjusted income	Currency	Sales income adjusted for change in WIP and FP
Adjusted net income	Currency	Net income adjusted for change in WIP and FP
Adjusted Earning power		Earning power adjusted for change in WIP and FP
Inventory turnover	#	The number of times the average value of WIP and FP is sold per year. The inverse gives an indication of throughput time
Delivery performance	%	The percentage of customer orders that can be fulfilled without delay

Table 5.7   Economical and market service results. Model totals

5.3.2.2 Economical and market service results. Product type details

This part is also different types of economical results and measurements. But this part is shown per product/component type. In the Excel presentation format there is a column for each of these result types, and a line for each product/component type. Wherever said product means product or component.

Result type	Unit	Explanation
Product type		Name/identification of product/component
Raw material costs	Currency	Sum of all raw materials used for making these products of this type
Other costs	Currency	Other costs that are allocated to the product. One example is engineering costs
Fixed running costs	Currency	Shows what, if any, fixed running costs are allocated to this product type
Variable costs	Currency	Variable running costs allocated
Requisites and small components	Currency	Costs of use or consumption of requisites and small components
Assembly costs	Currency	Costs of assembling these products
Total Product Costs	Currency	Total cost for this type. Sum of the above 6 lines
Start value	Currency	Value of one item of this type when production starts
Finished value	Currency	Value of item when production is complete. Is either given as input value, or calculated during the simulation (user-choice)
Value of WIP	Currency	The average, aggregated value of products/components in progress of this type
Value of finished products/components (FP)	Currency	The average, aggregated value of finished products/components of this type
Value of WIP and FP	Currency	Sum of the two above
Interest cost of WIP and FP	Currency	The calculated interest cost of all WIP and FP of this type
Change WIP	Currency	Change of value of WIP over the period
Change FP	Currency	Change of value of FP over the period
Change WIP + FP	Currency	Change of value of WIP + FP over the period

Table 5.8 Economical and market service results. Product type details

5.3.2.3 Production order results

This table shows what can be called the technical results on production order level. Each of the values in this table refers to production orders of the different product types. Again, in the Excel presentation format there is a column for each of these result types, and a line for each product type. The values (#) are in production orders units. The number of product units in each production order is given as input to the model, it is not a result.

Result type	Unit	Explanation
Product type		Name/identification of product/component
Started orders	#	The number of orders in progress at the start of the simulation period (= end of warm up period)
New orders	#	The number of orders started during the simulation period
Scrapped orders	#	The number of orders that are scrapped during the simulation period
Orders in production	#	The number of orders still not completed at the end of the simulation period
Finished orders	#	The number of orders completed during the simulation period
Slack time	Time units	The slack time at the completion of a production order. Can be positive or negative
Delivery performance	%	The ratio sales requests delivered without delay, to the total number of requests
Throughput time	Time units	Average throughput time for orders
Deviation	%	The ratio of standard deviation of throughput time to the through put time. Gauss distribution anticipated
Shortest throughput time	Time units	Shortest throughput time measured
Longest throughput time	Time units	Longest throughput time measured
Last throughput time	Time units	Last throughput time measured
Waiting time	Time units	The total average time spent in queues for production orders of this type

Table 5.9 Technical results. Production order details

For orders the following formula is valid;

FI;   Started + New = Scrapped + Orders in production + Finished

5.3.2.4 Product type results

The results listed in the next table are also created into the Excel format. There is one line for each product type, and one column for each of these result types. The values are in product units. Wherever said product means product or component.

Result type	Unit	Explanation
Product type		Name/identification of product/component
Start stock	#	The stock of finished products at the start of the simulation period
Started	#	The number of started, but not finished, products at the start of the simulation period
New	#	The number of new products which has been started during the simulation period
Scrapped	#	The number of products which has been scrapped during the simulation period
Completed	#	The number of products which has been completed during the simulation period
Assembled	#	The number of products which has been assembled during the simulation period
Sold	#	The number of products which has been sold during the simulation period
In production	#	The number of products which has been started, but not completed, during the sim. period
End stock	#	The number of products in stock by the end of the sim. period
Average in production	#	The average number of products in work during the sim. period
Average in stock	#	The average number of products in stock during the simulation period
Inventory turnover	#	The number of times the average value of Work in progress and Finished products is sold each year
Internal delivery performance	%	Percent of orders completed in time

Table 5.10   Product type results

For products the following formulas are valid;

FII;   Started + New = Completed + In production + Scrapped

FIII;   Start stock + Completed = Assembled + Sold + End stock

5.3.2.5 Resource results

The results listed in the next table are also created into the Excel presentation format by SIMMEK. There is one line for each resource type, and one column for each of these result types.

Result type	Unit	Explanation
Resource		Name/identification of the resource
Number	#	The number of units of the resource, as given in the layout
% Idle	%	The percentage of the time which the resource is idle
% Running	%	The percentage of the time which the resource is running
Average inventory	#	Average available number of a resource
Current inventory	#	Available numbers of a resource at the end of the simulation period
Number of reservations	#	Number of reservations of a resource type during the simulation period
Number of reserved units	#	Number of reservations of a unit of the resource
Average waiting	Time units	The average time an order is waiting in queue in front of the resource
Average queue	#	The average number of orders in queue in front of the resource
Max. queue	#	The maximum queue registered in front of the resource
Current queue	#	The size of the queue in front of this resource by the end of the simulation

Table 5.11   Resources' results

The two result types Average inventory and Current inventory need some further explanation.

When a batch of products or parts is completed in production or assembly, it may be put into a store.

But in other cases it is not interesting to model these stores. The products/parts are then simply present in model, "available" for sales or for assembly. They can now be regarded as resources. The "life" of these finished products/parts can be examined by examining the Resources' results. If there is a queue of jobs waiting to be assembled to a part B, the average queue can be found by looking at spreadsheet Resources' Results, line starting with "B" for the type, and column Average queue.

Also the Number of reserved units must be explained. This number may be different from the number of reservation, because one may reserve more than one resource unit. An example; a job requires two identical lathes to work in parallel.

	A	B	C	D	E	F	G	H	I	J
1	Resource	Number	%Idle	%Runnin	Aver.inv	Curr.inv	No of res	Res units	Aver.wai	Aver.Que
2										
3	Drill	1	41,3	58,7	0,4	0	38	38	41,8	0,1
4	Lathe	1	40,7	59,3	0,4	0	34	34	96,9	0,5
5	Cutter	3	47,1	52,9	1,4	0	36	36	72,2	0,3
6	Welding	1		99	0	0	43	43	794,5	9,9
7	Truck	1	91,6	8,4	0,9	1	38	38	0	0
8	Operator	1	87,2	12,8	0,9	1	118	118	9,4	0
9										

Figure 5.2 Example of resource type results

This table clearly shows that Welding is the bottleneck resource in this case, with a 99 % utilisation rate. The queue in front of this resource is almost 10 on the average.

5.3.3 Estimated expected results

To have an initial view on what can be expected as results from one simulation run, it is possible to calculate the expected value of some results. These values are calculated using the expected means of the distributions as deterministic input data, instead of the distributions themselves. This can be regarded as a deterministic and static simulation of the model. This compared to the stochastic and dynamic simulation normally performed.

This is useful in model verification, because it is possible to detect wrong input data. If one resource has a work load of 125 %, this should tell that there is probably some wrong data in the process operation times, or in the number of products planned to complete in the period. Or may even in the availability given for this resource.

Result type	Unit	Explanation
Resource		Which resource this line deals with
Number	#	The number of units of the resource, as given in the layout
...		...
Product types		A column for each type of product
...		...
∑ Requirement	Time units	Expected time requirement for the resource as a whole per 100 units of time
∑ Requirement/unit	Time units	Expected time requirement for a resource unit per 100 units of time
Maintenance repair	Time units	How much the resource is not available for production (maintenance, expected down time, etc.)
% Coverage	%	The ratio between: Number of time units required of this resource/number of hours available. May exceed 100%

Table 5.12 Estimated expected results. Resources

It can also be used in result analysis, comparing the results from a stochastic and dynamic simulation, with the results of a deterministic and static simulation. This can be seen as a comparison between a realistic, stochastic situation, and an ideal, deterministic situation. The

tables and figures below show the results available in this deterministic and static simulation of the model. Again it is split into resources and products.

	A	B	C	D	E	F	G	H	I	J
		Number	Shaft	Suspensi	Stay		∑Require	∑Req/uni	Maintena	%Coverage
1										
2										
3	Drill	1	30	25	40		95	95	0	95
4	Lathe	1	20,8	54,2	0		75	75	0	75
5	Cutter	3	0	104,2	121,7		225,8	75,3	0	75,3
6	Welding	1	100,8	16,7	20		137,5	137,5	0	137,5
7	Truck	1	1,7	8,3	3,3		13,3	13,3	0	13,3

Figure 5.3 Example of estimated expected resource results

This figure corresponds to the results of Figure 5.2. It shows that the expected load of Welding is 137,5 %, of course resulting in queues and delays.

For the products similar results can be produced, Table 5.13, and shown in the Excel spreadsheet in Figure 5.4.

Result type	Unit	Explanation
Product type		Which type of product this line deals with
...		...
Resources		A column for each resource
...		...
∑ Machines	Time units	Expected total use of time used in machine resources for this type of product
∑ Transport	Time units	Expected total use of time used for transport for this type of product
∑ Inventory	Time units	Expected total use of time used for transport for this type of product
∑ Total	Time units	Sum expected total use of time = shortest possible throughput time

Table 5.13   Estimated expected results. Products

	A	B	C	D	E	F	G	H	I	J	K
		Drill	Lathe	Cutter	Welding	Truck		∑Machine	∑Transpc	∑Invento	∑Total
1											
2											
3	Shaft	180	125	0	605	10		910	10	0	920
4	Suspensi	30	65	125	20	10		240	10	0	250
5	Stay	120	0	365	60	10		545	10	0	555

Figure 5.4 Example of estimated expected product results

The example shows that the expected minimum throughput time for a batch of stays is 555 time units, out of which machining is 545 time units.

5.3.4 Detailed results from one replication

All tables in 5.3.2 are showing average results from one replication in one simulation run. It is also possible to extract even more details from one replication. The purpose of these result reports is to be able to examine in detail what has happened during the simulated period.

These reports come in two parts. The first is two reports showing the exact times of start, finish, etc., for all production orders. The second is a complete trace of all events that has taken place during a simulation run. This is, of course, a huge file, and can only be used with any efficiency for extracted periods of a longer simulation runs. These reports are shown and explained in the next sections.

5.3.4.1 Products and resources

For each individual production order it is possible to list some information. For all products this information are parameters measured in time. Table 5.14 lists these parameters, while Figures 5.5 and 5.6 show how this is presented in Excel.

For all Production orders

       The exact time of start
       The exact time of stop
       The throughput time
       The time spent machining
       The time spent in queues

For all Resources

       The change in (actually the new value) demand
       for the resource and the exact time it changed

Table 5.14 Detailed results from one replication. Products and resources

	A	B	C	D	E	F	G	H	I	J	K	L
1	Shaft	943,1	1073	1387	1625	1822						
2	Suspensi	356,4	880,9	826,3	815,4	888,3	900,7	800,6	1006	953,2	980,7	10
3	Stay	540,3	1056	880,7	1317	1170	1482	1296	1730	1615		
4												
5												

Figure 5.5 Example of detailed product results from one replication

It is interesting here to mark that the first batch of stays was completed with a throughput time of 540 time units, lower than the expected minimum. This is a combination of the fact that it is the first batch, (working in an "empty" factory), and the use of distributions. The need for a warm up period is here obvious.

	A	B	C	D	E	F	G	H	I	J	K
1	Drill	-1	0	-1	0	-1	0	-1	0	-1	
2	Ω-Drill	0	324,4	356,4	443,1	540,3	753,5	943,1	972,9	1003	1(
3	Lathe	-1	0	1	0	-1	0	-1	0	1	
4	Ω-Lathe	0	0	23,5	121,8	182,5	617,5	739,6	762,8	782,8	82
5	Cutter	-3	-2	-1	-2	-3	-2	-1	0	1	
6	Ω-Cutter	0	78,7	182,5	314,9	434	826,1	840,9	890	938,4	95
7	Welding	-1	0	1	0	-1	0	1	2	3	
8	Ω-Welding	0	0	0	23,5	78,7	121,8	122,4	237,6	290,9	37
9	Truck	-1	0	-1	0	-1	0	-1	0	-1	
10	Ω-Truck	0	314,9	324,4	434	443,1	743,7	753,5	962	972,9	1(
11	Operator	-1	0	-1	0	-1	0	-1	0	-1	
12	Ω-Operator	0	78,7	80,7	121,8	123,8	182,5	184,5	311,9	314,9	31
13											

Figure 5.6 Example of detailed resource results from one replication

If we look at lines 7 and 8, we see that at time 0 the demand for Welding changes from -1 (one resource available) , via 0, to 1 (in queue). This changes at time 23,5 (line 8, column E), when the job starts in the Welding machine.

5.3.4.2 The log - The event trace

	A	B	C	D	E	F	G	H
1	Time	Event	Prod.order	Group	Prod.type	Arguments.......		
2								
3	3177,84	FiniP	17	0/0	Suspension	1249,8	269,87	1000
4	3255,57	HoldR	4	0/0	Shaft	0	1	Operator
5	3255,57	Oper.	4	0/0	Shaft	3	743,2	1000
6	3258,57	FreeR	4	0/0	Shaft	1	1	Operator
7	3258,57	FreeR	4	0/0	Shaft	1	1	Welding
8	3258,57	HoldR	18	0/0	Suspension	0	1	Welding
9	3258,57	HoldR	4	0/0	Shaft	0	1	Truck
10	3258,57	HoldR	4	0/0	Shaft	0	1	Operator
11	3258,57	Oper.	4	0/0	Shaft	10,14	753,34	1000
12	3258,57	Oper.	18	0/0	Suspension	23,52	23,52	1000
13	3261,95	NewP	28	0/0	Suspension	132,59	3394,54	1000
14	3261,95	WaitR	28	0/0	Suspension	16	1	Welding
15	3268,71	FreeR	4	0/0	Shaft	1	1	Operator
16	3268,71	FreeR	4	0/0	Shaft	1	1	Truck
17	3268,71	HoldR	4	0/0	Shaft	0	1	Drill
18	3268,71	Oper.	4	0/0	Shaft	187,81	941,15	1000
19	3282,1	FreeR	18	0/0	Suspension	1	1	Welding
20	3282,1	HoldR	8	0/0	Stay	0	1	Welding
21	3282,1	HoldR	18	0/0	Suspension	0	1	Lathe
22	3282,1	Oper.	18	0/0	Suspension	67,13	90,65	1000
23	3282,1	Oper.	8	0/0	Stay	56,74	56,74	1000
24	3289,82	NewP	12	0/0	Stay	303,68	3593,5	1000
25	3289,82	WaitR	12	0/0	Stay	16	1	Welding
26	3338,85	FreeR	8	0/0	Stay	1	1	Welding
27	3338,85	HoldR	19	0/0	Suspension	0	1	Welding
28	3338,85	HoldR	8	0/0	Stay	2	1	Cutter

Figure 5.7 Example of the log - The event trace

The event trace gives a complete list of the events that has occurred in the experiment.

One should only log these events over a very limited simulation period. The event trace is very useful in detecting dead lock situations.

If we again look at the figure, line 7, we see that at time 3258,57, the resource is freed (FreeR) from its previous job which was welding of a batch of stays. The next operation, which can start immediately, line 8, is the welding of a batch of suspensions.

5.3.5 Average over average results from more than one replication

These results are simply the average from more than one replication over the average results. All result tables from 5.7 to 5.11 are available.

The reasons for running more than one replication is that this improves the reliability of the results. Each replication starts with a different seed, but with all input values equal between the replications. The average values from several replications are then more reliable estimates of the real values.

5.4 Monitor

Resource queues and stock quantities of products may be monitored during experiment execution. The monitor set-up for one experiment is shown in Figure 5.8. Up to 5 different displays can be used to specify;

*   **name** of the resource or product

*   object to watch (**q**ueue/**s**tock)

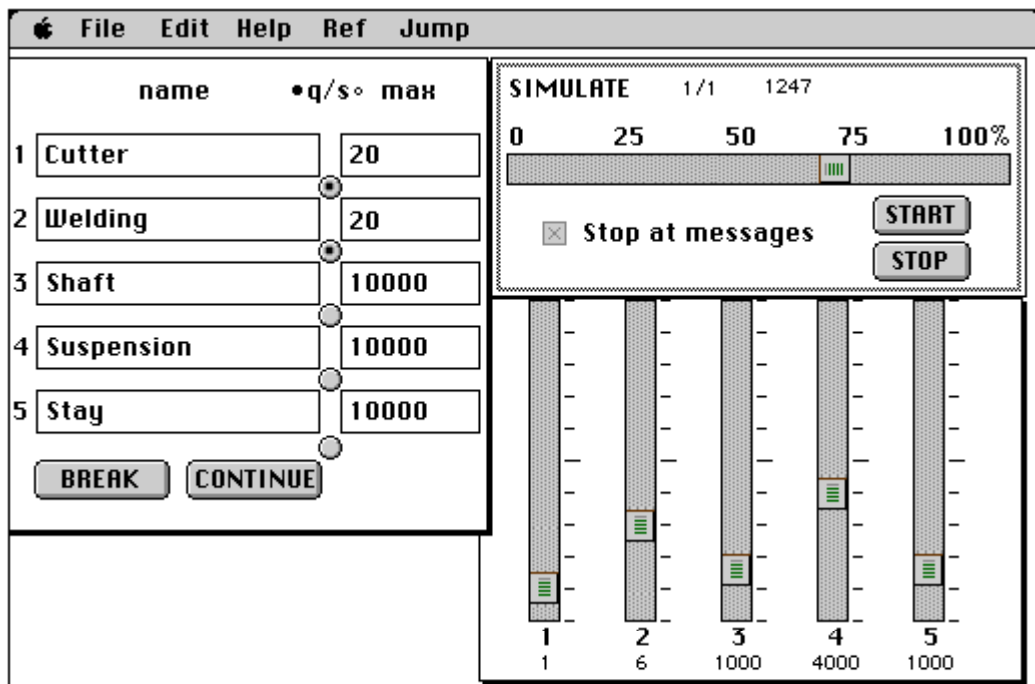*   **max**imum level (top value) of the monitoring bars

Figure 5.8 Example of the monitor function in use

During execution, the user may interrupt the experiment if illegal conditions in the monitored queues and stock quantities are discovered.

The monitor function can give valuable information during the model building and validation. It gives instant results, and the user can stop the whole experiment when special effects and situations, or crazy results, occur.

5.5 Post processing and integration with SIMMEK

Two important aspects of result presentation and analysis are post processing of simulation results and the possibility to integrate the simulation tool with operative computer based management systems, in particular MRP II based systems.

Post processing of simulation results will be dealt with in Section 7, Operational use of simulation. The integration aspects will be covered in Section 9.