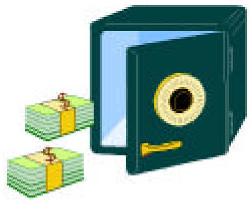
Simulation

a Modern Aid for
Planning Developing Controlling

As is well known, the removal of development errors during the development phase of a project is the cheaper, the earlier the errors are found. Whereas the consistency of proposed static solutions in a system specification nowadays can be reached by the use of so-called CASE or modelling tools, this does not apply to the proposed dynamic properties defined in the specification which define the course behaviour of the planned system.

Most development tools support only the development of the static parts of specifications. The dynamic behaviour of the planned system can only checked after the systems specification has been finished with expensive prototypes or even more expensive at the "living" system (e.g. at the business organisation already changed). In most cases errors in the specified dynamic behaviour of the system are found, which are nor relevant in a pure static considerations or are not noticed at all.

An improvement can be reached by simulation systems which support the static as well as the dynamic parts of system specification and make it possible also to check the dynamic behaviour of the future system. By the use of modern simulation systems as planning tools the development and maintenance costs can be noticeably lowered because the erroneous behaviour of a system can already be recognised very early.



With the simulator development system ***PACE*** commercial and technical systems are modelled exactly in all details and completely up to an arbitrarily defined depth. The developed virtual systems (models) can be executed on a computer and deliver results about the dynamic behaviour and the co-operation of system parts and about the effectiveness of the planned actions. ***PACE*** simulation models particularly make it possible to find local and global optimisations or improvements already in the planning phase of a project.

Simultaneously by the modeling with ***PACE*** the understanding of the processes in the real system is very often promoted which among other things leads to a more efficient behaviour of the employees in the business and in the disturbance case.

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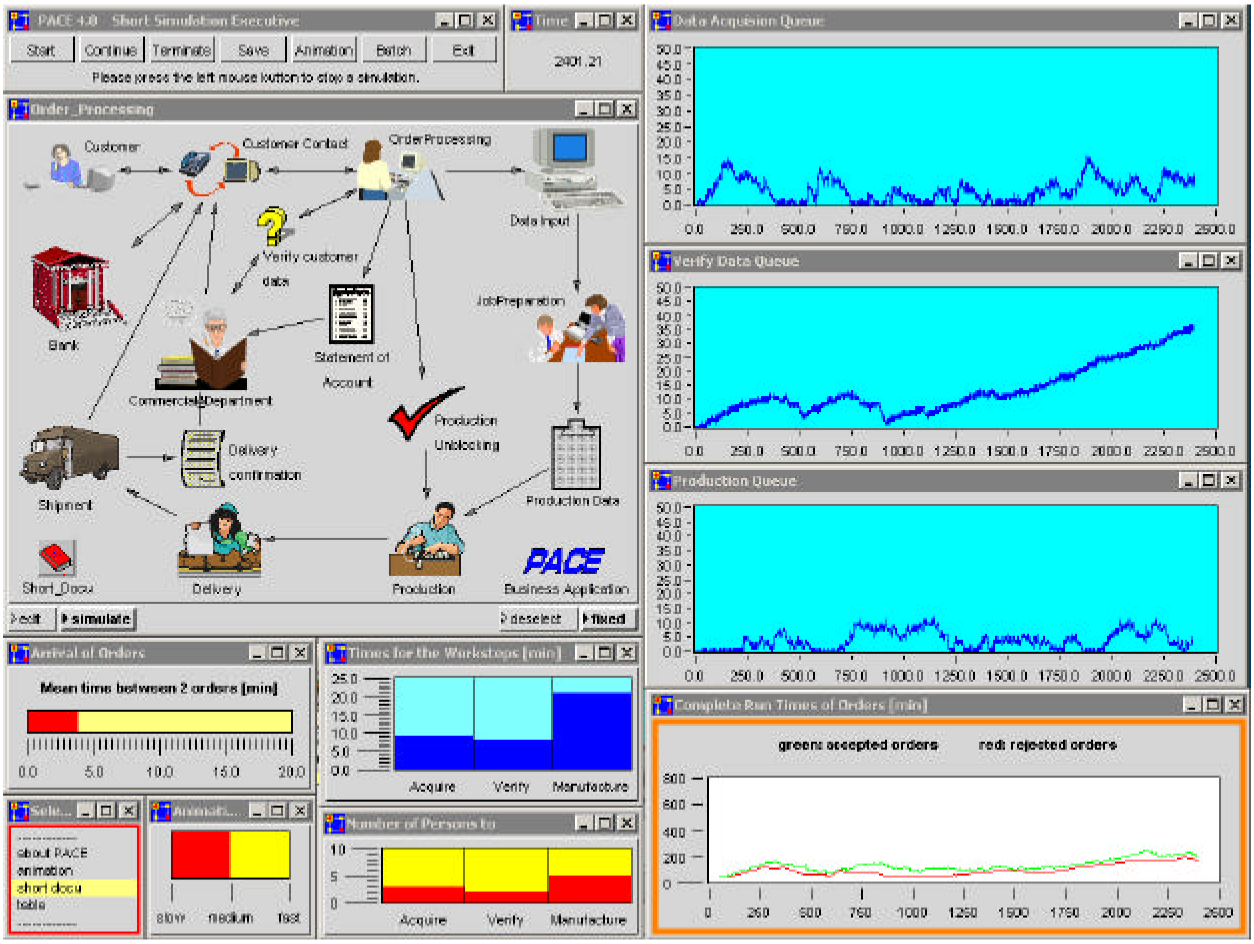
E-Commerce

Configuration of a Business Center

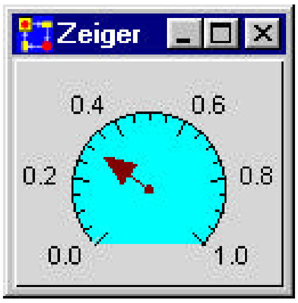


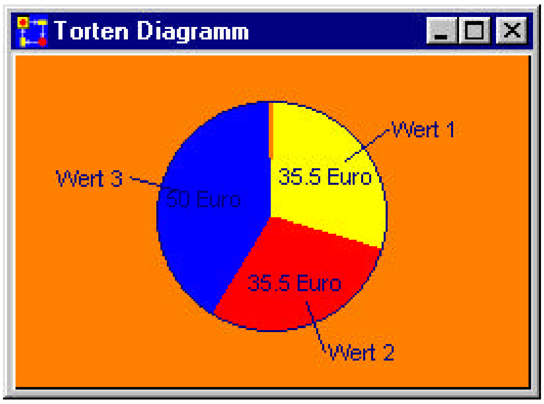
Before a short introduction into the development of simulators is given a simple application is discussed for clarification. On later pages many examples from other application areas are shown. Several of the discussed models can be loaded down from our homepage.

For the configuration of an e-commerce center the number of the officials in charge has to be adjusted to the time needed for a single work step and to the average number of the incoming orders. The employees in different places of the center shall if possible be occupied fully well but the length of the queue before every processing position must be limited.

The simplified model represented above allows for the adjustment of the mean number of orders which is interpreted as mean average value of an exponential distribution. Also the time needed for the different processing steps of an order and the number of officials in charge for every processing position can be adjusted.. With the three curve windows (with blue background) one can see the behavior of the queues in front of the processing positions. If necessary the number of officials in charge must be changed. The queues should neither be empty nor permanently increase.

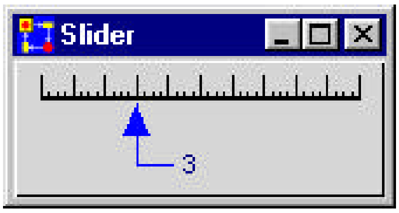
The preceding examples shows that ***PACE*** models are nets (exactly: High Level Petri Nets) which can be animated during their execution. They are entered with a convenient graphic editor. To show the results of a simulation and for user input an extensive set of special visualization graphics (pies, bar gauges, instruments, curves, tables, button boards, etc.) has been developed which can be connected easily to any simulation model.



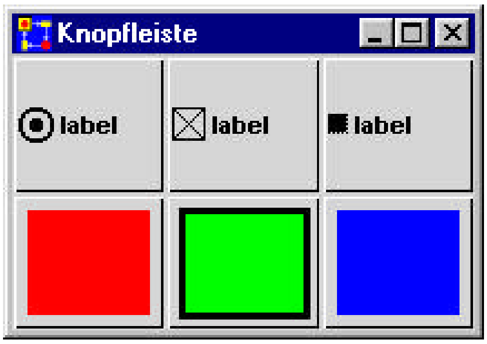


There are many extensions of classical Petri nets in ***PACE***. One of the most important is the possibility to organize a net hierarchically and as a consequence to display only the interesting model constituents of an application on the screen hiding the rest of the model (module technique). A user also can add graphic visualization windows and windows for user input. A powerful user oriented programming language is available for the processing of data (Smalltalk). The user also can form the appearance of his nets user friendly by replacing the standard pictures of the static and dynamic network elements with pictures from the respective application area.

To make a model usable in the practical work, e.g. for understanding, verifying and optimizing the dynamic behavior of the real system, there must be a mapping as simple as possible between reality and model. This is ensured in ***PACE*** by the fact that the static and dynamic properties of the real system are copied into the model as far as possible.



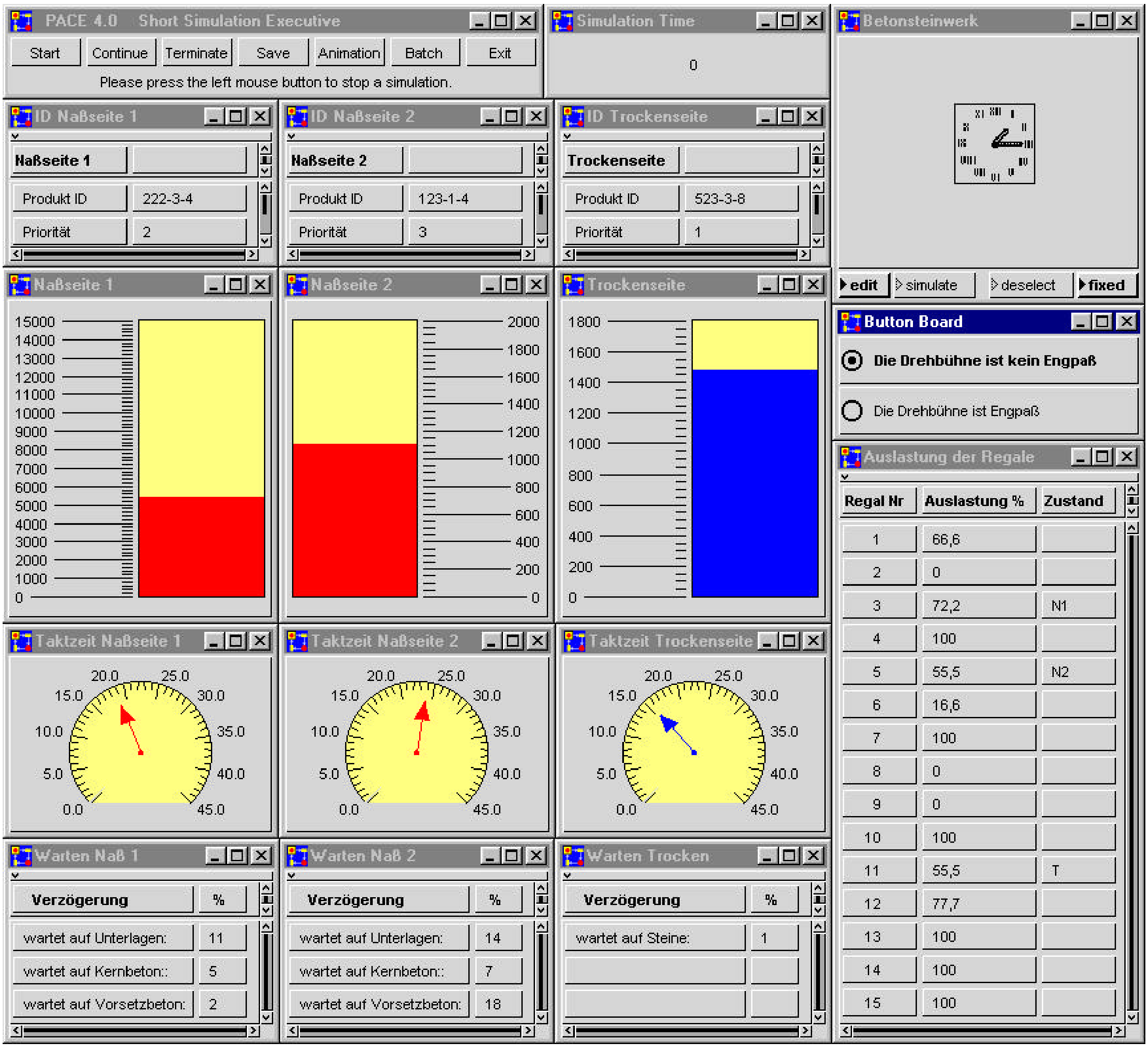
The subdivision into statics and dynamics has proved itself in other scientific disciplines and makes an adequate system description possible. Therefore ***PACE*** models deal with time-independent physical or logical entities (objects) and with time-dependent events (processes) which have an effect on the objects, i.e. transport objects and/or change objects into other objects. As a result of this division ***PACE*** can also be seen as an engineering modeling tool. The facts or systems to be modeled can both be represented as regards content and spatially like in the reality. By the animation one can follow the action of the real system visually in the model and can vary the model to find out improvements.



Concrete Paving-Stones Production

Throughput Raise by Scenario Simulation

The model describes a plant for the production of concrete paving-stones. The difficulties to develop an optimized plant control came from the fact that a considerable share of the mass production was replaced by individual little orders whose product specific overlapping impaired the total throughput.

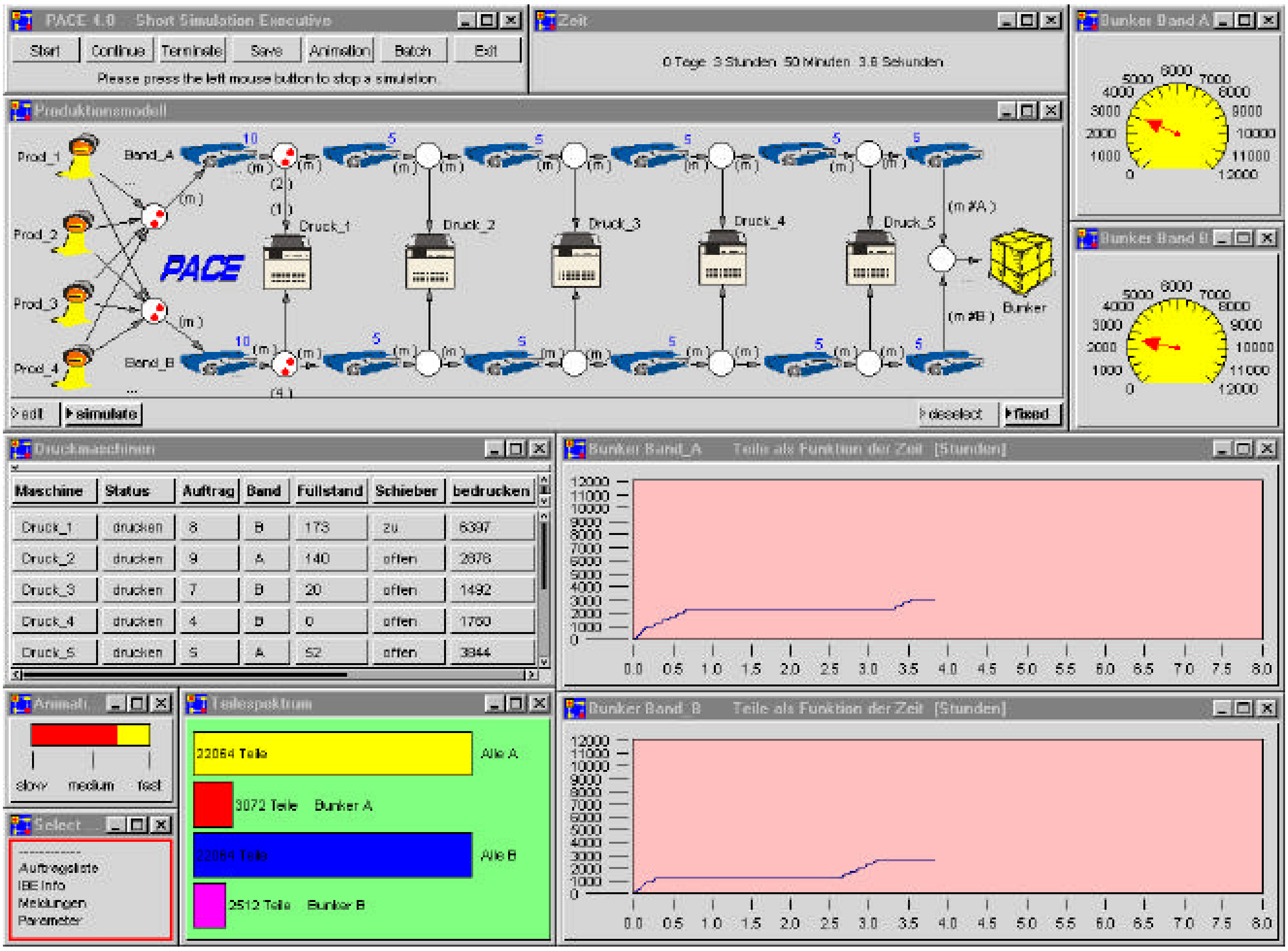


The impairments resulted directly from the tightly coupled machines. Dependent of the respective product various bottleneck situations occurred in one production or packing cycle, which restricted the throughput of the complete system.

This problem was solved dividing the year production of the plant into different product classes by action-relevant parameters and by analyzing the specific bottlenecks of the product classes (see: Volkhard Franz, Matthias Enkelmann: Simulation optimiert Pflastersteinproduktion, BFT Betonwerk + Fertigteil-Technik 9/98).

Production of Parts

Efficiency Increase by Bottleneck Elimination

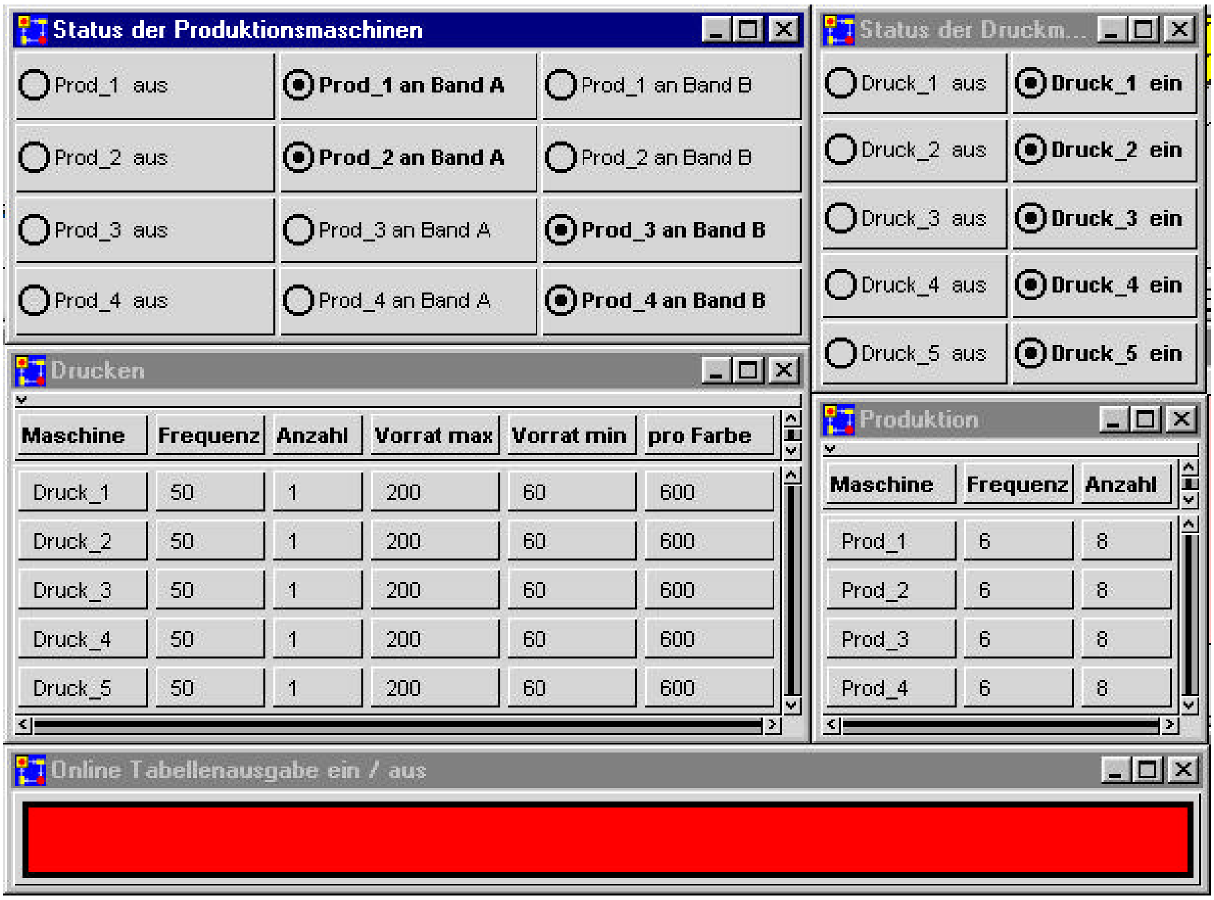


The model shows the asynchronous cooperation of machines in a production process as it can be found in numerous plants. Parts are produced in several production machines and are transported to independently working reprocessing machines with conveyor belts.

Depending on statuses of the reprocessing machines bottlenecks can arise in the processing of the parts arriving on the conveyor belts.

With the presented model order scenarios can be processed to investigate the behavior of the so called “bunker” which stores surplus parts. The model allows for numerous handicaps to configure the plant, the production machines and the reprocessing machines (see the next figure).

Our model configuration consists of maximum 4 machines which produce parts (e.g. plastic parts, bolts). The parts are transported on two conveyor belts to 5 reprocessing machines in maximum (e.g. printing machines, packaging machines). The “bunker” takes the parts which have passed the reprocessing machines on a conveyor belt without having been picked up by a reprocessing machine. These not finished parts are supplied later either automatically or manually to the reprocessing machines .



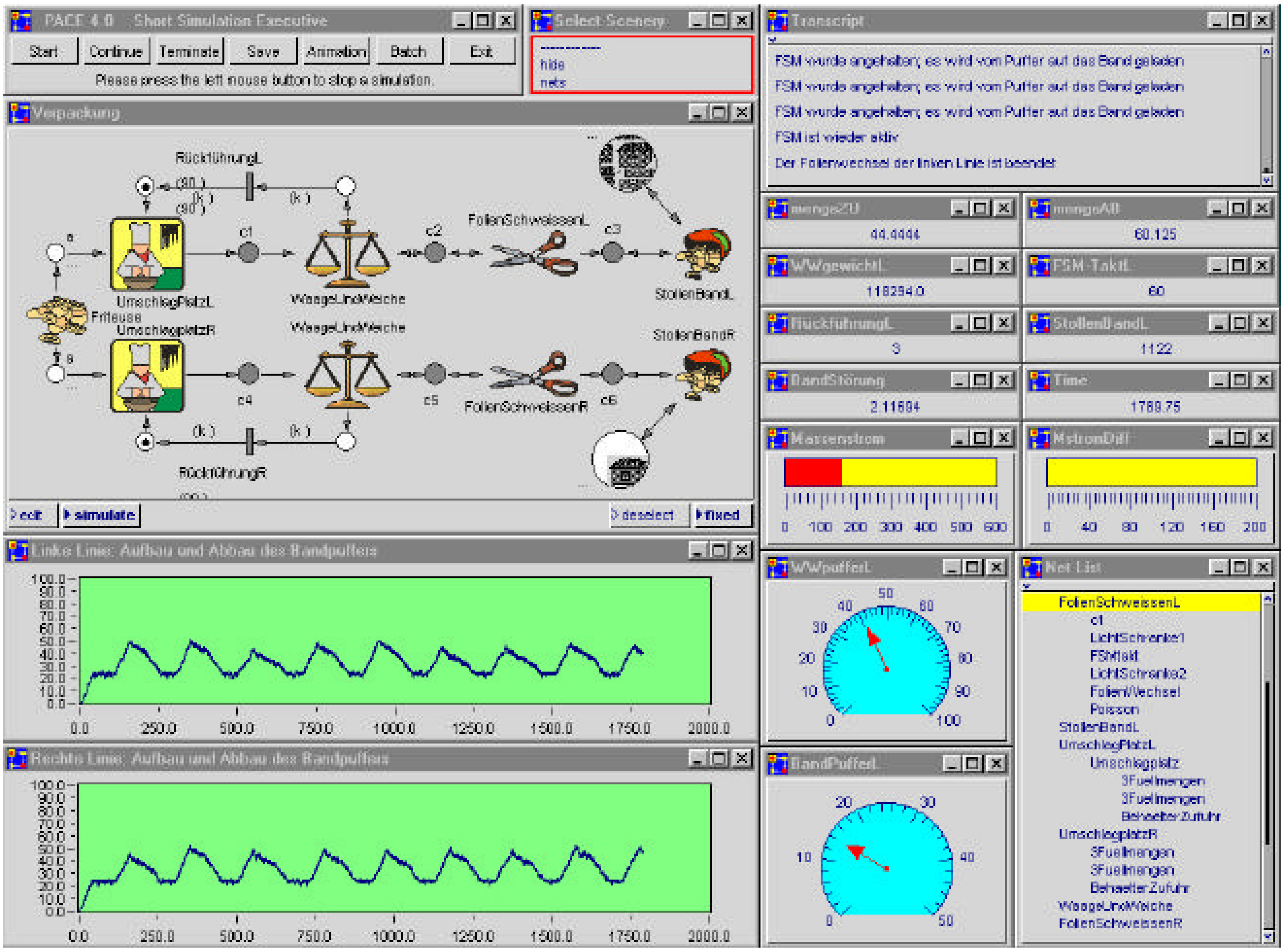
Our model uses the following configuration:

- 2 conveyor belts which transport the same or different types of parts respectively.
- 4 production machines, which can be connected to each of the two conveyor belts.
- 5 printing machines, which can be connected to each of the conveyor belts dependent of the actual production order.

The working speed of all 9 machines can be adjusted individually. Each of the machines can be switched on/off individually. The levels of the stock and of the catch container of every printing machine can be adjusted. The time needed for preparing every printing machine can be assigned.

Packing of Food

Weak Point Examination and Optimization

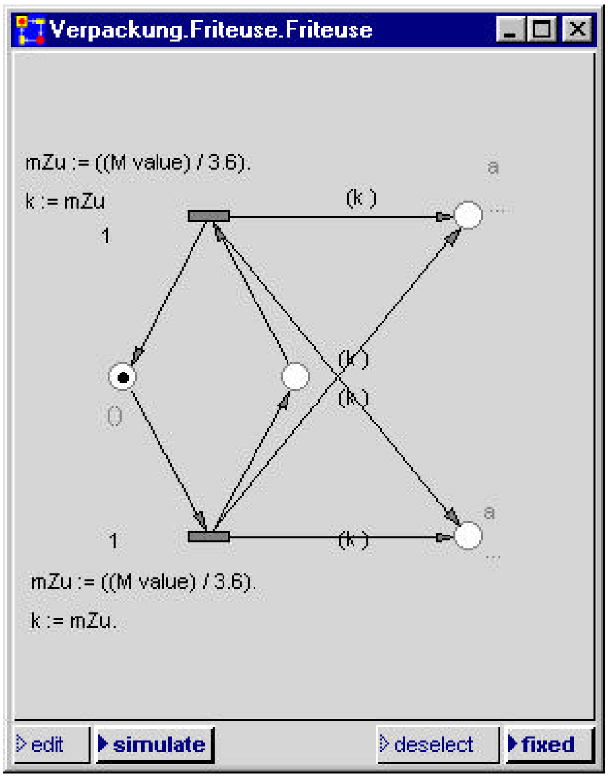


The model simulates the partial process ‘packaging’ in food production. Production and packaging are connected by a handling area. This is the critical place of the whole production process.

In the handling area from the continuous product stream (in our case potato chips) portions with a special weight are taken out by hand and put on a conveyor belt. The manual taking out of portions leads to inaccuracies of weight which make corrections necessary. Even if the grade of automation is very high, a disharmonic course of the packaging process is created with frequent disturbances up to the stoppage.

The situation is marked by high effort in personal and by most modern automation technology. Increase of production speed results immediately in the increase of rejects. The economical success can only be manipulated in narrow limits!

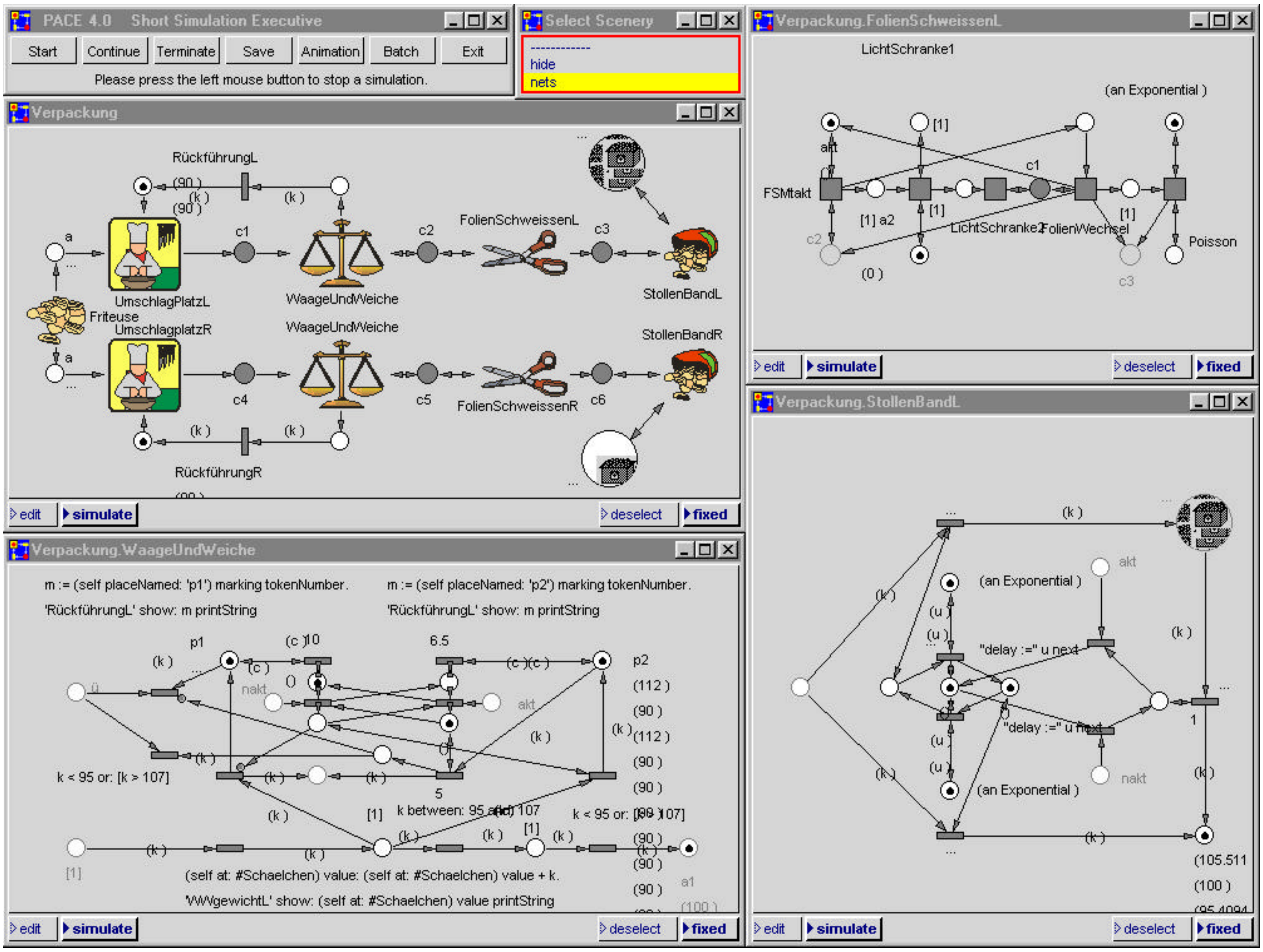
An very critical phase happens when one of the packaging machines has to be provided with new packaging material. In this case a queue is build up inevitably which has to picked up and dismantled.



During the reduction of the tailback stochastic disturbances can occur which prevent a complete dismantling until the next provision of packaging material. The different disturbances influence one another and it is not clear immediately, how the behavior of the system can be organized better altogether.

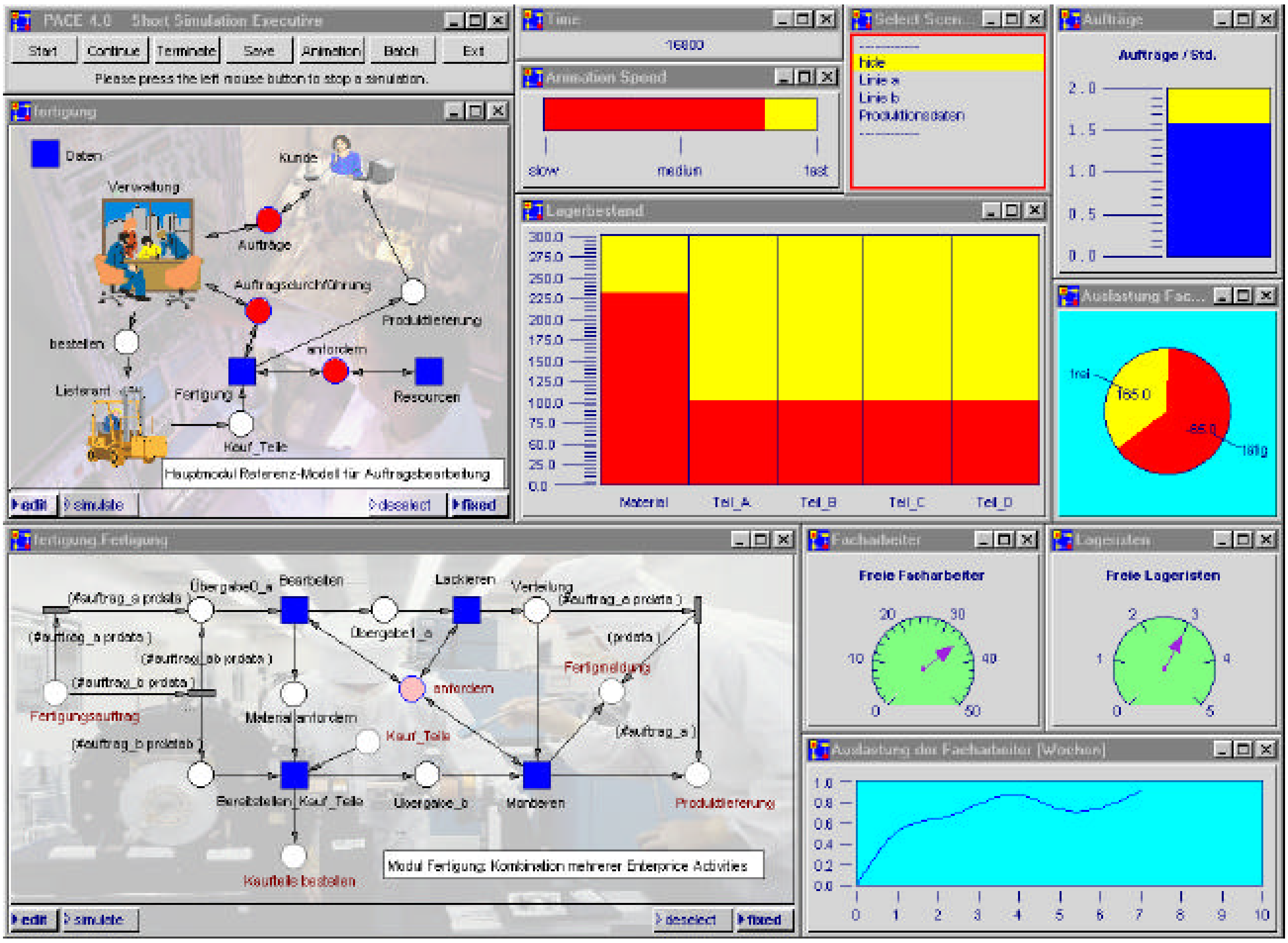
The improvement of the system performance by trying directly and testing is not possible by cost and time reasons. There is only one solution: modeling and simulation! (see: Gerd Feistl: „Simulation von Verpackungsprozessen: Findet des Nadelöhr“, neue verpackung 4/98)

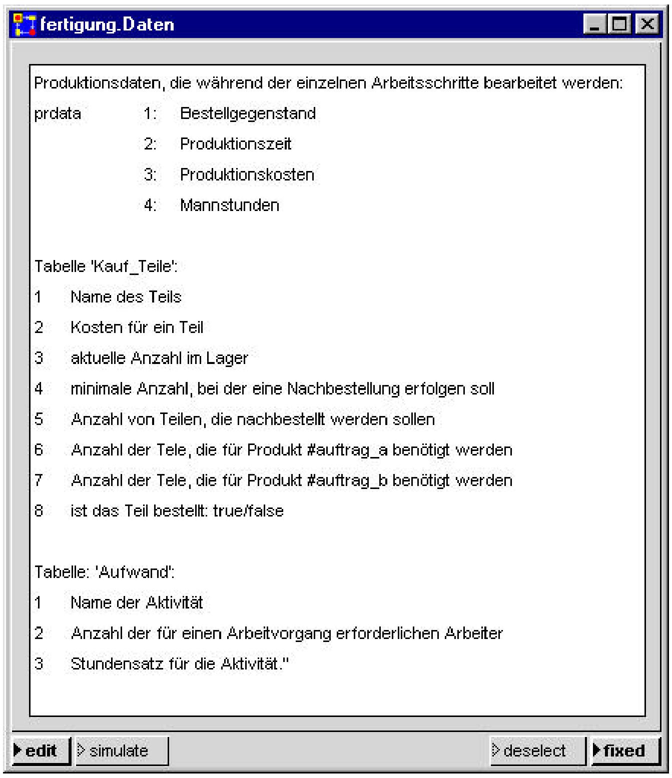
The following illustration shows the same model, where the scene 'hide' (see above) replaces the scene 'nets' . The net windows and the illustration above show one part of the processing modules which usually are hidden during the application of the model.



Production in Two Lines

Coordination and Optimization of Resources





fertigung.Daten

Produktionsdaten, die während der einzelnen Arbeitsschritte bearbeitet werden:

prdata 1: Bestellgegenstand
2: Produktionszeit
3: Produktionskosten
4: Mannstunden

Tabelle 'Kauf_Teile':

1 Name des Teils
2 Kosten für ein Teil
3 aktuelle Anzahl im Lager
4 minimale Anzahl, bei der eine Nachbestellung erfolgen soll
5 Anzahl von Teilen, die nachbestellt werden sollen
6 Anzahl der Teile, die für Produkt #auftrag_a benötigt werden
7 Anzahl der Teile, die für Produkt #auftrag_b benötigt werden
8 ist das Teil bestellt: true/false

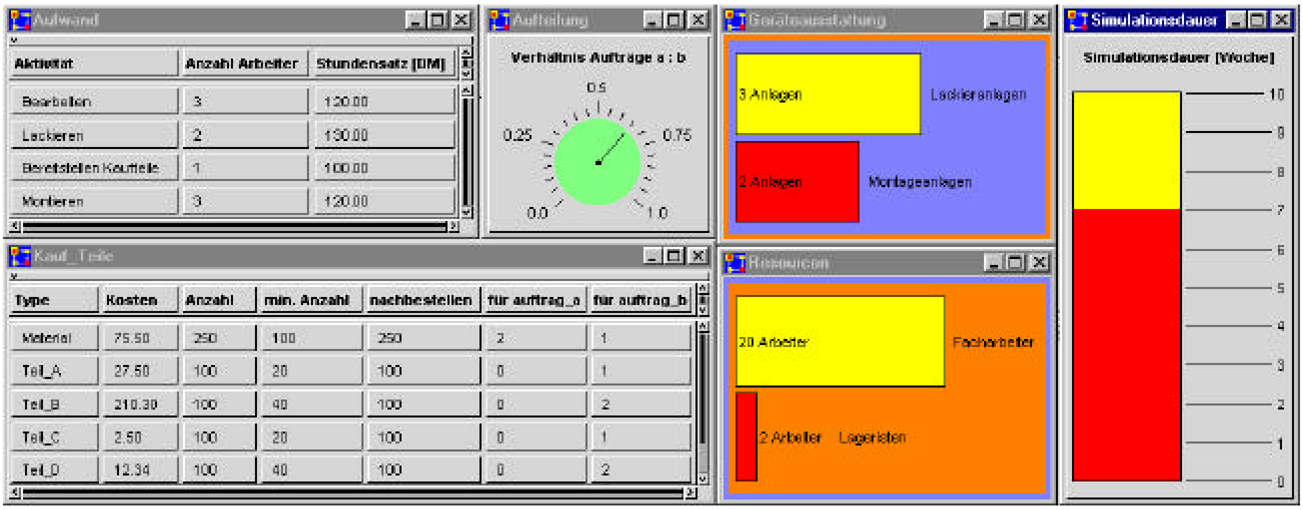
Tabelle: 'Aufwand':

1 Name der Aktivität
2 Anzahl der für einen Arbeitvorgang erforderlichen Arbeiter
3 Stundensatz für die Aktivität."

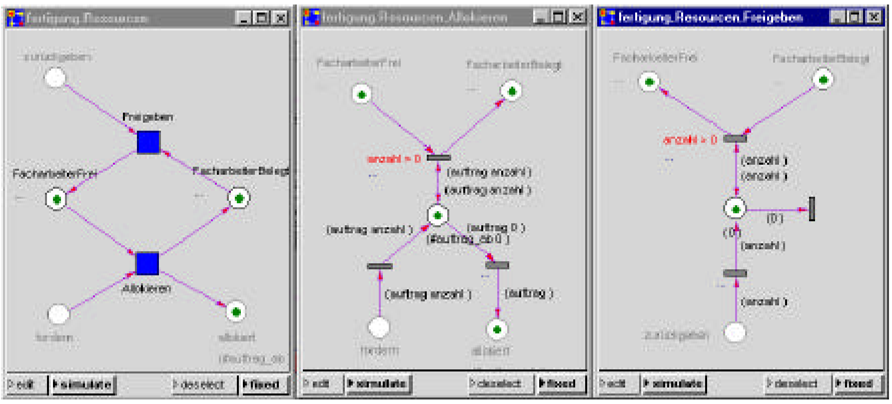
edit | simulate | deselect | fixed

The model shows the order processing from incoming orders up to the delivery and the rendering of account for a production in two lines. One line is dependent from the other sofar as one partial product of one line is also used in the other line. The model shows a simple treatment of stock-keeping and restocking and also deals with the action of stock-keepers and of skilled workers.

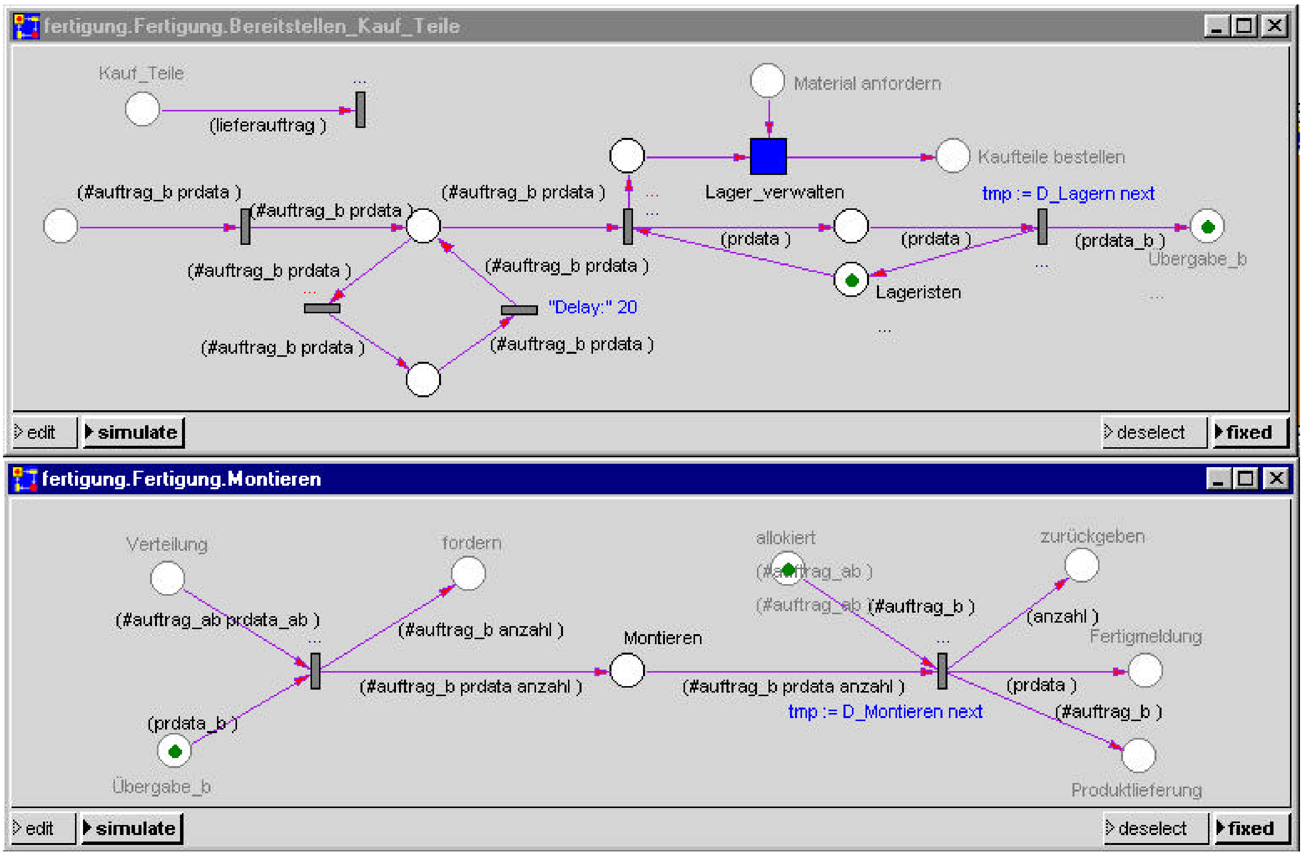
The model uses sceneries and can be parameterized by many input windows which are comprised in the scene ‘Produktionsdaten’. On the next page several subnets of the model are shown which give an impression of the models implementation.



Scene 'Produktionsdaten': Windows for the parameterization of the model



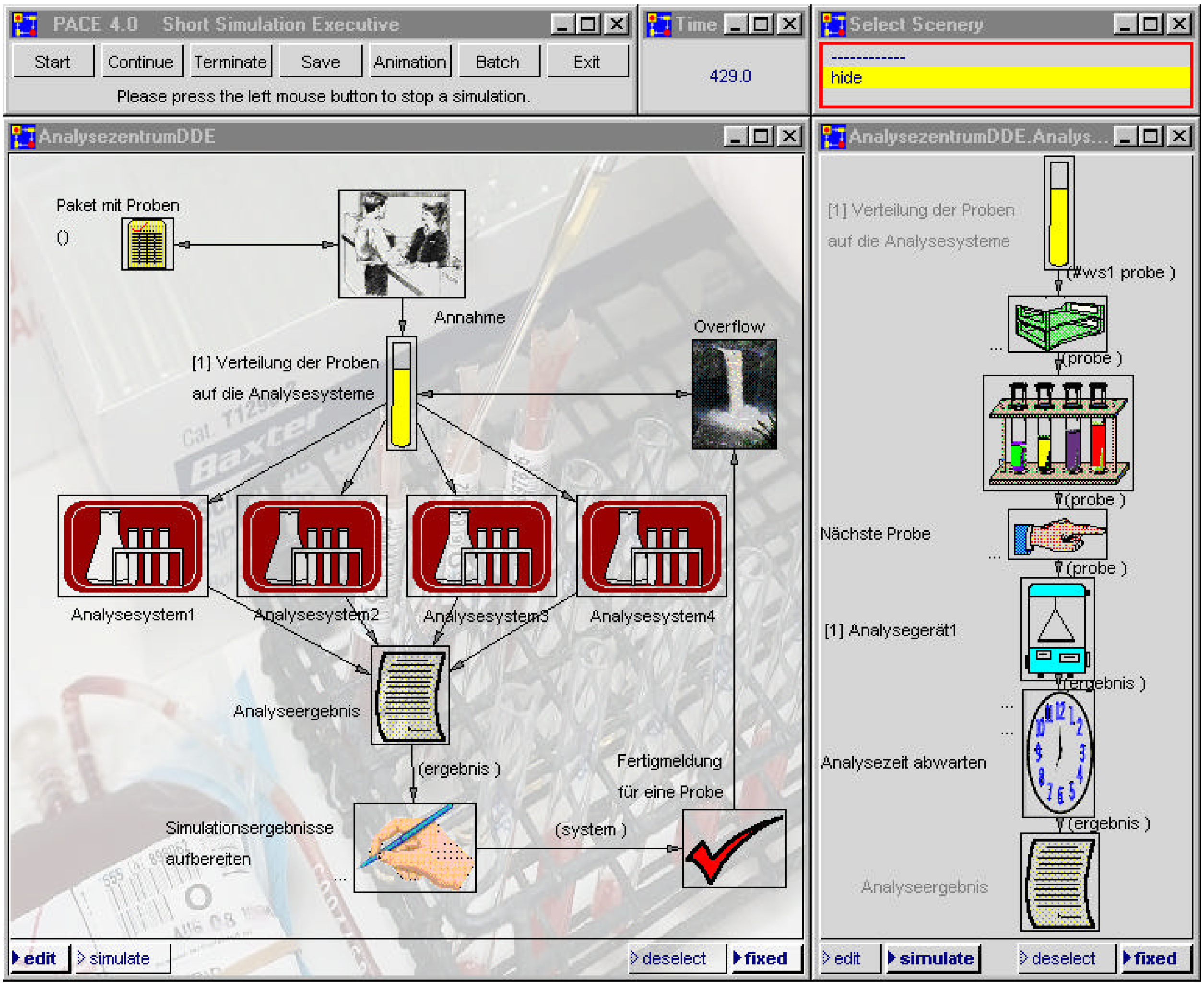
Allocation and release of resources

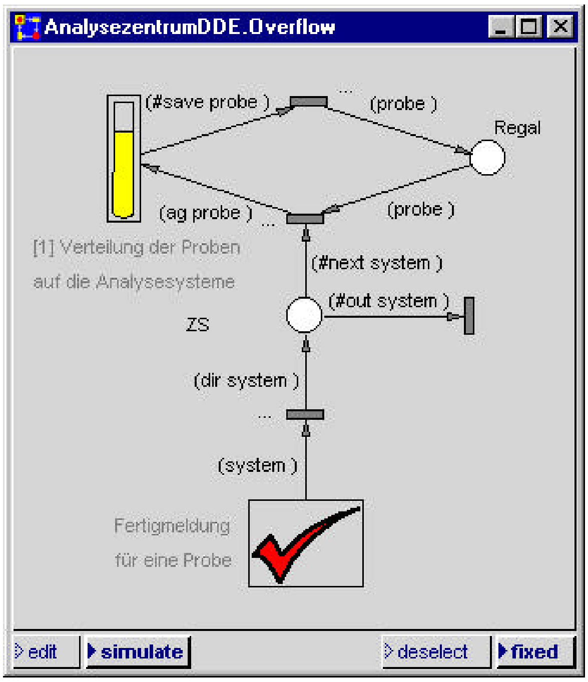


Scene 'Linie b': Modelling of production line b

Medical Analysis Center

Cost Reduction and Investigation of Reserves

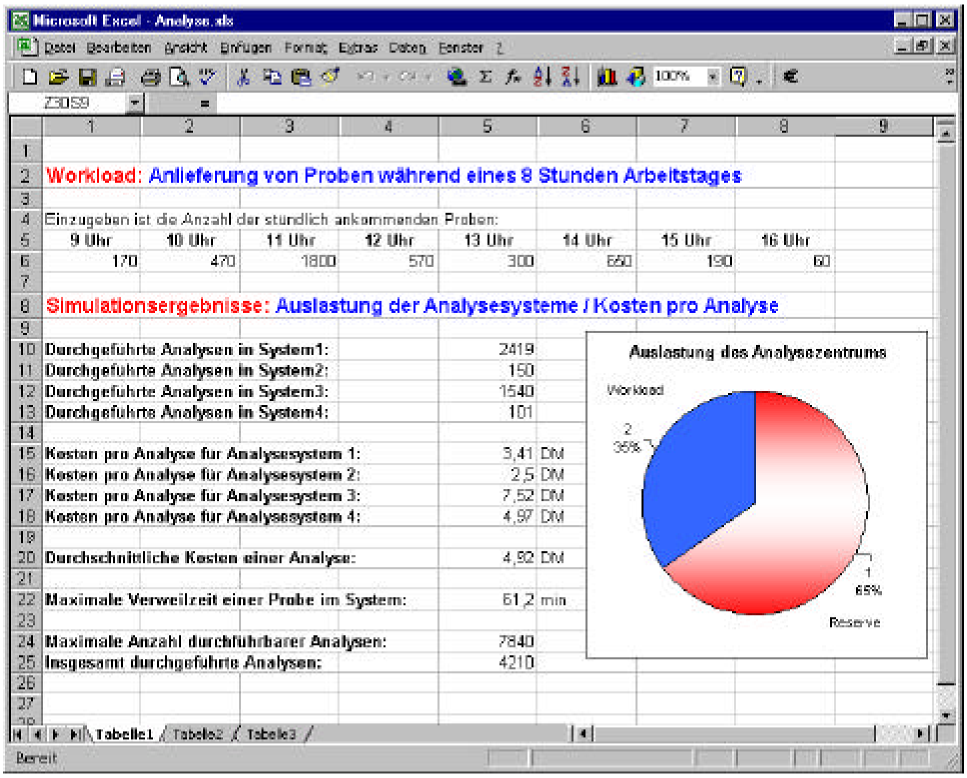




The configuration and the operation of medical analysis centers requires the selection of adequate analysis devices and of adequate operation modes to minimize the cost per analysis taking in account adequate response times and organizational practicability. A simulation model can verify the optimal configuration of an analysis center and the cost optimal use of the resources (particularly of the analysis devices). The model can also be used online to find the actual utilization, to evaluate the actual available resources and to determine completion times.

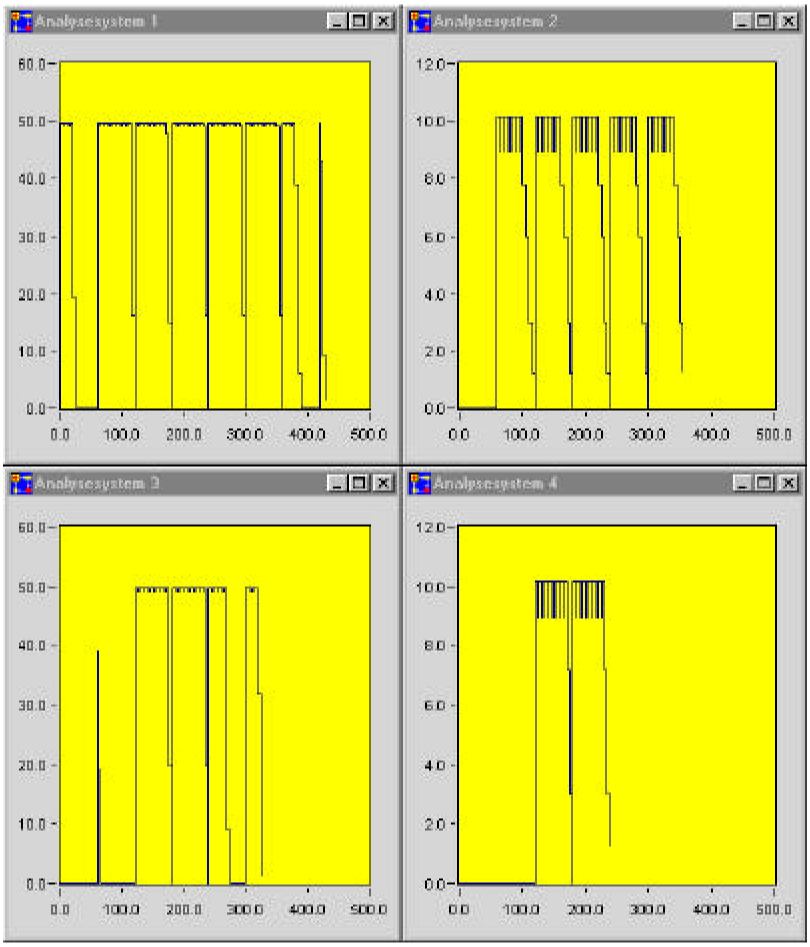
The model simulates the working capacity of four analysis devices which process the blood samples of an eight hour day. The number of hourly arriving samples is defined by an Excel worksheet or by a database.

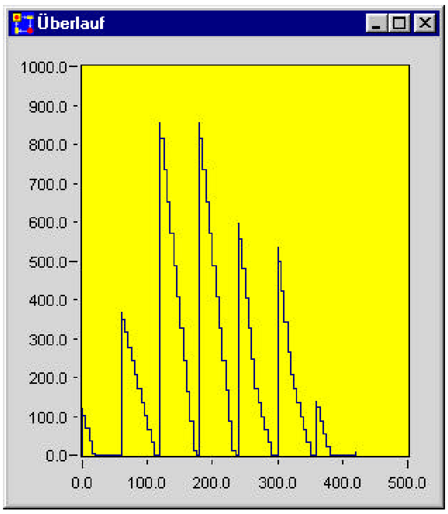
The model evaluates the utilization of the center and calculates the price per sample. The simulation puts out the results into several ***PACE*** line diagrams and the Excel worksheet.



In Line 6 of the Excel worksheet the number of samples to be processed in the next hour has to be entered. Afterwards the simulation is started by pressing the start button of the ***PACE*** simulation executive. At the end of the simulation the results are inserted in column 5 of lines 10 to 25.

In the following five line diagrams the utilization of the analysis devices and of the overflow storage is shown as function of the time. The overflow is used when the stack of an analysis device cannot hold all arriving samples. The abscissa shows the time in minutes whereas the ordinate gives the occupancy of the stack resp. of the overflow.

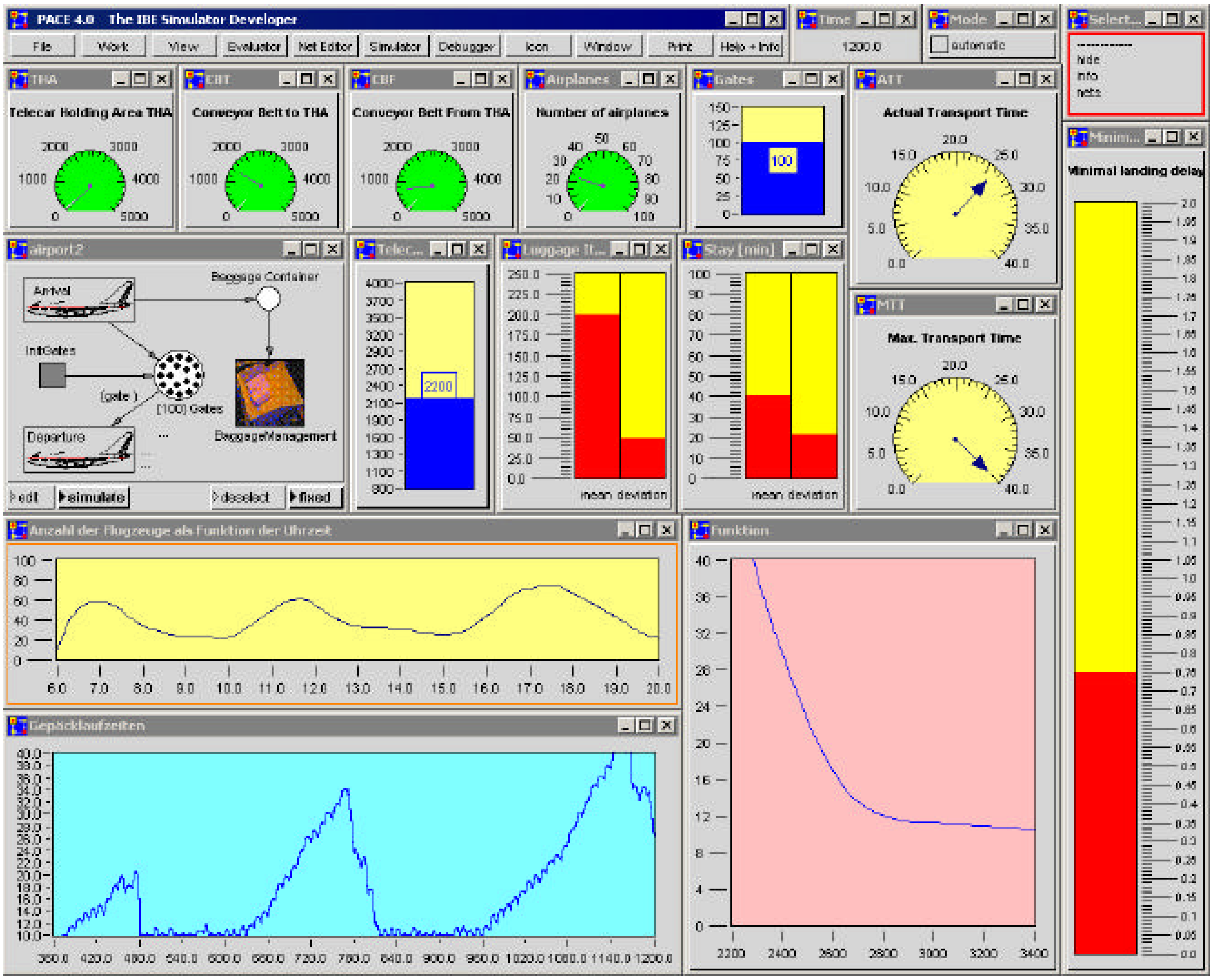




Baggage Transport System

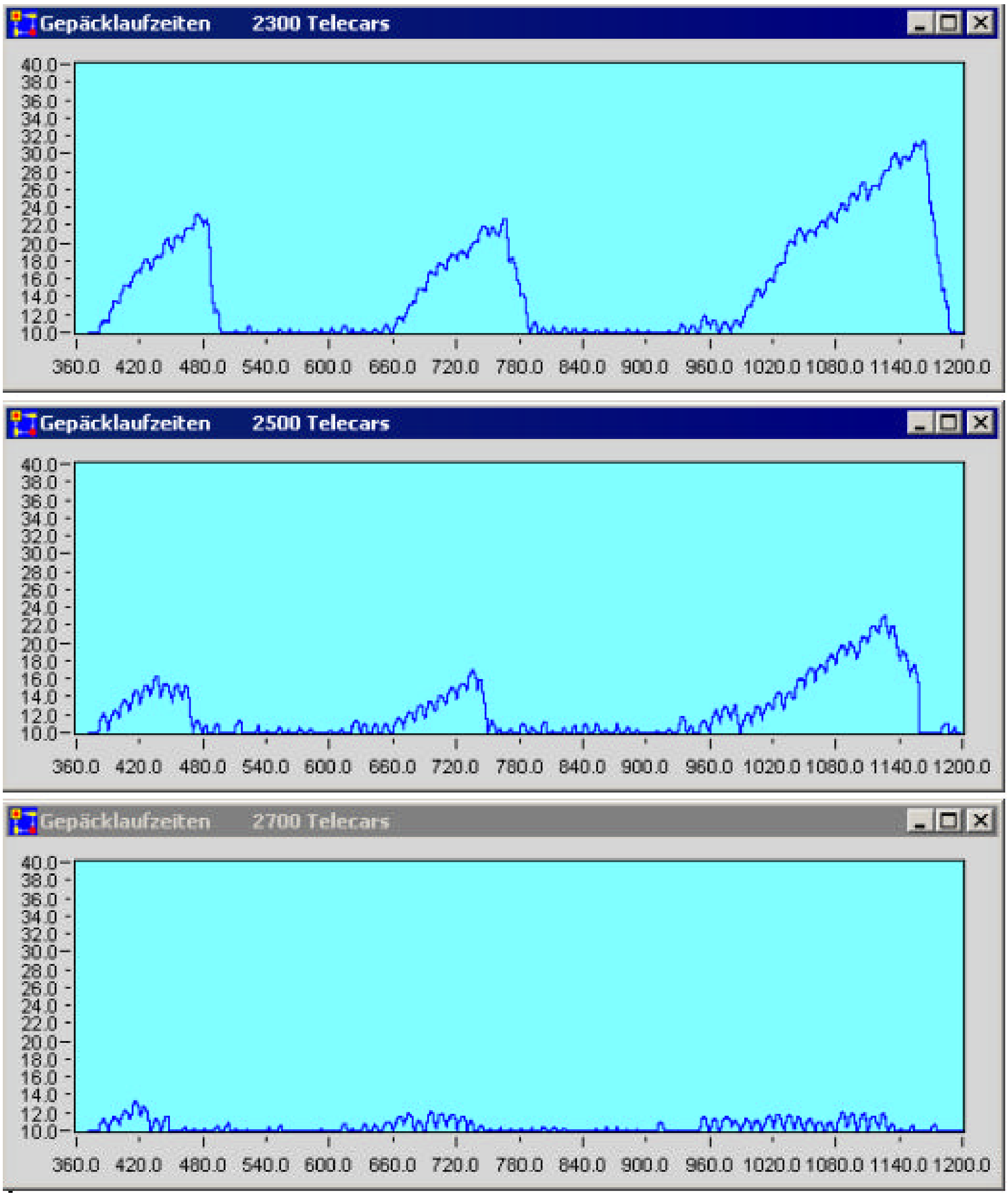
Minimizing the Baggage Waiting Periods

The model examines an airport baggage system under realistic conditions by entering the number of airplanes measured empirically at the airport as function of the time into the simulation (curve with yellow background). The simulation tries to follow this curve under consideration of system parameters of the airport (e.g. minimal time between two landings, middle dwell time of an airplane in the airport) as far as possible.



The simulation presented here answers the question how many telecars are required to bring the baggage from the gates to the baggage area and in opposite direction without additional delay. It is assumed that the pure baggage transport time is 10 minutes, that up to 80 gates are occupied and that 200 telecars are needed per airplane. For the dwell time of the airplanes and for the number of pieces of baggage Gauß distributions are used whose definition parameters are adjusted in two multiple bar gauges.

The problem is not trivial sofar as it does not use a rigid allocation of telecars from the THA (telecar holding area) but also takes into account the dynamic flow of telecars in the airport. Simulation shows for example that one can manage the incoming and outgoing air traffic optimal with about 2500 telecars, i.e. the baggage is availlable in the baggage claim area when the passengers arrive after 20 minutes to pick it up.



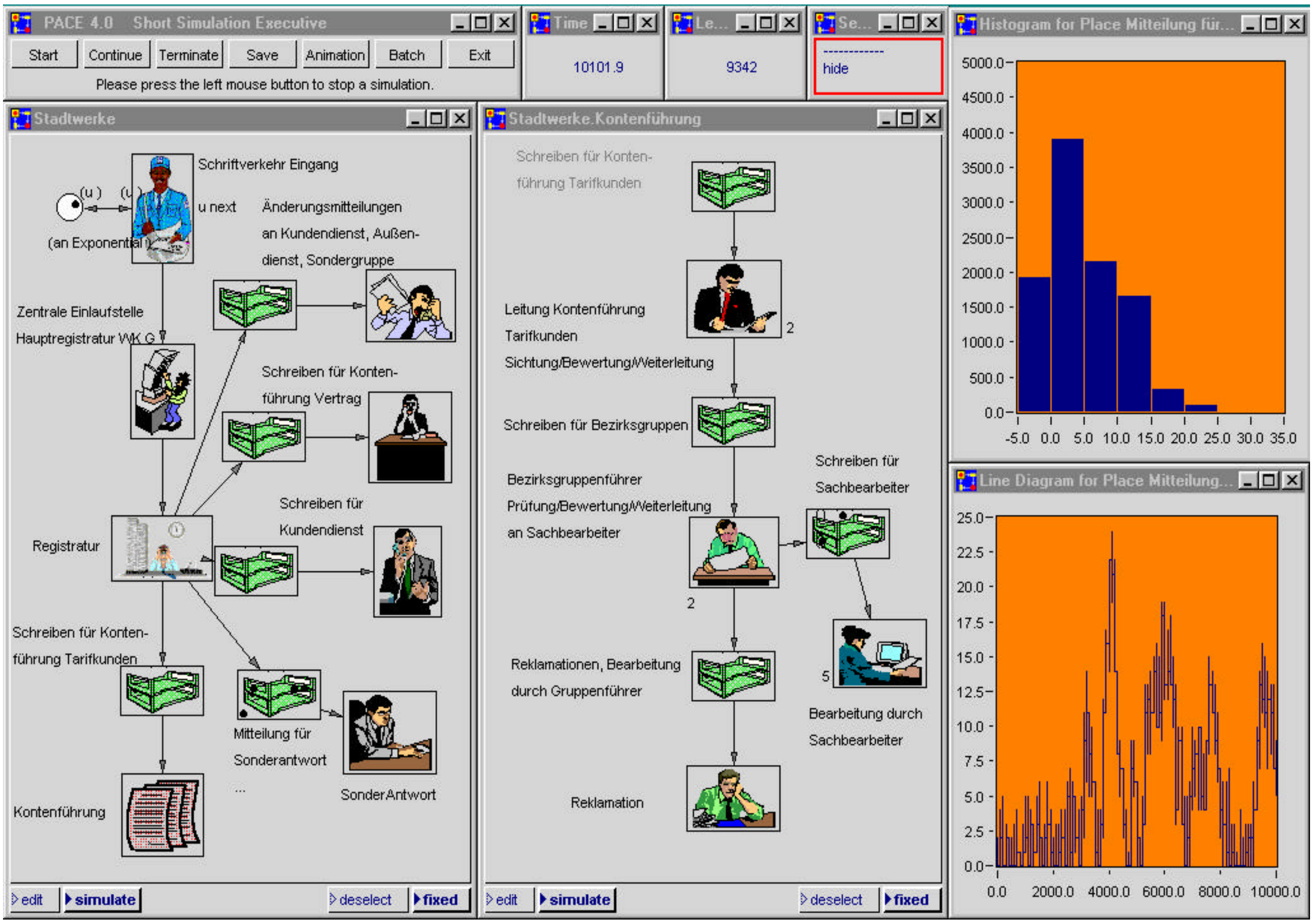
The illustrations above show the baggage running times for three numbers of telecars.

The model can be operated in two modes. On one side it shows the baggage running times within the main business hours of the airport for an arbitrary occupancy of the airport. On the other side one can (using the mode 'automatic') vary the number of telecars in steps between two adjustable limits and can evaluate for every number of telecars the maximum baggage running time. The functional dependency between the number of telecars and the baggage transport time is painted in the window 'Funktion'. From the appearing curve one can deduce the minimal number of telecars to produce a customer-friendly baggage transport system.

Workflow

Understanding and Optimizing Workflow

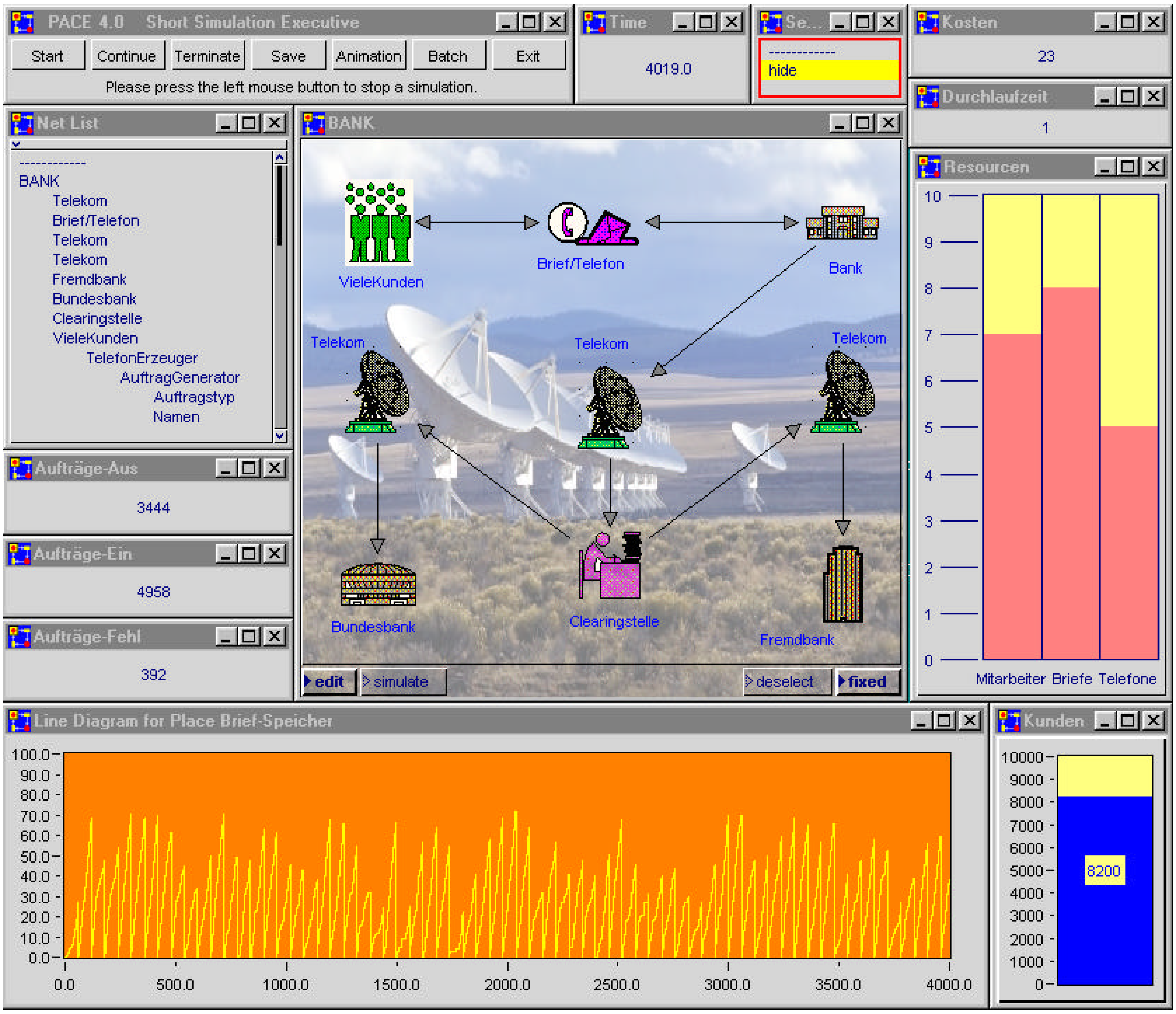
The development of an exact simulation model of the actual or intended workflow is a prerequisite for the non-appearance of unpleasant surprises when changing or planning greater organization units. Everybody knows examples of failed reorganizations from the daily press. Most of these failings can be avoided by exact simulation of models which make possible to measure, analyze and optimize the future workflow already in the planing phase. The exact PACE simulation models protect the planning of the workflow for new organization units and for changes in organizations! Two small examples:



The first example shows a simplified model of the accountancy in a public service organization. The model considers the workload of the officials in charge by connecting a histogram and a line diagram to the input basket 'Schreiben für Abteilungsleiter' in the middle picture.

The histogram shows the time shares for 0 letters, up to 5 letters, 6 to 10 letters, etc. in the input basket. The number of documents in the input basket is obvious in most cases below 15. The line diagram shows the number of documents in the input basket as a function of the time. From both diagrams we see that the number of officials in charge is sufficient to process the letters.

A similar problem is treated by the simulation model whose surface is represented in the next figure. For a predefined number of customers, which trigger a definite number of processing events with the bank per month (letters, telephone calls, e-mails) the resources (employees, computers, telephone lines) have to be evaluated, which make a stable processing of the incoming orders possible.



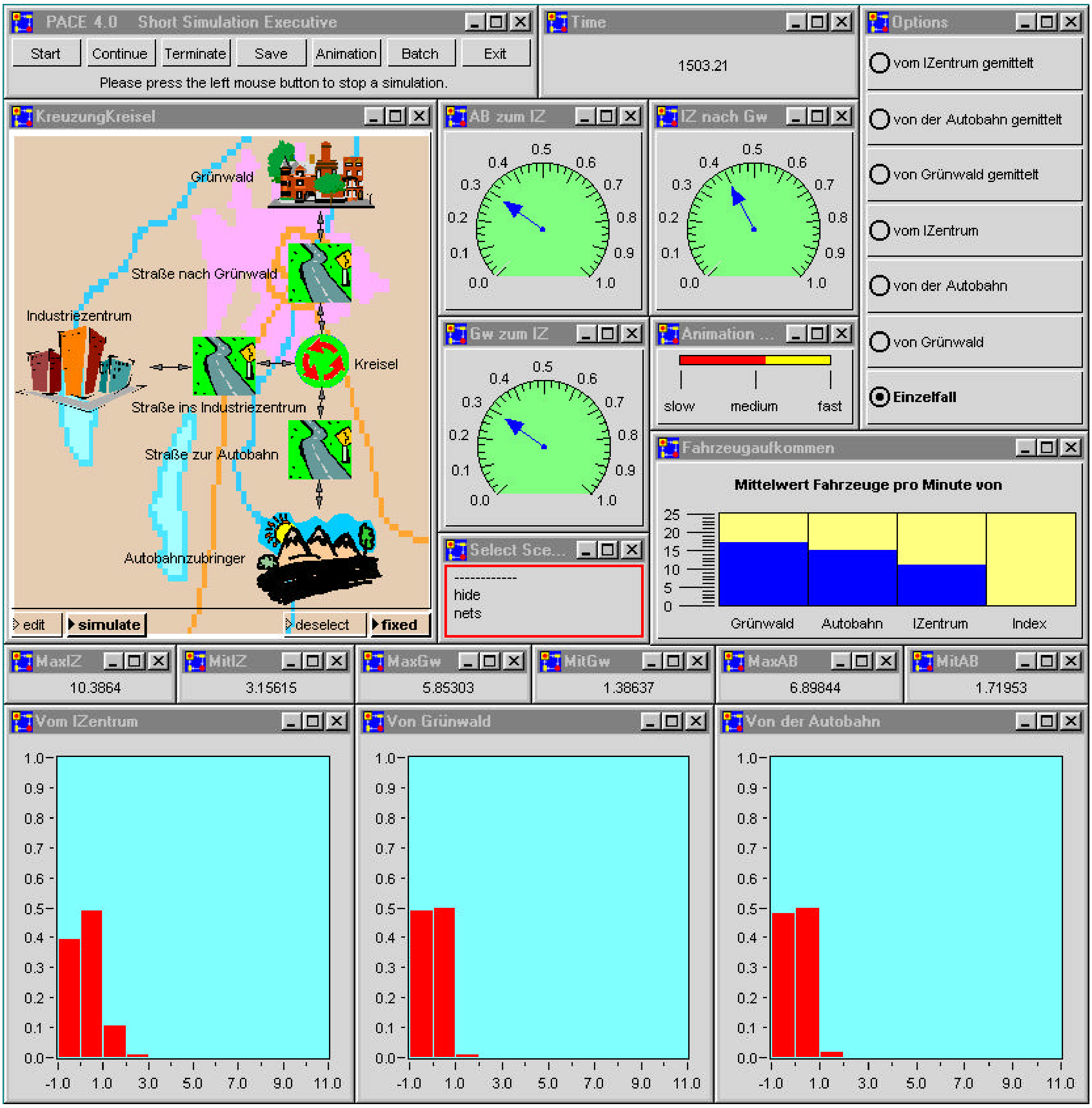
The line chart shows the number of the orders as a function of the time. One can recognize whether the arising orders can be finished resp. whether a sufficient amount of resources were provided for the processing of the incoming mail.

The workflow in a large organization can normally be divided into singles problems of a kind described in the first example which have to be harmonized with each other. Since the single organization units depend on each other it is not sufficient to model them one by one and optimize them independent of each other. Even here the general rule is valid that an optimal overall system cannot be put together necessarily from optimized parts? Also the dependencies and the feedback between the different organization units as well as influences from outside have to be taken into account (e.g. handicaps from the management and from the market). This is the most easy considered in the frame of a simulation model of the overall system.

Traffic Control

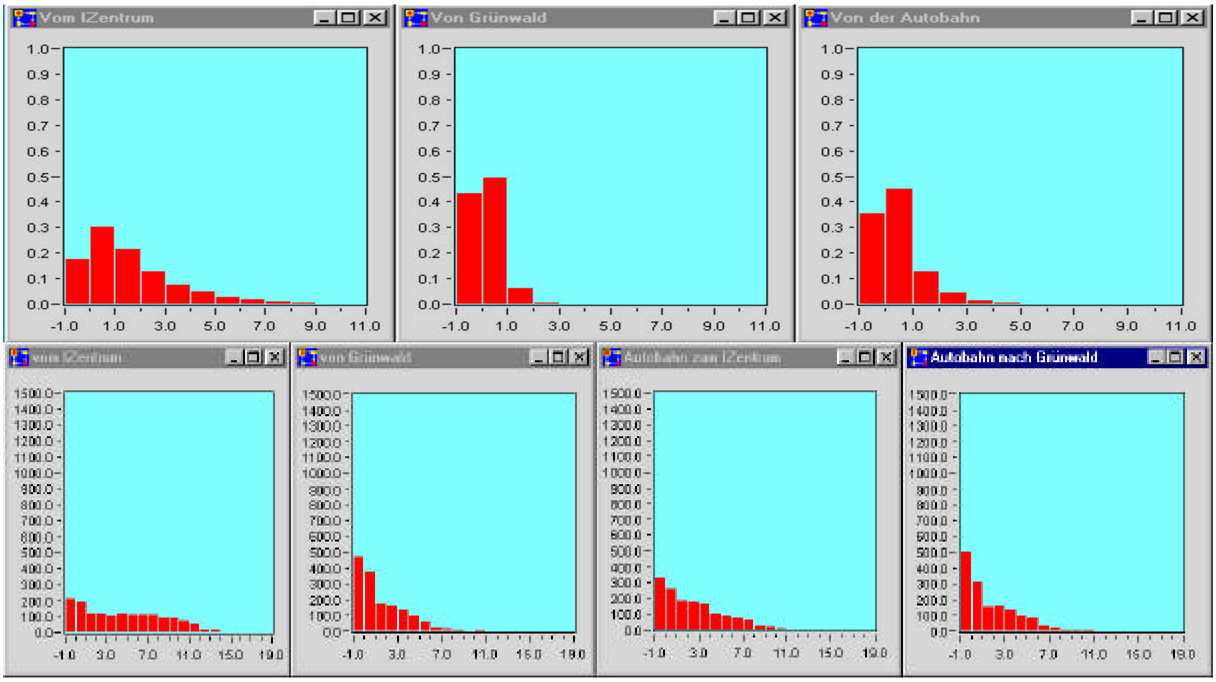
Investigating Planning Alternatives

Actions to control the traffic (e.g. the installation of traffic lights) are often very expensive and lead -as many examples show- not always to the desired lasting improvement of the traffic situation. Also here the use of simulation models can support and protect the planning. With simulation models the effectiveness of improvements can be evaluated and possible planning alternatives can be compared economically.



As an example for the use of simulation models in traffic engineering an intersection with three arms shall be looked at here. This intersection consists of a main street with heavy traffic at times and street aside which leads to an industrial center and which is used heavily in particular times of the day (in the morning and in the evening). Such an intersection is shown in the left upper picture of the figure above.

Alternatives to the priority road control are the traffic lights control and the traffic circle. For all three possibilities which differ only in the module which describes the intersection point simulation models have been developed. A part of the model surface for the traffic circle was shown above. Under the numerous tests which were done with the models here only the "worst case" provided for the models will be represented. If 25 vehicles per minute drive towards the intersection from all three directions, we obtain the following histograms for the traffic circle and the traffic lights:



The upper row of histograms shows acceptable queue lengths and a sufficient reserve for the traffic circle despite the high traffic density. The further simulation experiments with both models also show the superiority of the traffic circle for the intersection looked here over the traffic lights control. If sufficient place is available, the traffic control to be recommended is the traffic circle; blockades never appear practical or can be avoided by suitable structural provisions. A further advantage of the traffic circle is that he can be operated maintenance-free. Therefore no regular subsequent costs occur.

The earlier mentioned rule (see the section about workflow) which states that local optimizations not necessary lead to an optimal overall system also hold for the planning of traffic control systems. In case of the special intersection we had in mind, when we developed the models, we expected that the long in the industrial center queues will disappear because of the change from the priority road to the traffic circle. One can convince oneself by matter, if one drives to the intersection from the industrial center on a working day during the rush hours. But this local optimization had influence on another intersection with traffic lights near the 'Autobahn', where queues are of several hundred meters to one kilometer occur now during the rush hours. The problem was not solved but only shifted to another intersection by the lack of harmonization of the altogether four intersections concerned.

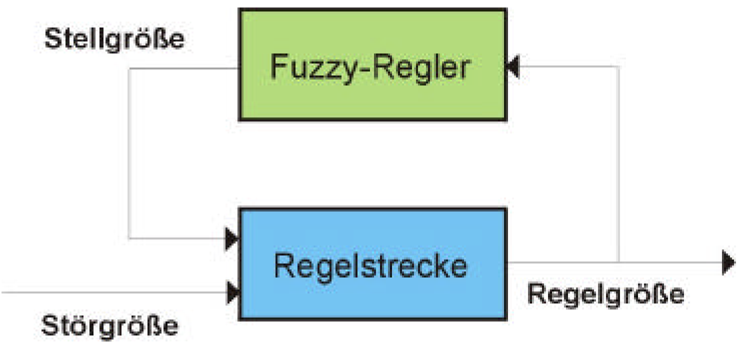
Fuzzy-Technology

Decisions and Vague Knowledge

The Fuzzy technology delivers aids for the decision-making if connections and facts are only vaguely known. It was used within the last decades with increasing success in numerous application areas (e.g. control engineering, vehicle technology, robot technology, consumption products, business administration, sample recognition). In the future Fuzzy is one of the essential design technologies of a system developer.

To be able to model and simulate systems in which fuzzy technologies are partially used the basic mechanisms for the description, the processing and the evaluation of Fuzzy sets have been implemented in ***PACE***.

As an example a simple control circle with a Sugeno controller and one linguistic variable is considered here. The controller whose behavior is represented by the curve on the overleaf work surface with gray background shall keep the controlled magnitude in the interval from -1 to +1. The disturbances which are shown in the window with yellow background color can be selected largely arbitrary, e.g. nonlinear.



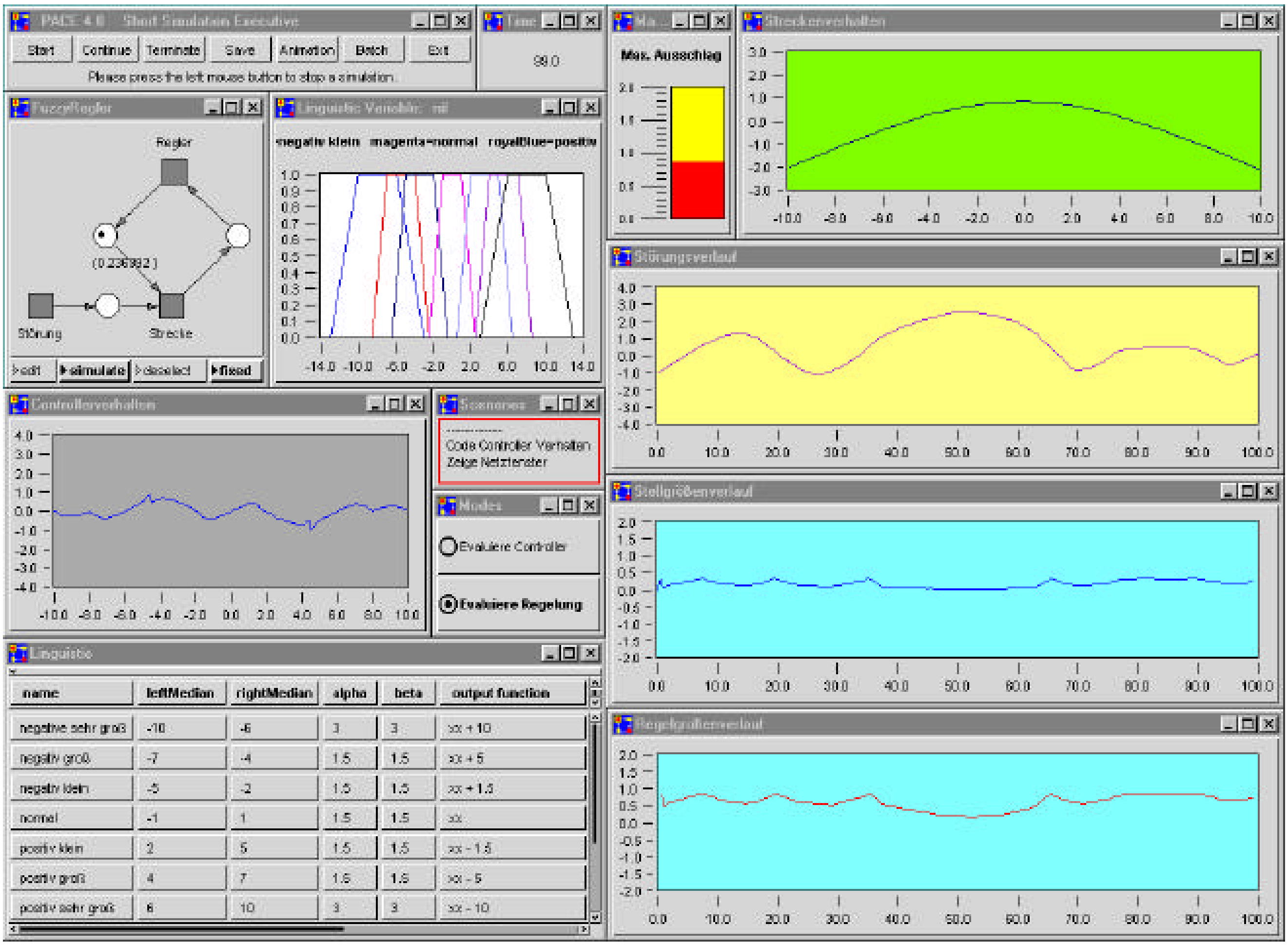
To define the Fuzzy controller one has at first to lay down the inference rules. These are fixed using the table 'Linguistic' (on the left below on the work surface).

In the present case the controller uses Fuzzy intervals in LR representation. This means that the medians and the deviations of the Fuzzy sets have to be specified. Because of using a Sugeno controller an output function has to be assigned to every rule (line).

At first to determine the tabular values the simulator has to operate in the mode 'evaluate controllers'. The window with gray background lying above the table shows the behavior in the interval of the possible input values. By insertions into the table the controller is fixed and can be tested by pressing the button 'Evaluiere Regelung'. The behavior of the control route is represented here graphically in the window with green background. It could also be described by an algorithm or a simulation model. If the desired controller behavior cannot be reached with the present Fuzzy rules, the number of rules has to be extended and/or the rule system has to be enlarged by adding further linguistic variables.

If the controller behavior has been fixed in the described way the controller is tried out using the mode 'Evaluiere Regelung'. In the window with yellow background largely arbitrary, realistic disturbing curves are entered . After the start of the simulator the behavior of the control variable and the controlled magnitude can be seen in the two windows with blue background. If the controlled magnitude cannot be kept with realistic disturbing curves in the desired interval 'normal' the inference rules have to be changed as described above. As the example points out one can already obtain quite good results with relatively simple rule systems.

The powerful methods provided by ***PACE*** for the processing of unsharp values allow among other things the efficient development of largely arbitrary Fuzzy controllers.



The processing methods for common controllers such as Mamdani and Sugeno controllers are already supported by ***PACE***.

The advantage of simulation models with integrated fuzzy controls is that one can study and optimize the controlling of flows in detail without exact knowledge about the dependencies of the flow parameters and about their influence on the magnitudes to be controlled. Even if such knowledge is available it is often so complicated that it is much easier to use Fuzzy methods. The system developer has to decide in the individual case whether he uses a classic control method for his application or a Fuzzy controller.

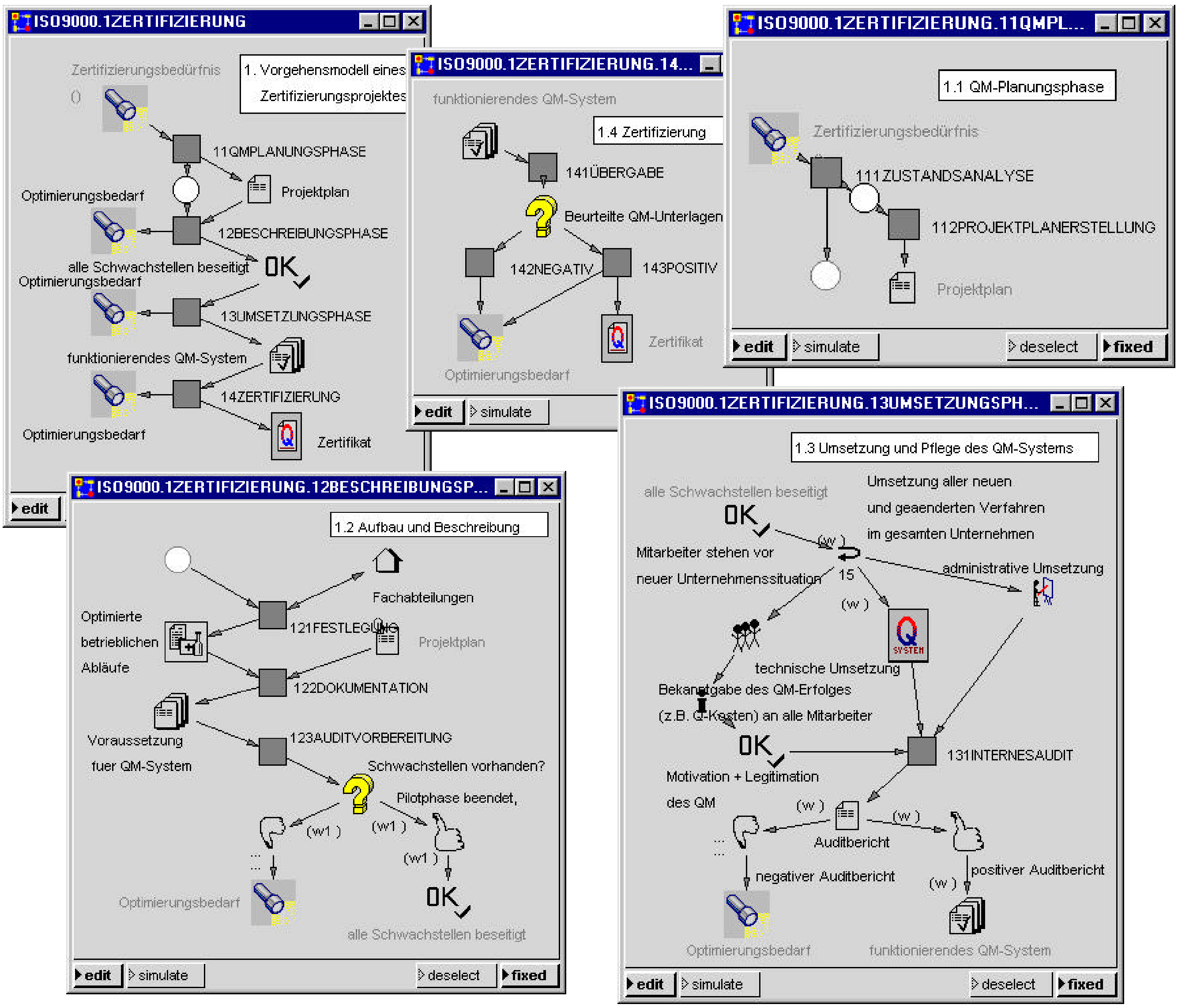
Apart from the controller development Fuzzy methods can be used advantageously during modeling if connections or data are only approximately known.

Planning and Controlling Projects

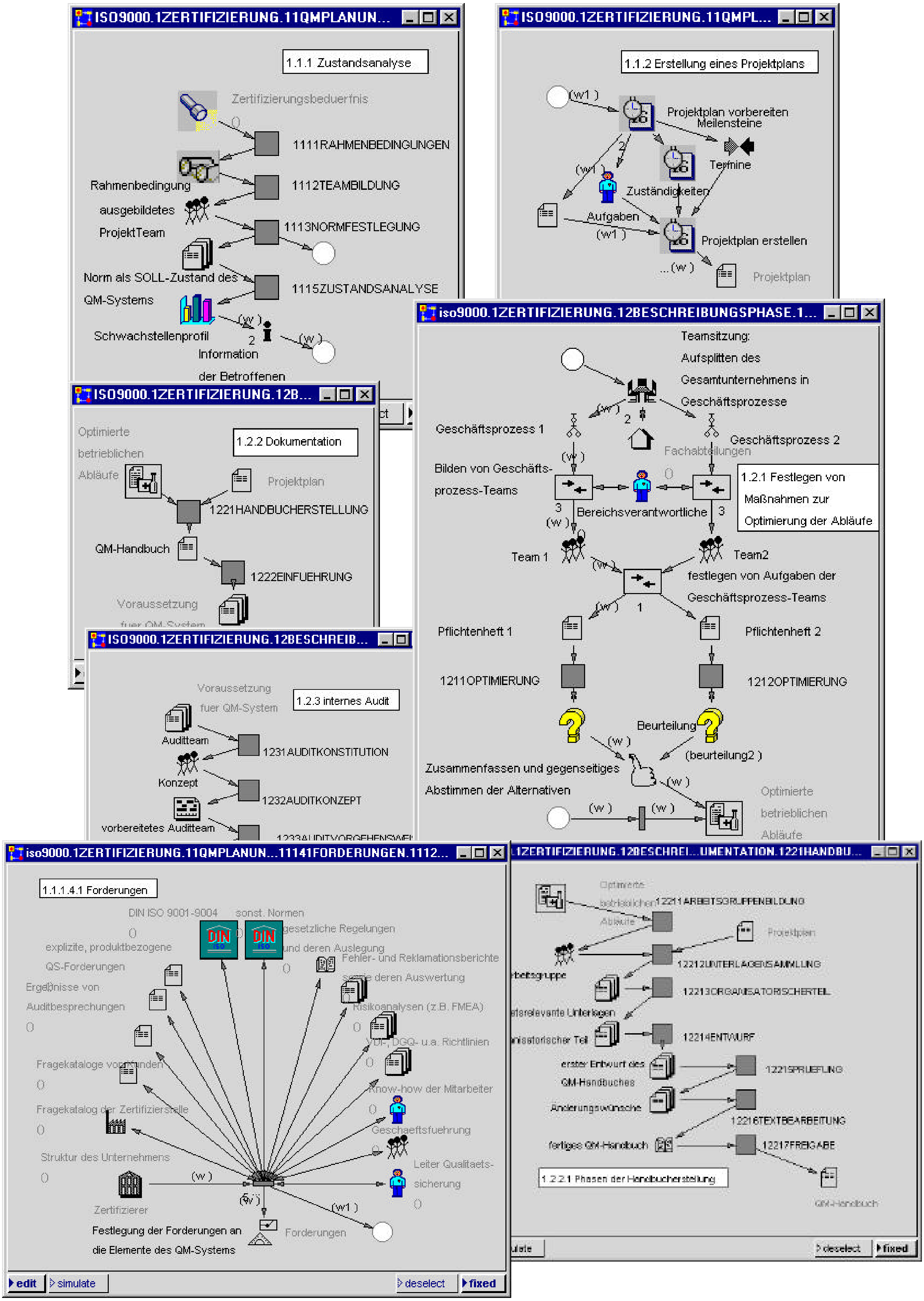
Shorter Runtime and Better Use of Resources

Modeling and Simulation are also an interesting tool for the planning of large projects and a helpful addition to the static time scheduling tools. The modeling on one hand makes possible to specify all required flows and connections up to any desired detail with the assignment of the costs, resources and the expected length of time. On the other hand also the dynamic aspects of the planning can be checked by executing the model (simulation). Because of this one can investigate wether the whole project can be carried out in the expected time and in the frame of the budgeted costs. The simulation shows among other things bottlenecks and critical paths. Looking at planning alternatives optimal time and cost solutions can be found. Project controlling deepens the knowledge about the single working steps and make possible a even more exact project planning in the future.

To get an impression of the configuration of a planning model in more detail, several modules of the topmost specification levels of an ISO 9000 certification are represented in the following figures..



PACE



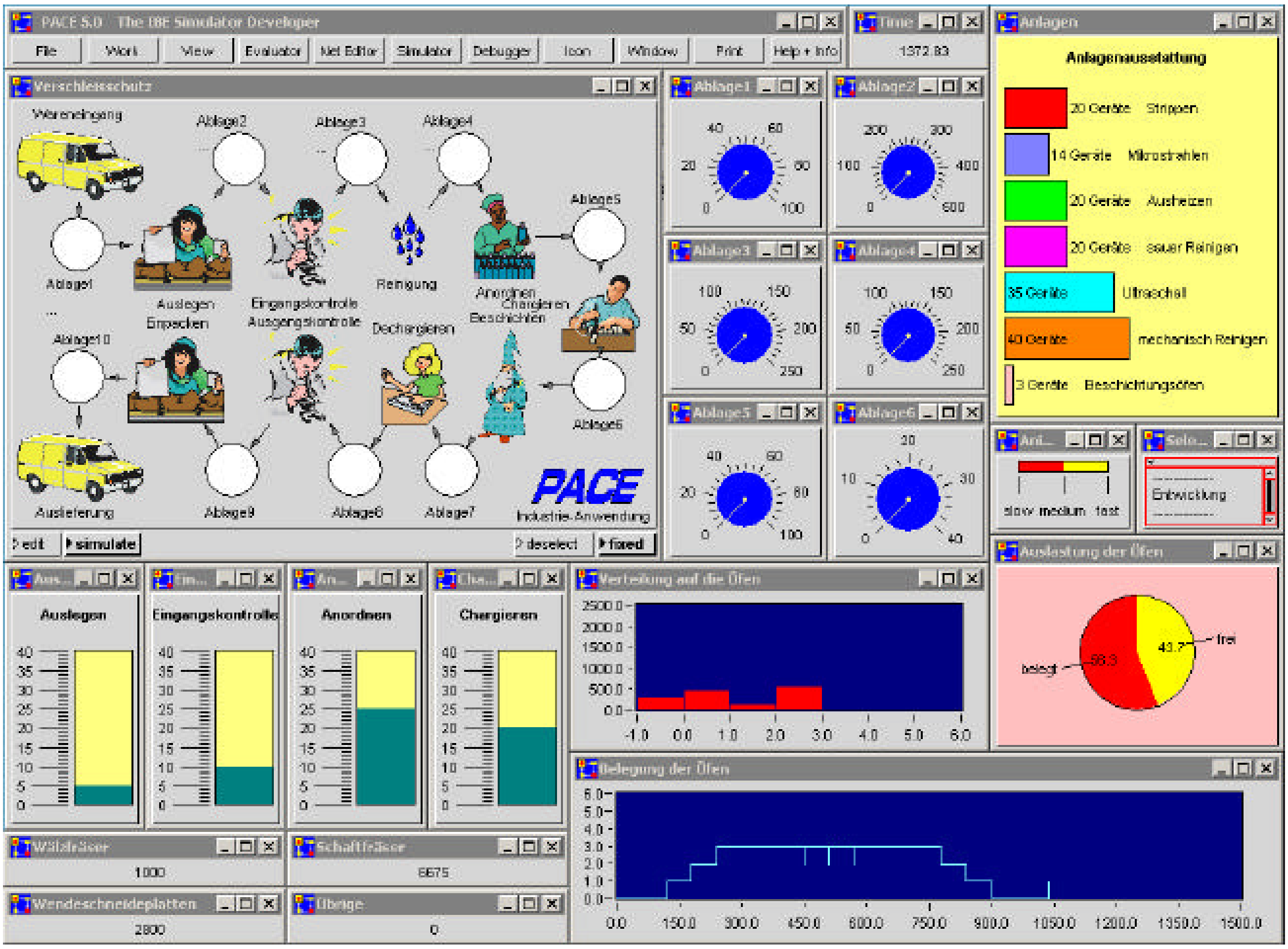
ISO9000.1ZERTIFIZIERUNG.11QMPLANUN...
1.1.1 Zustandsanalyse
Zertifizierungsbeduerfnis
1111RAHMENBEDINGUNGEN
Rahmenbedingung
1112TEAMBILDUNG
ausgebildetes
ProjektTeam
1113NORMFESTLEGUNG
Norm als SOLL-Zustand des
QM-Systems
1115ZUSTANDSANALYSE
Schwachstellenprofil
Information
der Betroffenen
ISO9000.1ZERTIFIZIERUNG.11QMPL...
1.1.2 Erstellung eines Projektplans
Projektplan vorbereiten
Meilensteine
Termine
Zuständigkeiten
Aufgaben
Projektplan erstellen
Projektplan
iso9000.1ZERTIFIZIERUNG.12BESCHREIBUNGSPHASE.1...
Teamsitzung:
Aufsplitten des
Gesamtunternehmens in
Geschäftsprozesse
Geschäftsprozess 1
Geschäftsprozess 2
Fachabteilungen
Bilden von Geschäfts-
prozess-Teams
1.2.1 Festlegen von
Maßnahmen zur
Optimierung der Abläufe
Bereichsverantwortliche
Team 1
Team2
festlegen von Aufgaben der
Geschäftsprozess-Teams
Pflichtenheft 1
Pflichtenheft 2
1211OPTIMIERUNG
1212OPTIMIERUNG
Beurteilung
(beurteilung2)
Zusammenfassen und gegenseitiges
Abstimmen der Alternativen
Optimierte
betrieblichen
Abläufe
ISO9000.1ZERTIFIZIERUNG.12B...
Optimierte
betrieblichen
Abläufe
1.2.2 Dokumentation
Projektplan
1221HANDBUCHERSTELLUNG
QM-Handbuch
1222EINFUEHRUNG
Voraussetzung
ISO9000.1ZERTIFIZIERUNG.12BESCHREIB...
Voraussetzung
fuer QM-System
1.2.3 internes Audit
Auditteam
1231AUDITKONSTITUTION
Konzept
1232AUDITKONZEPT
vorbereitetes Auditteam
iso9000.1ZERTIFIZIERUNG.11QMPLANUN...11141FORDERUNGEN.1112...
1.1.1.4.1 Forderungen
DIN ISO 9001-9004
sonst. Normen
gesetzliche Regelungen
und deren Auslegung
explizite, produktbezogene
QS-Forderungen
Fehler- und Reklamationsberichte
sowie deren Auswertung
Ergebnisse von
Auditbesprechungen
Risikoanalysen (z.B. FMEA)
VDI-, DGQ- u.a. Richtlinien
Fragekataloge von Kunden
Know-how der Mitarbeiter
Fragekatalog der Zertifizierstelle
Geschaeftsfuehrung
Struktur des Unternehmens
Leiter Qualitaets-
sicherung
Zertifizierer
Festlegung der Forderungen an
die Elemente des QM-Systems
Forderungen
edit
simulate
deselect
fixed
1ZERTIFIZIERUNG.12BESCHREI...UMENTATION.1221HANDBU...
12211ARBEITSGRUPPENBILDUNG
Projektplan
12212UNTERLAGENSAMMLUNG
12213ORGANISATORISCHERTEIL
12214ENTWURF
erster Entwurf des
QM-Handbuches
12215PRUEFUNG
Änderungswünsche
12216TEXTBEARBEITUNG
fertiges QM-Handbuch
12217FREIGABE
1.2.2.1 Phasen der Handbucherstellung
QM-Handbuch
deselect
fixed

Wear Out Protection

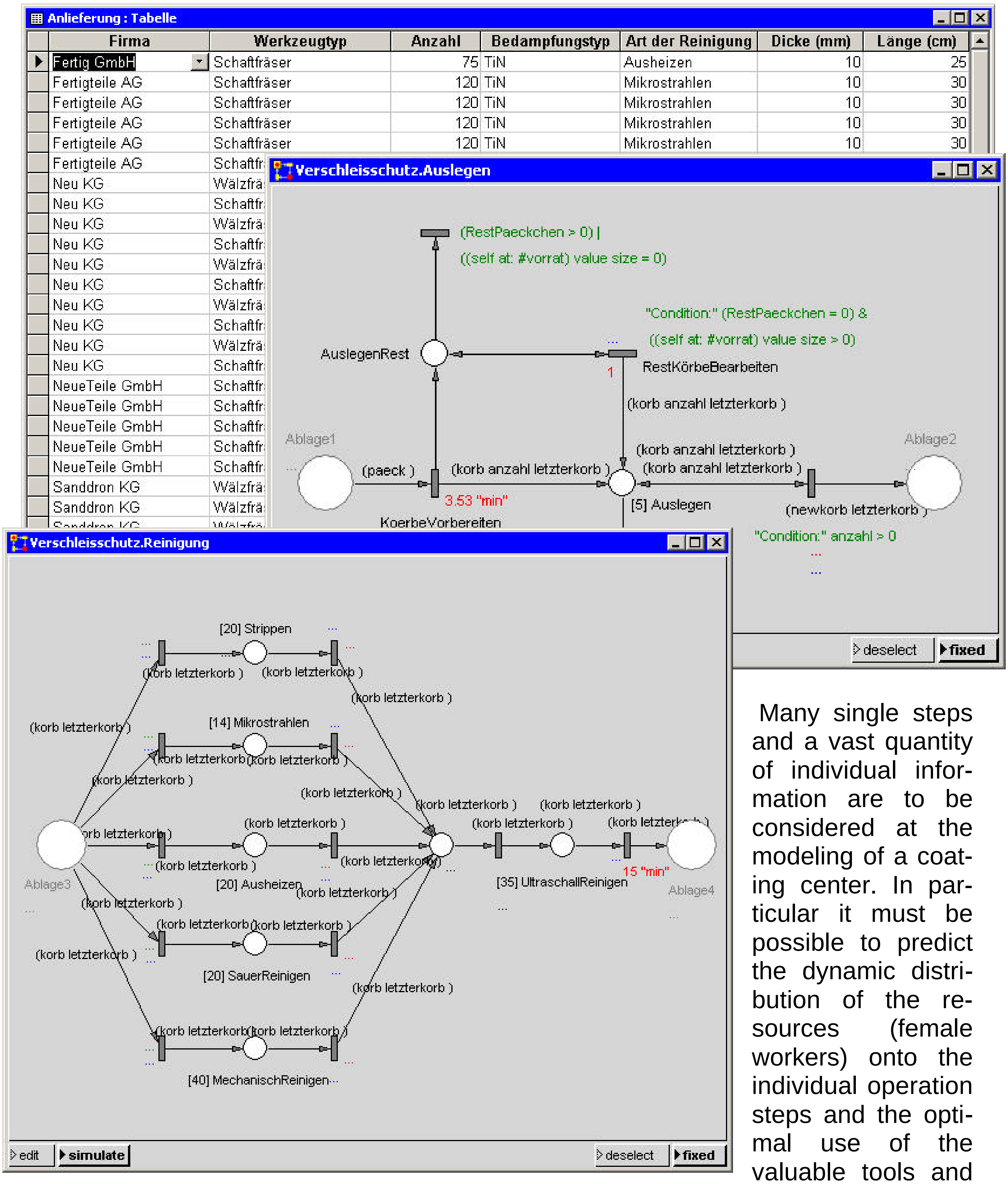
Step-by-Step Processing of Workpieces

In industrial manufacturing processes which normally contain many parallel activities simulation systems can be used especially effectively and can lead there to considerable cost savings. They can be used here during the planning and mechanical design as well as for the use planning of production plants. In many cases the situation forbids the direct trying out by modification and adaptation of the hardware. Therefore if one wants to achieve a deeper understanding of the connections and wants to develop optimal procedural strategies, the use of sufficiently precise simulation models is necessary.

The present model of a coating center stands in for all kinds of linear production processes with sequences of consecutive single steps (chains) and serves as a model for similar manufacturing processes.



A coating center is a plant, in which parts being subject to a strong wear like gear wheels, drills, cutter heads etc. for the purpose of prolongation of its life time (wear protection) are reworked in special stoves with a metallic atmosphere by evaporation of thin coatings. The parts are received in parcels by mail, by express services or by Pick-Up services and are prepared for coating in several personal intensive preparation steps. After the coating the coated parts are delivered again by mail, express service or by special delivering to the customer.



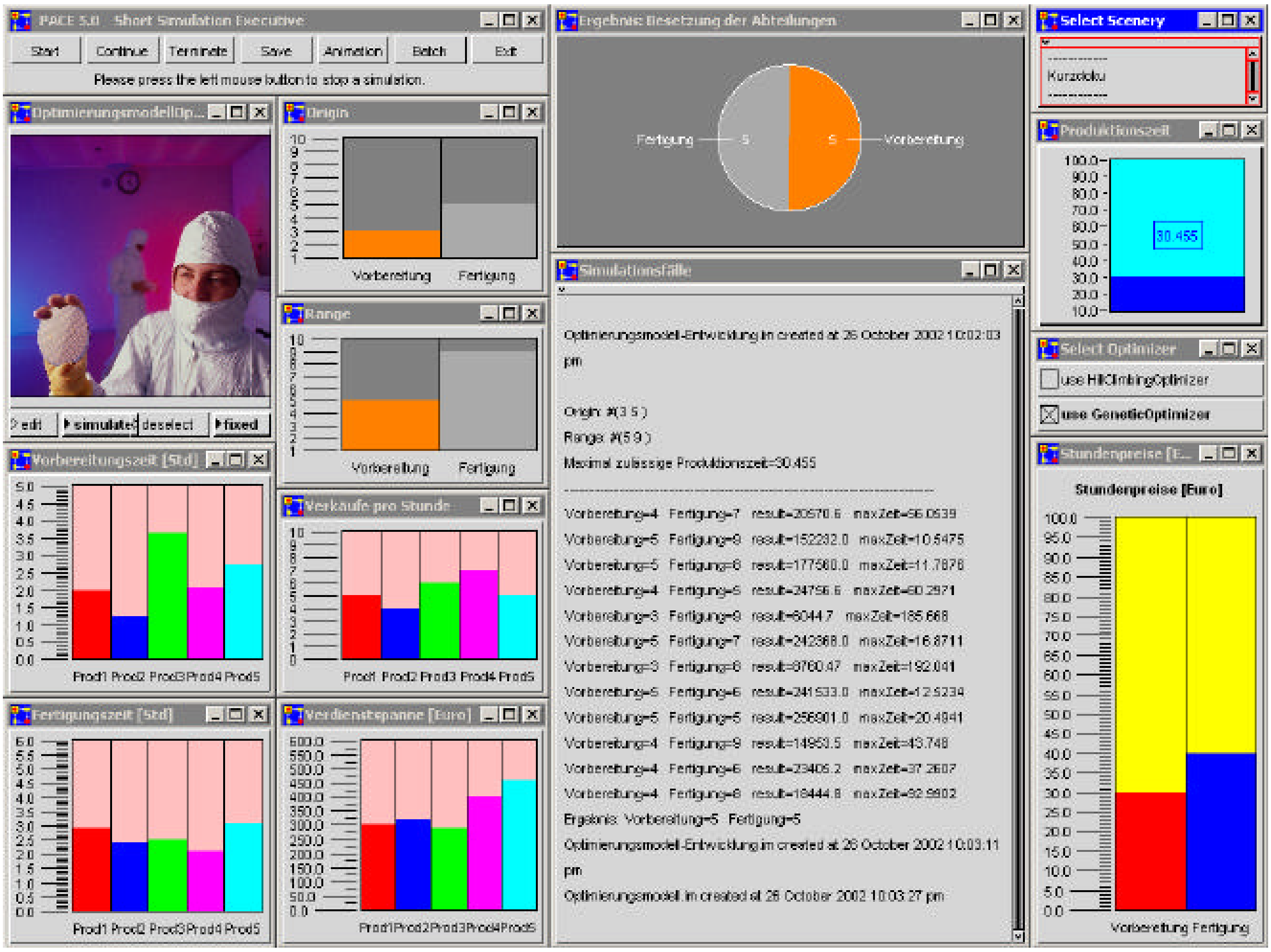
Many single steps and a vast quantity of individual information are to be considered at the modeling of a coating center. In particular it must be possible to predict the dynamic distribution of the resources (female workers) onto the individual operation steps and the optimal use of the valuable tools and stoves. The situation is characterized by state-of-the-art technology of the automatable subprocesses at simultaneously high personnel expenditure during most operation steps.

In order to be able to use the model in the daily manufacturing processes additional specific customer-oriented features must be installed . E.g. the model must deliver information about the completion dates of orders, a today indispensable service, and must offer possibilities to prefer "good" customers.

Optimizing a Production

Profit-Optimizing Manufacturing

Optimization procedures are of enormous economical importance. Besides of many other commercial and technical possible applications they can be applied also for the optimal design and/or setting of manufacturing plants. The following example shows a simulation model in which one of the optimization procedures available in PACE is used for the optimization of net functions to determine the profit-optimal occupation of a manufacturing plant with skilled workers.



A simple manufacturing which consists of two work sections, namely a production planning and a production is considered. 5 products are manufactured that are designated with Prod1 to Prod5. Their characteristic parameters are tuned in the following four multiple bars Gauges:

'Vorbereitungszeit' ('Preparation time'):
Time in hours that are necessary for the preparation of the manufacturing.

'Fertigungszeit' ('Manufacturing time'):
Time in hours that is needed for the manufacturing.

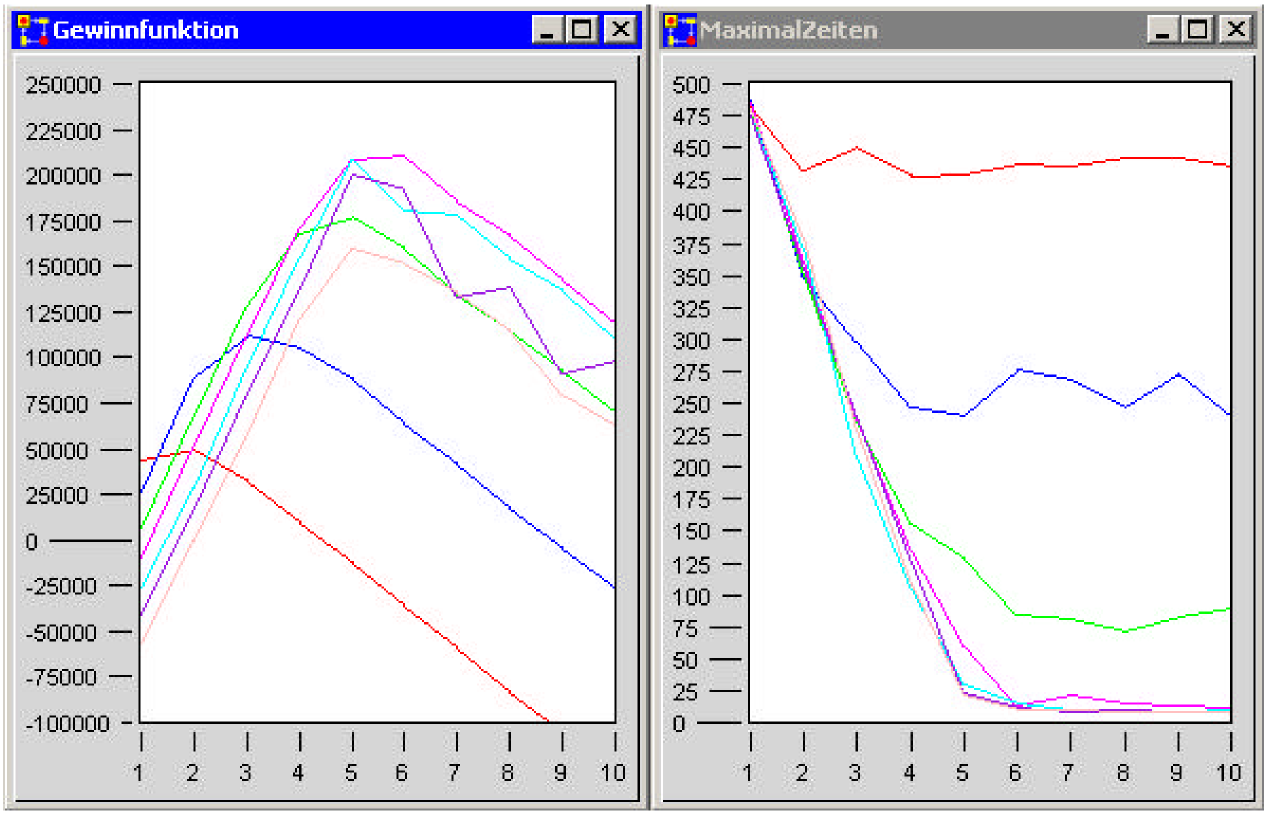
'Verkäufe pro Stunde' ('Sales per hour'):
Mean number of sales per hour.

'Verdienstspanne' ('profit margin'):
Sale price. Costs of materials without processing costs (for example in Euro).

With the Bar Gauge 'Stundenpreise' ('hourly prices') the costs per hour for the skilled workers in the production preparation and in the manufacturing can be set. The maximum system production time from the entry of an order up to the delivery of the product can be restricted in the Bar Gauge 'Produktionszeit' (' production time').

Starting with the value pair for the occupation of the two production sections with skilled workers from the Bar Gauge 'Anfangswerte' ('initial values') the model calculates the profits arising in a sufficiently large time (600 hours) for further value pairs considering the costs for the skilled workers, until the occupation of the production sections with optimal profit is found. A Hill-Climbing-Optimizer which was connected to the net takes over the selection of the further value pairs. Further costs, for example the financing costs for the warehouse, were not considered in the example.

Because only two parameters occur the model can be solved also easily with graphical means. The following two illustrations show the results of the individual simulation runs as curves.



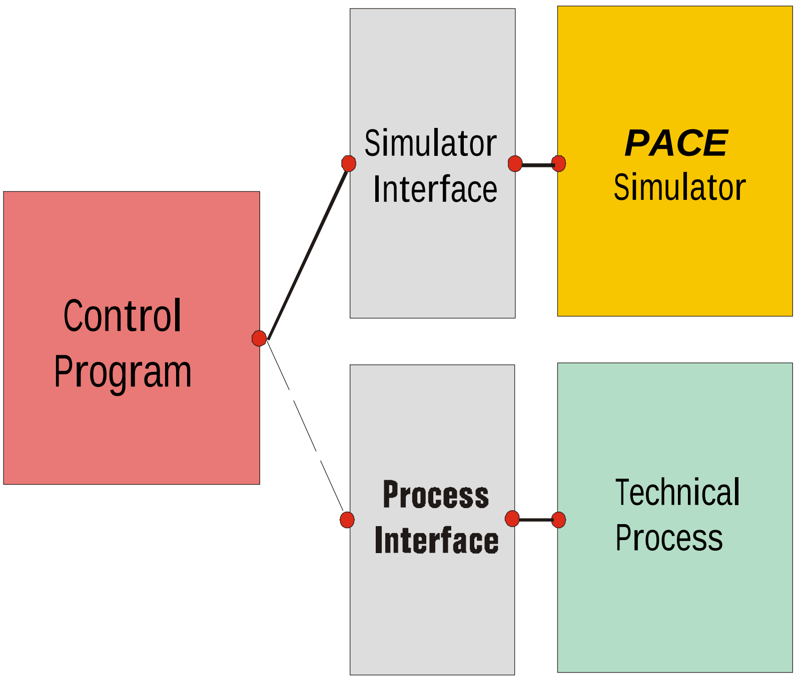
The left graphics show as the optimum 4 skilled workers in the production planning division (Color Magenta has the index 4) and 6 skilled workers in the manufacturing. This is the same result as is found with the optimizer. The right window shows the maximum task operation time found during the simulation run. The use of the computed optimum clearly does not lead to an unacceptable long order processing.

Program Test and Preintegration

Test and Integration Without Hardware

In most cases the construction of automation systems could be done in shorter time and with lower cost, if the development and the test of the software could be carried out at the same time as the development of the hardware. The time consuming and expensive integration effort after completion of the hardware could be reduced by that effort. Very often the hardware is developed but so expensive or not available that a simulator during the program development and for the maintenance of the programs is recommended. Such an approach would for instance cheapen the development of factory plants, assembly lines or bus systems of airplanes enormously. The simulator for the food packing described on page 8 to 9 was developed because is was not permitted by cost reasons to stop the expensive food packing machine temporarily for testing purposes.

The efficient handleability and the universal usability of PACE make simulator developments possible for complex discrete applications in an adequate time. The savings on the system development and system integration normally exceed the development effort of a simulator by a multiple. If PACE is used as the specification system the simulator can be developed in such a way that he can be used to verify and optimize the planned flows as well as for the later program tests.



The figure on the left shows the basic interaction between the simulator and the automation program. Program and simulator communicate via a simulator interface which is made in C/C++ and attached at run time as a DLL (Dynamic Link Library). The interface between the simulator and the automation program imitates the interface between the technical process and the automation program, avoiding a difference between the two interfaces.

After the end of the program development instead of the simulator interface the process interface is linked to the automation program. By this the largely tested automation program can be used for further integration work with the hardware.

The described procedure also offers advantages with respect to further developments and the maintenance of an automation system. Most parts of proposed software changes and improvements can be developed and tested economically without the hardware.