Simulation Scheduling in Food Industry Application

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Abstract

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Nowadays manufacturers are facing rapid and fundamental changes in the ways business is done. Producers are looking for simulation systems increasing throughput and profit, reducing cycle time, improving due-date performance, reducing WIP, providing plant-wide synchronization, etc. Planning and scheduling of coffee production is important for the manufacturer to synchronize production capacity and material inputs to meet the delivery date promised to the customer. A simulation model of coffee production was compiled. It includes roasting, grinding and packaging processes. Using this model the basic features of the coffee production system are obtained. An optimization module of the simulation SW is used for improving the current structure of the production system. Gantt charts and reports are applied for scheduling. Capacity planning problems related to coffee production are discussed.

Keywords: simulation; scheduling; coffee production

BERARD & CHARLES (2000) and SCHILLING & PANTELIDES (1997) deal with a general approach to multipurpose batch plants planning. The methodology consists of two steps. It commences with the development of a Discrete-Event Simulation (DES) model to describe the all over dynamic behavior including food production bounds. More precisely, the different stages applied to the design of an object-oriented DES are presented. Then the global simulation tool is coupled with a stochastic optimization procedure to solve efficiently the production planning problem of a highly combinatorial nature.

LOZA-GARAY & FLORES (2000) and POSNER & HIBBS (1997) focus on the flow characteristics of the product through the flour mill at the total flow rate. This is considered following a flow with normal distribution variations. The model describes the flow of total matter in a stochastic (probabilistic) analysis. The mass flow is linked directly to wheat attributes and to the specific process conditions of the pilot mill.

Production planning in fish processing factories is marred by uncertainty in both the demand for final goods and the supply of raw fish. The SLAM II discrete event simulation model is used to study the potential of multisupplier sourcing as a strategy for minimizing stock related costs under variable demand and variable supply yield (HARVEY & KWEKU-MUATA 2000).

MINEGISHI and THIEL (2000) discuss the comprehension of the industrial management behavior of food industries, which have short or long manufacturing processes and short or long sell-by date products. Three generic models have been implemented according to the duration of the manufacturing processes and the sell-by date of the food products. Management recommendations are suggested without changing the basis of the operating system structure.

There are few research papers dealing with scheduling problems in food industries (KEDAD *et al*. 1994, 1996), or with food manufacturing resources planning MRP II combined with a Just-In-Time system (CONCEICAO 1996).

SIMEONOV (1999) and SIMEONOV & SIMEONOVOVÁ (1996, 1999) discuss capabilities of APS systems for Planning and Scheduling of production systems.

PEGDEN (2000) focus on changes in simulation technology and discuss the impact of these changes on the role and importance of simulation modeling in the future design and operation of complex systems. Simulation provides a simple yet flexible method for generating a finite capacity schedule for a factory floor.

ESPRIT projects are top research projects supported by EU (http://www.cordis.lu). The objectives of the project "Computer Integrated Manufacturing System for the Meat Processing Industry" were to develop a generic CIM concept and additional methods that will enable an effective implementation of CIM systems in specific factories, focusing especially on dynamic production planning, scheduling and control/monitoring at factory floor level, coordination of cells/production of lines, control and monitoring of production processes, links to (typically existing) administrative and order long term planning systems.

Description of Coffee Production

The material flow in the process of coffee production is illustrated in Fig. 1. One roasting machine is available for roasting. Its per hour output and production load are known to be identical for all types of coffee. The transportation of ground coffee to the silos is ensured by a pipeline system connecting the roasting machines with the respective silos. The coffee transfer from the roasting machine to the silo is controlled from the production control center.

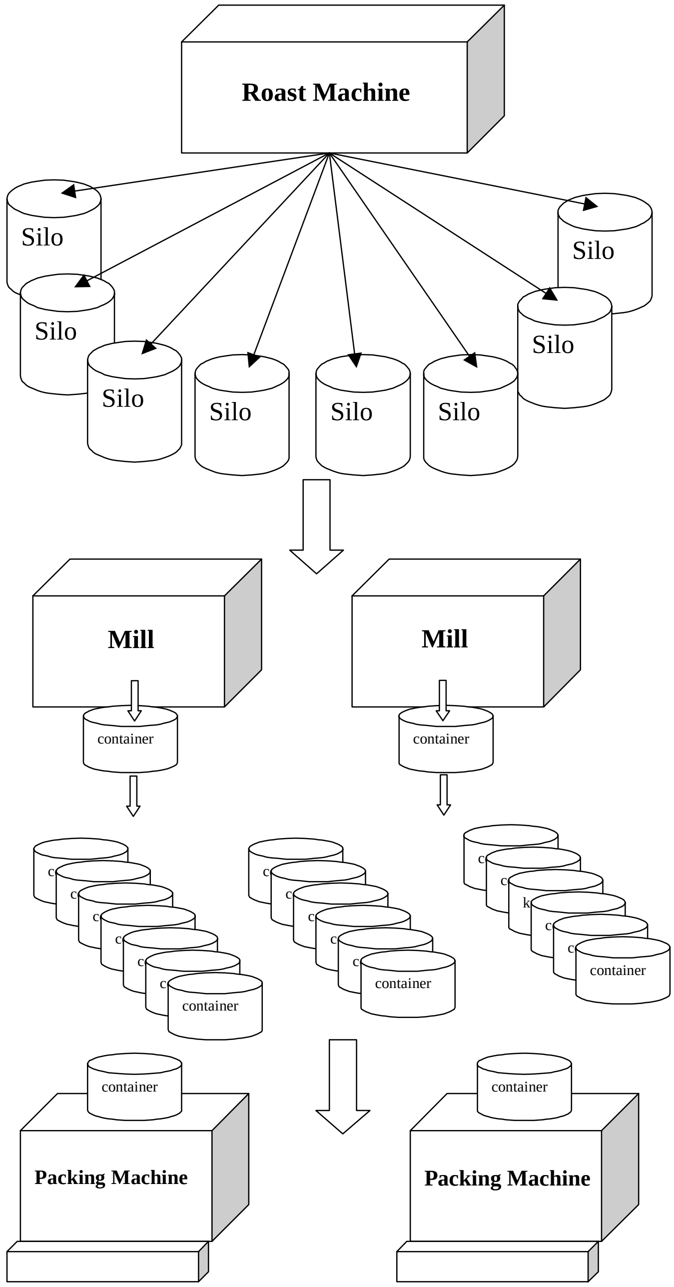

Fig. 1. A material flow in the process of coffee production

Based on the technology of coffee production, coffee is degassed immediately after roasting. For that purpose it is stored in eight degassing silos of known maximum capacity. Only one type of coffee can be stored in a silo. The minimum duration of degassing after roasting is specified by the technology and must be strictly adhered to. Apart from this, it is absolutely necessary to observe the maximum period of keeping coffee in the silo. These conditions must be implemented into the simulation model, where various rules are created to control the material flow. Based on the assumption that there are three kinds of coffee processed, the table illustrating the minimum and maximum storage time in the silos can be as follows:

Type of coffee	Time (h)	
	min.	max.
Coffee type A	8	50
Coffee type B	10	50
Coffee type C	12	50

Coffee is transported from the silos to the mills by a tube system controlled by the dispatcher.

Coffee is ground in two mills of known per hour output. Ground coffee is transported via the pipeline system to the containers, where additional degassing is carried out. The maximum capacity of each container is known and cannot be exceeded. As shown by the actual process and by the simulation model, the containers are considered to be the bottleneck of the production chain. The duration of degassing after grinding is again specified by the technology. For the three types of coffee it is as follows:

Type of coffee	Time (h)	
	min.	max.
Coffee type A	2.5	14.5
Coffee type B	20	30
Coffee type C	6	17

After degassing the containers are transported to three packing machines, where coffee is poured into the loader of the packing machine. The per hour output of the packing machine depends on the type of coffee. Some products require a certain packing machine, others can be packed using any of the packing machines.

Capacity Planning and Scheduling Problem

Bottleneck points occur in the above-mentioned system of coffee production. They represent a limiting factor for the system productivity and a danger of failure of production technology. The occurrence of these bottlenecks depends on the current status of unfinished production as well as on mix of production orders (orders entering the production). Without a simulation tool for production scheduling the identification of bottlenecks can be difficult. Based on the previous experience, it is known that the containers filled up with coffee need a longer period for degassing. Due to this the mills (upstream workplace) as well as the packing machines (downstream workplace) must break work.

As it is difficult to predict the occurrence of a bottleneck in time, the production cannot be scheduled satisfactorily. The scheduling manager uses a backward scheduling starting from the time when the order is due to be completed. With respect to wide production assortment, production scheduling is very difficult if not impossible. The capacity of the containers reaches its limit and consequently grinding and packing are interrupted. Packing machines finalizing the production cannot be utilized at the maximum and the efficiency of the system decreases. A production scheduling tool is therefore needed to predict bottleneck points and generate a realizable production schedule to ensure maximum production capacity.

Simulation Model of Coffee Production

The purpose of the simulation model for coffee production is to provide an efficient system for production planning and scheduling, which also enables the continuous improvement of the production process. This consists in the continuous efforts of the company management to improve production logistics processes so that marketing, production and other aims of the company can be achieved. These efforts can involve the implementation of new control rules into the production process, the optimization of machinery, better planning and scheduling, etc. All the situations mentioned require a tool that will make it possible for the manager to verify the changes and ideas in advance before their application. At the same time a tool is needed for an everyday operational production control (including production scheduling). Such a versatile tool is planning and scheduling based on a simulation model. The versatility of this tool is achieved due to the fact that it can be easily modified (SIMEONOV *et al.* 1996).

The simulation model of coffee production has been created by means of FACTOR/AIM (www.compsim.cz). The model contains packing machines, mills, roasting machines and silos represented by the modeling element Resource/Machine. Altogether several resources/machines with the overall capacity equal to 1 are used because it is expected that one load (i.e. one production dose) is processed in one resource/machine. As the simulation model deals with the problems of production scheduling, it does not involve elements of probability, for example breakdowns of machines and equipment, differences in processing and set up time, etc. If this simulation model is used for a longer period simulation to determine the characteristics of production system (e.g. its potential capacity), it is easily possible to add those elements that will convert the deterministic model into a probability model. The number of shifts is defined for each machine. For most machines two shifts are considered (planned). Resources are grouped in dependence on the type of products. For instance, two groups can be defined for the packing process: one group of packing machines producing 60 to 100 g packages and the other group producing 60 to 250 g packages. Each machine can be integrated into different groups.

As the simulation model should be preferably used for production planning, its major role is to identify fluctuations in demand. This demand changes in a dynamic way with regard to both the types of coffee and the size of packages. The changing demand is reflected in production orders that are scheduled by means of this simulation model. The manager then only puts production orders to be processed into the corresponding interfaces.

The capacity limits for the number of mobile containers are presented as the capacity of buffers of the type Pool/WIP.

For the convenience of the user, all time values (process, setup or transportation times) are presented in the tables in the MS Access or MS Excel format. The user can modify the tables without entering the simulation model. All the products, e. g. type of coffee A, B, C… are defined in the model. The technology of coffee production is included in the so-called processing plan, which contains the respective processing steps such as roasting, degassing, grinding, etc.

The rules of production system control are also included in the model. Production orders are defined through the following data:

Type of product – e.g. Coffee type A

Required amount – e.g. 3440 kg

Priority of the order – e.g. 3

Deadline of the order – e.g. 6 February, 2001

The user of the simulation model can modify the model to create various alternatives for solving problems. The alternatives can be compared by means of various graphical and textual inputs offered by the system.

Outputs of Simulation Model for Production Scheduling

The users of this simulation model can easily modify it and create various alternatives for the solution of their problems. It is also possible to compare these alternatives by means of various graphical and textual outputs that are provided by the simulation system as well as by other SW system.

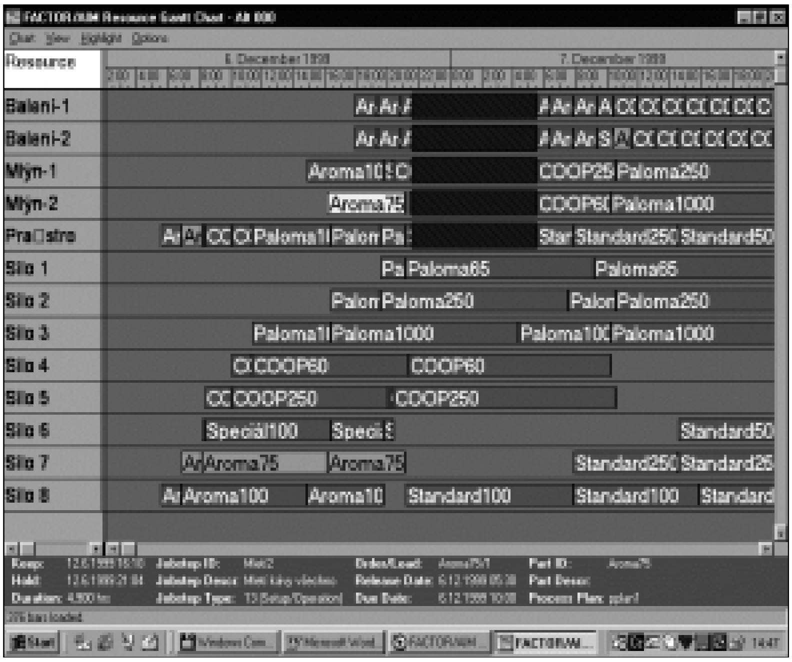

Fig. 2. Gantt charts for all machines

For production scheduling the simulation system generates Gantt charts, both from the point of view of resources (machines and equipment) and from the point of view of loads (Load Charts). Gantt charts illustrate the time sequence of the events arising in the simulation system in a graphic form. In Fig. 2 the Gantt charts for all machines and equipment of the production system is illustrated.

For example, it is possible to read from this chart that Silo 7 is connected to Mill 2, which grinds the first load of the given order. This operation lasts from 4:10 p.m. to 9:04 p.m.

The Gantt charts in Fig. 3 describes a part of the weekly schedule for the coffee production. A course of the individual production loads can be followed in detail. It

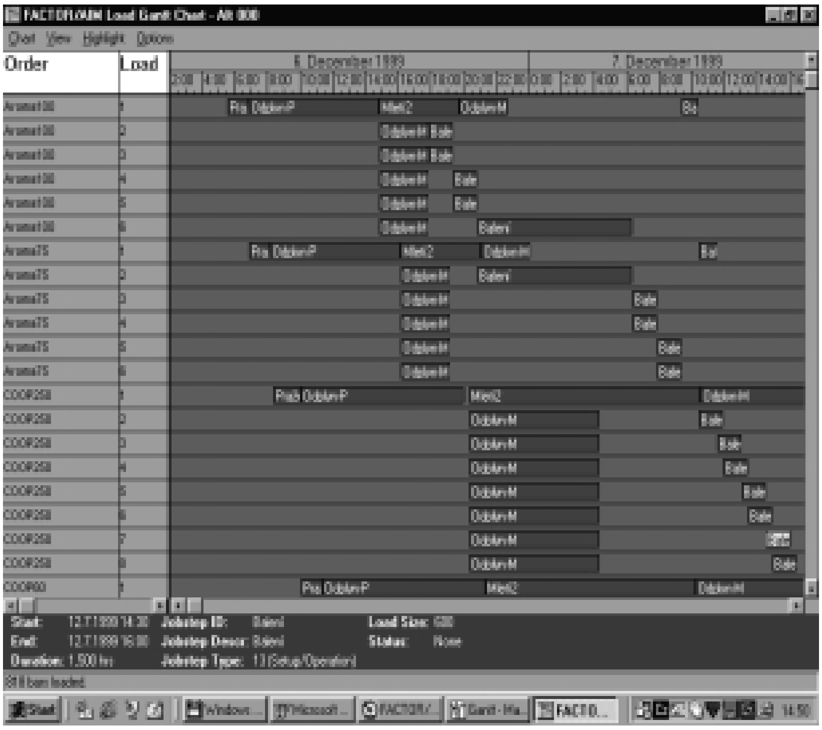

Fig. 3. Week schedule for the coffee production

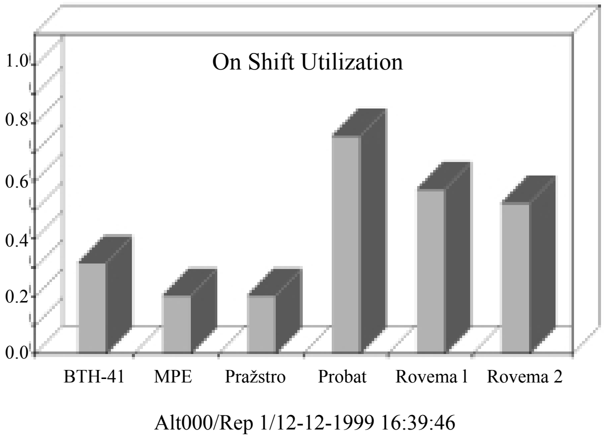

Fig. 4. Identification of bottlenecks

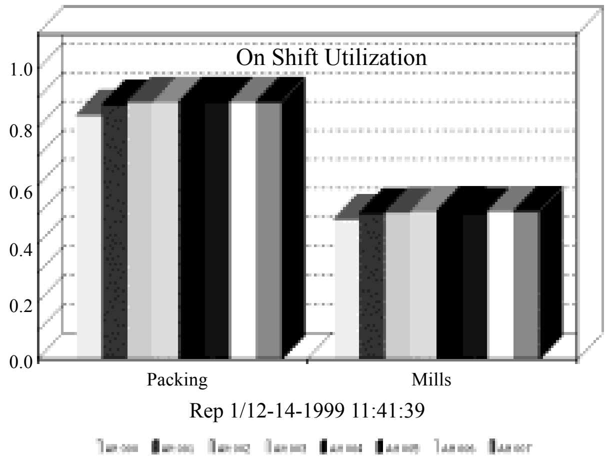

Fig. 5. On shift utilisation vs the number of containers

is obvious that with all the production loads, minimum times of degassing are maintained.

One of the problems that the manager can identify from the Gantt charts is the break of work of the packing machines due to the lack of empty containers. The occurrence of the bottleneck caused by containers can be revealed, among others, from the graph showing the state of the packing machines versus time, as well as from the graph illustrating the fluctuation in the number of empty containers.

Further analyses have been carried out using a variety of outputs offered by the simulation system. If the relevant output lacks a suitable format, then the user easily generates the required output, as the results of the simulation course are stored in the database.

The simulation model supports the application of the approach known as TOC/OPT (GOLDRATT ELIYAHU 1992). It identifies bottlenecks of the production process and enables their analysis and correct scheduling (Fig. 4).

Simplan – Optimal

It is necessary for the user (manager, planner-scheduler) of the simulation model of coffee production to perform a number of simulation experiments with the aim to find the most suitable and, under given conditions, the optimum solution. For instance, if it is found during the production scheduling for the following week that the bottleneck (lack of empty containers) interrupts the work of packing machines, then it is possible to modify the input parameters to minimize this break. For the scheduling these parameters are as follows: input time of production orders, their priority, production loads controlling rules, etc. If the simulation model is used to improve the production process, the user performs simulation experiments and observes how the production parameters are being modified. For instance, if the user decides to increase the number of containers, then he/she can also find out how many containers to add, to what extent this is profitable in respect to the cost of newly purchased containers, where a bottleneck can occur, etc. Fig. 5 shows the dependence between On Shift Utilization of packing machines and mills and the number of containers. The number of containers varies from 40 to 75 with the increments of 5. If the On Shift Utilization of these machines were the only criterion, then it can be assumed that the number of containers exceeding 50 does not result in further increase of On Shift Utilization.

Optimisation tasks require a large number of simulation experiments as well as their assessment. For this purpose the optimisation system SIMPLAN-Optimal was developed (SIMEONOV & SIMEONOVOVÁ 2000). This system enables to change the input parameters of the optimisation, to define standard criterion (objective) functions and to assess the results. The following optimisation methods have been applied in this system (ČERMÁK 1998; ZÍTEK 1990):

– all simulation possibilities (all combinations of chosen variables and their values)
– VFSR (Very Fast Simulated Reannealing)
– Simulated Annealing
– Genetics Algorithm
– Modified Box's Method of Complexes
– Method of Gold Cutting (only for vehicle speed).

CONCLUSION

Integration of the simulation system into the plant IS: An efficient use of the simulation model within the process of production planning and scheduling can be reached only in case of its integration into the managerial structure of the production plant. If there is an information system (IS) in the company, the simulation subsystem can develop an efficient planning module. Integration of simulation (planning) model is implemented at the level of the database of both these systems. An interface enabling its connection with the plant IS has already been elaborated for the described simulation model. This interface can be modified depending on the type of IS and its database. Recent experience with the integration of the simulation system into the plant IS indicates that the transfer of data runs without any problems. However, it should be emphasised that the "classical" IS (i.e. with the planning module of MRP type) does not (and even cannot) include all data that are required for simulation planning (e.g. advanced rules of control). For that reason it can be said that this simulation module not only enables a qualitatively new approach to the solution of planning problems, but also efficiently supports the overall management approach to the continuous improvement of the production process.

If the company lacks a uniform integrated IS, the simulation system can operate independently. Its database can be used as a basis of the plant IS because it contains all important data about the production system.

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Souhrn

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Každý výrobce je v současné době vystaven rychlým změnám trhu a proměnlivým požadavkům odběratelů-zákazníků. Dynamický výrobce proto používá simulační systémy, které mu umožňují zvýšit výrobu a zisky, snížit průběžné doby a rozpracovanost výroby, synchronizovat kapacity, suroviny, materiál a požadavky odběratelů-zákazníků. Příklad řešení je uveden na simulačním modelu výroby kávy. Simulační model výroby kávy obsahuje procesy pražení, odplynování, mletí a balení. Tímto modelem jsou získávány základní charakteristiky výrobního systému a sestavovány výrobní plány a rozvrhy. Výrobní systém je zdokonalován za využití optimalizačního modulu. Jsou diskutovány kapacitní problémy související s výrobou kávy. Zvolený přístup je aplikovatelný na celou řadu potravinářských provozů.

Klíčová slova: simulace; plánování a rozvrhování výroby; výroba kávy

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