Case Study 4: Detailed description of the problem - model of a lacquer production

Sonja Loeschmann, Dr. Dagmar Ludewig

2.6.2003

AMETIST Deliverable 3.4.1

Project acronym: AMETIST
Project full title: Advanced Methods for Timed Systems
Project no.: IST-2001-35304
Project Co-ordinator: Frits Vaandrager
Project Start Date: 1 April 02
Duration: 36 months
Project home page: http://ametist.cs.utwente.nl/

Demonstration model of a lacquer production

In the following you will find a detailed description of the lacquer production. The described production originates from a real project. The production characteristics (production times, production costs, performance factors etc.) were changed due to reasons of confidentiality. To have an easy starting point the production is strongly simplified. We reduced the number of products dramatically to 3, the number of resources and the number of orders. Furthermore we do not consider the cleaning and setup and working times. Step by step we will modify the model by adding more complexity.

1.1 Production sequence

The production consists of 5 steps:

Step 1 and 2:

Pre-dispersion and dispersion – solid and liquid basic materials as well as solvents are prepared for the actual production and mixed (to some extent distribution systems are required for these steps).

Step 3:

After the pre-dispersion or dispersion the previously prepared materials are filled into mixing vessels with the help of dose spinners. Each dose spinner contains 200 valves, which emit predefined quantities of those basic materials which are required for the lacquer production into the vessels below- this is all done automatically. When the quantity required for a certain lacquer production has been obtained the mixing vessel is moved to a different place in the hall – and there begins to mix the components during a defined period of time in order to obtain the end product. For production around 5 of these mixing vessels are available. Thereby you should keep in mind that the mixing vessels can be of different size and therefore of different filling quantity (volume capacity). Therefore the assignment of mixers is dependent on the order quantity. When the mixing procedure has finished the lacquer quality is checked.

Step 4:

If the quality does not meet the requirements the mixing vessel is once again moved under the dose spinner and the dosing procedure is repeated. After this the gained colour value is once again checked. The checking times can in some single cases last up to three weeks (in the model you can presume that a re-dosing is always needed).

Step 5:

If the lacquer is of the desired quality then the mixing vessel is moved to a filling station, starts with docking and is then emptied. The mixing vessels are treated as occupied until the mixing procedure has finished and the lacquers are considered as having the desired quality. The filling stations are also, as well as the dose spinners, critical resources, where bottlenecks can frequently occur.

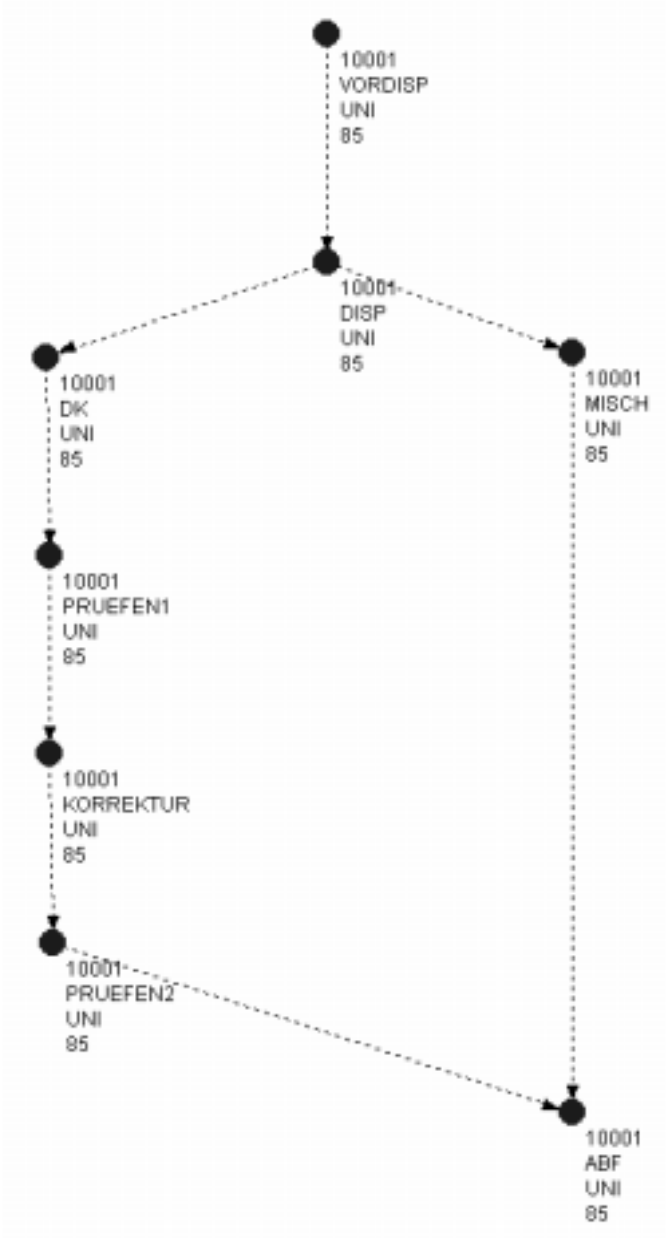
The model contains three different end products with their specific production sequences. In our software for each process that is part of the cycle an individual product is created. In the following chapters the process flow for each of the three products is explained.

1.2 Sequence uni lacquers

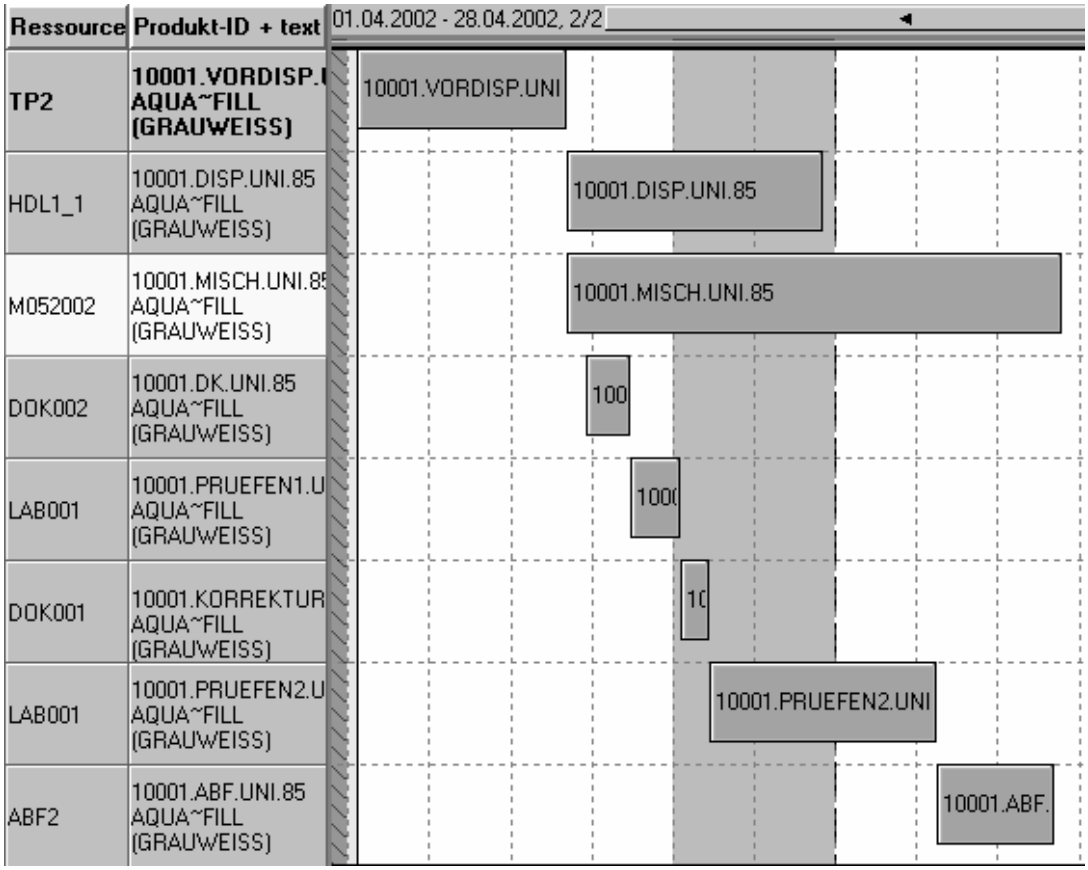
The production of uni lacquers starts with the pre-dispersion and dispersion of the basic materials. In between 4 hours after the pre-dispersion the dispersion has to take place. At the same time when the dispersion starts, the usage of the mixing vessel starts. 6 hours after the start of the dispersion the dose spinner will be allocated.

When the processes on the dose spinners have finished the first checking procedure takes place in the laboratory. This has to be done directly after the procedure on the dose spinner has finished or maximally four hours later. After the first checking procedure a correcting procedure is now started. When this has been finished a second checking procedure has to be performed. When this checking procedure has once again finished the lacquers can be filled at the filling stations. There is no time restriction with these procedures. It can be performed immediately after the predecessing procedures but also hours or days later (You should however try to perform these procedures if possible without long waiting times as this can influence the length of the mixing vessels' use). If the lacquers have been fully filled then the assignment of the mixers is over. Due to cleaning procedures however the assignment of the mixing vessels has to be two to four hours longer as the filling of the lacquers would take time.

In the following you can find a graphic of the production flow or an example for the resource assignment when producing uni lacquers.



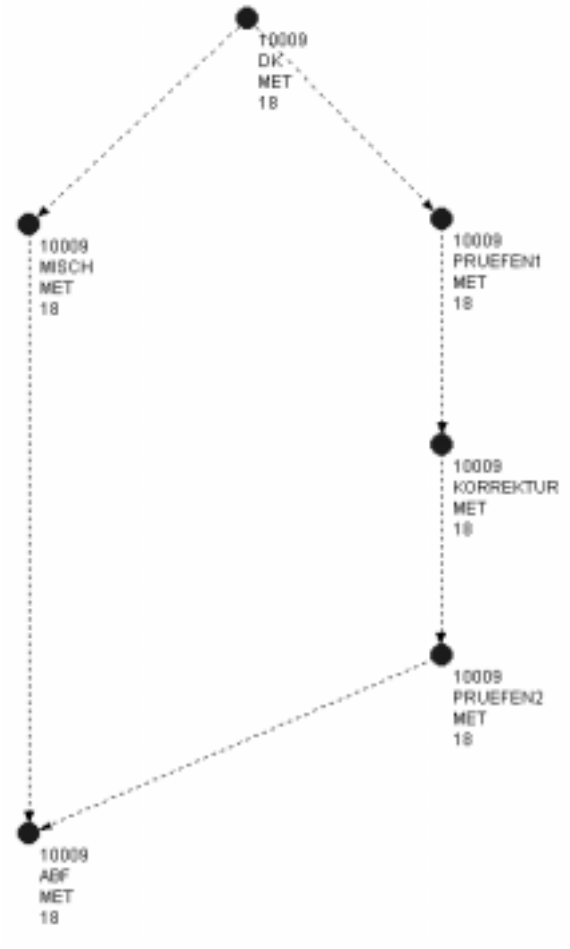
Graphic 1: Process sequence for uni lacquers as bill of material



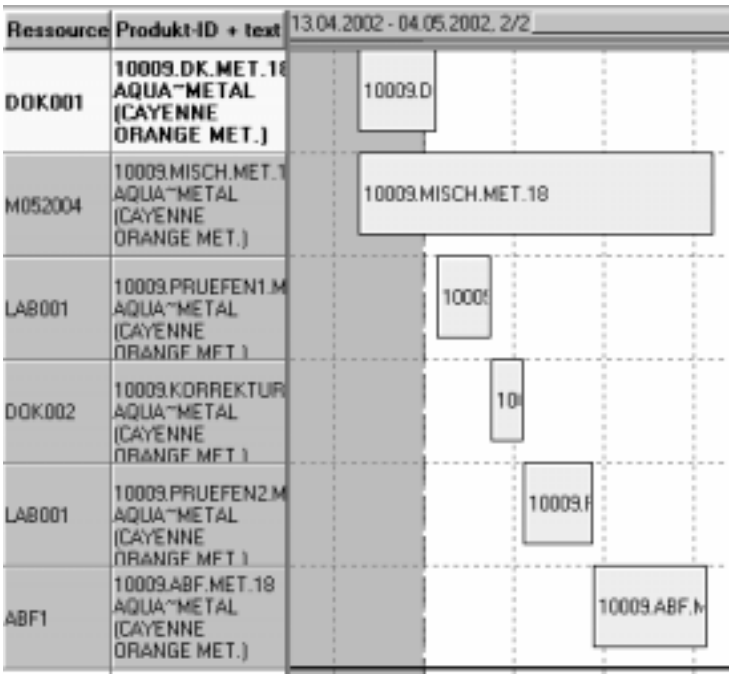
Graphic 2: Example for a ressource assignment when producing uni lacquers

1.3 Sequence metallic lacquers

The sequence when producing normal metallic lacquers differs from the sequence when producing uni lacquers to the extent that in this case no pre-dispersion or dispersion has to take place. The production sequence is the same as the production sequence when producing uni lacquers beginning with the dose spinners until the filling procedure.



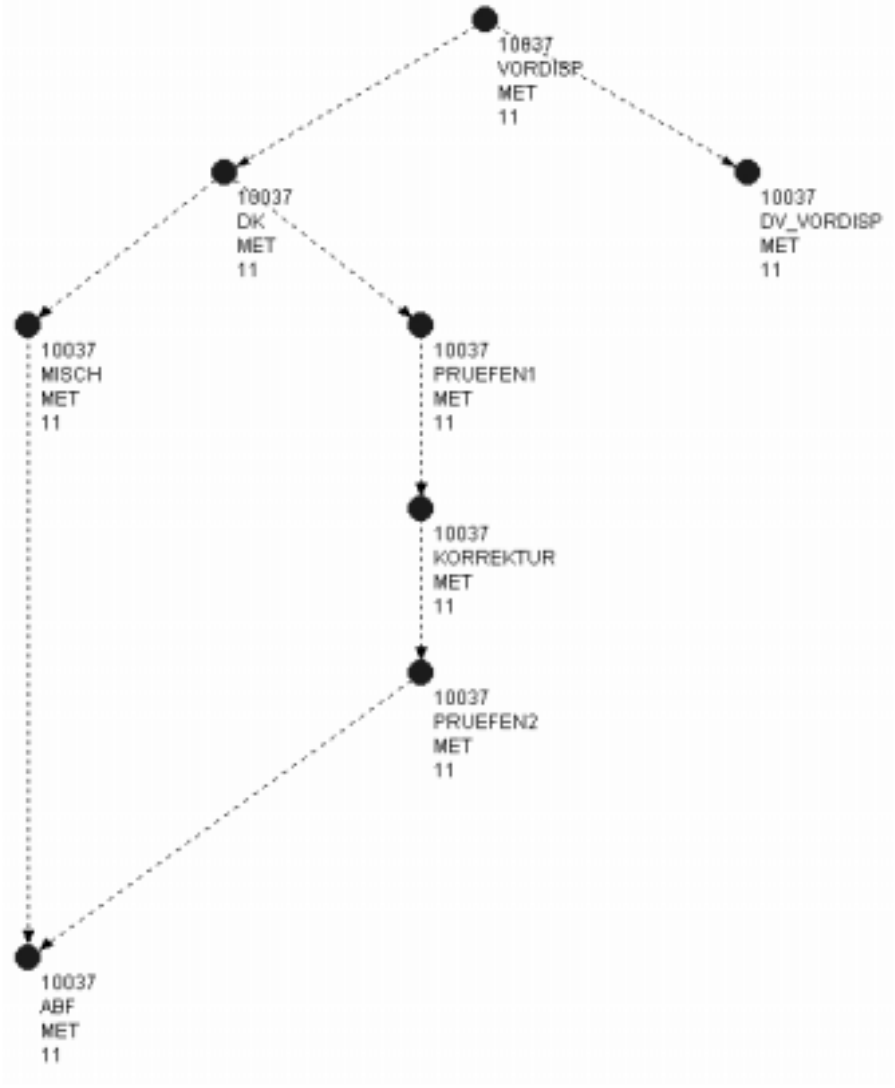
Graphic 3: Process procedure for metallic lacquers as bill of material



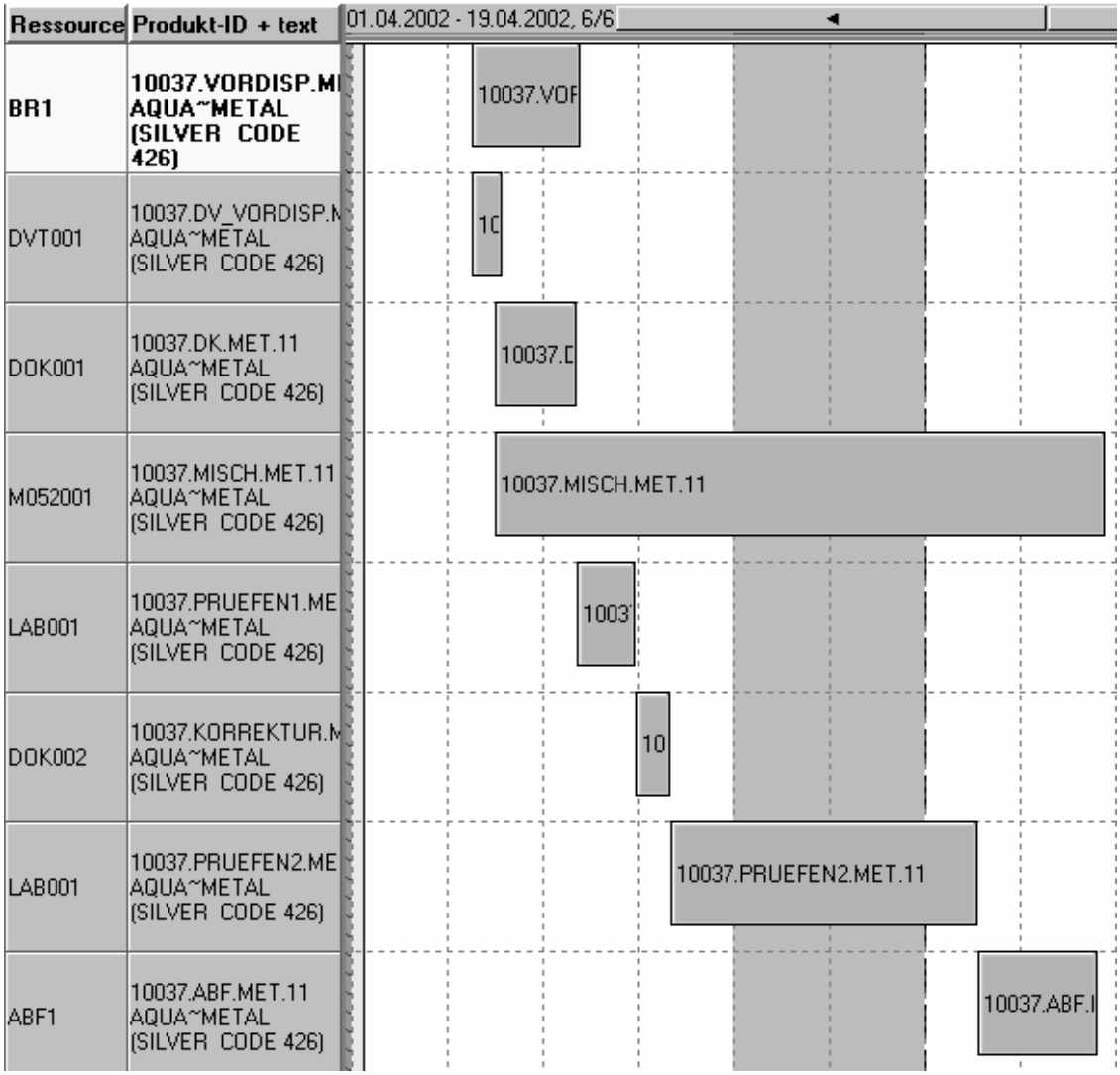
Graphic 4: Example for a resource assignment when producing metallic lacquers

1.4 Sequence special metallic lacquers

For some special metallic lacquers it is necessary to perform a pre-dispersion of the basic materials. For this process an additional dose distributor is required for the pre-dispersion resources. The assignment of the dose distributor starts at the same time as the assignment of the pre-dispersion resource. When the pre-dispersion process has finished the procedures on the dose spinner and on the mixer begin. The following production steps are equal to those of the standard production sequence.



Graphic 5: Process sequence for special metallic lacquers as bill of material



Graphic 6: Example for a resource assignment when producing special metallic lacquers

1.5 Products/ Product characteristics

For each end product or pre-product the density, the product value and the delay costs have to be determined (see attachment **product.xls**). The density is necessary in order to convert the order quantity (kg) into order volume (l) (order quantity divided by the density of the according product equals the order volume).
Delay costs arise in case the product cannot be produced for a certain deadline. In order to determine these the value specified for each product is multiplied with the amount of days which the product has been produced too late (Example: Delay costs = 100 Euro, production end 4 days after the date ➔ 400 Euro delay costs arise).
The additional columns in the table can be ignored for the moment.

1.6 Product flow

In order to produce an end product several procedures have to be executed. As already mentioned OR*ion*-PI® treats each process that is to be optimized as an independent product. This results in product relations which are similar to a bill of material. Each product relation is marked by certain restrictions. These restrictions are determined by the material factor, the link type and the offset times (see attachment **product flow.xls**). The material factor states how many pre-products are necessary for the production of a succeeding product. In our example always one pre-product is necessary for the production of a succeeding product.
The link type 13 states that the production start of the succeeding product may only be set after the production end of the pre-product. The minimum offset time mirrors a minimal transport time so that in the earliest case possible the production of the successor can start at the time of the production end of the predecessor plus minimum offset. The maximum offset equals a maximal transport time so that the production of the succeeding product can start in the latest case possible at the time of the production end of the predecessor plus maximum offset. The offset times therefore limit the time window for the production start of the successor.
The link type 15 determines the time window for the production start of the successor on the basis of the production *start* of the predecessor and not as with the link type 13 on the basis of the production *end* of the predecessor.
Product relations with the link type 98 state that the end of the successor determines the end of the predecessor. This is for example necessary for the calculation of the mixing vessels'

assignment time. For example the assignment of the mixing vessel is only then finished when the filling has taken place. However the filling is a succeeding production step if you consider the material flow logic. The assignment of the mixer can therefore in the earliest case possible be finished when the filling has stopped and the offset time has passed. In the latest case possible it has to be finished when the filling has stopped and the maximum offset time has passed.

1.7 Resource layout

The resources necessary for production can be derived from the attachment **resource.xls**. The production on these resources can take place 7 days a week. We opted not to create a shift time model at this stage of the project.
The minimum and the maximum filling quantity is stated in litres. Therefore only orders can be produced on the single resources which have an order quantity or order volume that is within these filling quantity limits.
The table performance/costs states, which resource groups are available for the production of each product group. The cost statement is some kind of punishment term (Example:The production of a product on a certain resource is more expensive than on a other resource due to higher power consumption.)

1.8 Order data

The attachment **order.xls** contains 29 orders. Each order is marked by an order quantity, an earliest start and a deadline. The earliest start states at what time an order can be produced in the earliest case possible (production start of the first process). The deadline is the desired delivery date (production end of the latest process) of the end product. If the order can only be dealt with after the deadline has passed delay costs arise.
The quant ID is an additional identification characteristic similar to the order number.

The products (process steps) which are necessary for meeting an order can be derived from the attachment **quants.xls**. It is stated to which order the single quants (products) belong. The single products can be derived from the production flow (bill of material) which was described in the previous passage. It also determines in which sequence and with what time restrictions the products are planned.

In this stage of the project we have already defined both the production time of the single quants as well as the resource on which the quants should be planned in an optimum way.
The deadline of the single quants in an order differ as a backward termination is performed. This means that the quant for the filling process or the quant for the mixing process have the latest date as they equal the end in the production chain. The quants for the pre-dispersion or the dispersion on the other hand have the earliest date as they equal the beginning in the production chain (Information: The calculation of the deadline is equal to the date of the end product and the production times and transport times of the single processes).
The column production time states in which time period a process has been scheduled. For the process of the mixing vessel assignment no production time was determined as this is dependent on in which period the other production steps (dose spinner up to filling) can be terminated/planned.

1.9 Objective function

The objective function is based on costs.

Following terms should be taken into account:

Delay costs per day
+
operational costs per kg as given in the table performance/costs

This objective function will be extended in future, considering :
Setup/ Cleaning, storage, production, delay, raw materials and transport during optimization.