Trading and marketing of recycled glass

In my project, I have analyzed the trading and marketing of recycled glass. In Germany providers of so-called “dual systems” organize the collection and recycling of waste glass under the well-known license symbol “Der Grüne Punkt” (“The Green Dot”). The customers bring their waste glass to bottle banks, where the customers are instructed to separate the waste glass into different containers for colorless, green and brown/amber glass. The separation is necessary, because the different colors of glass are usually incompatible for further recycling. Vehicles empty the glass containers and deliver the waste glass to glass recycling plants. In the glass recycling plants the waste glass is ridded of heat-resistant glass (like flat glass), the wrong glass color and other contaminations like pieces of metal or ceramic. Furthermore the waste glass is crushed. Afterwards the cullet is delivered to glassworks, where it is remelted and new products are produced.

Providers of dual systems coordinate which quantities the glass recycling plants obtain from the locally collected glass and which quantities the glass recycling plants deliver to which glassworks. The companies have to consider the transportation and storage costs. The problem is to determine the optimal distribution of the quantities in the network. In Germany, dual system providers coordinate a recycling chain comprising a total of 425 districts, up to 30 glass recycling plants and up to 30 glassworks. In my project, I have simulated the phase, during which the glass recycling plants deliver the cullet to the glassworks. Here, 24 glass recycling plants and 17 glassworks are included in the analysis.

For the implementation of the simulation model, the simulation software ExtendSim AT was selected. First, a simulation model is implemented, where the glass recycling plants deliver a glasswork, if the glasswork cause from the perspective of the glass recycling plant, the lowest transportation costs. Afterwards the simulation model is extended. Now a delivery is not triggered by the minimal transportation costs from the perspective of a single glass recycling plant, but by the globally minimal transportation costs of all glass recycling plants.

The simulation model first associates the cullet to glass recycling plants (see figure 1) and then the cullet is sorted by color. For this, a Create block reads a schedule from a database. This includes information about the arrival times, the identification number of the glass recycling plant, where the cullet is available, the glass color and the glass quantity. Using the identification number of the glass recycling plant, the cullet can now be distributed in a Select Item Out block to the appropriate glass recycling plant.

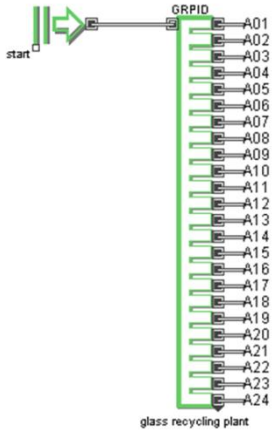

Fig. 1 : Distribution of the cullet to the glass recycling plants

Each glass recycling plant is modeled by a hierarchical block. The cullet flows into the hierarchical block and is then sorted by the glass color. The following course of the process is

identical for the glass colors brown, colorless and green, since all the glassworks have a demand for these glass colors. Therefore, now the following process is described for the brown cullet only. First the brown cullet is stored until at least one glasswork has a demand for the brown cullet. If the cullet has already stored more than six weeks, storage costs accrue. In the simulation model the warehouse is represented by two queues (see figure 2). First the cullet flows into a queue, where no storage costs accrue. If, after the six weeks the cullet is not delivered to a glasswork, the cullet leaves the first queue. The storage costs for the current week are calculated and then the cullet will be stored for a week in a second queue. If after a week the cullet is already in the second queue, because no glasswork has a demand for this cullet, the storage costs have to be recalculated. As long as there is cullet in the second queue no cullet from the first queue is delivered to the glassworks. Once a glasswork has a demand for the cullet the gate will be opened and the cullet leaves the warehouse.

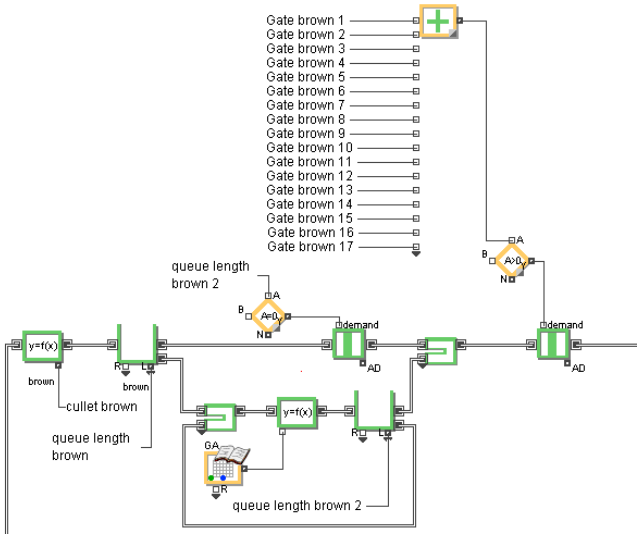

Fig. 2 : Sub process warehouse

When the cullet leaves the warehouse, because at least one glasswork has a demand for the cullet, the decision follows which glasswork to deliver the cullet to. One selection criterion is that only glass factories will be supplied which currently have a demand for the cullet. If several glassworks have a demand for the cullet, the glasswork with the lowest transport cost will be supplied (see figure 3). For each glasswork a value is first determined by an Equation block that is used as the basis for the calculation of minimum transport costs. If the glasswork has no demand for the cullet the value is set to 9,999, otherwise the transport cost is returned. The minimum of these values is then determined. The cullet flows into a Select Item Out block, this block routes the cullet to a glasswork by using the specified minimum.

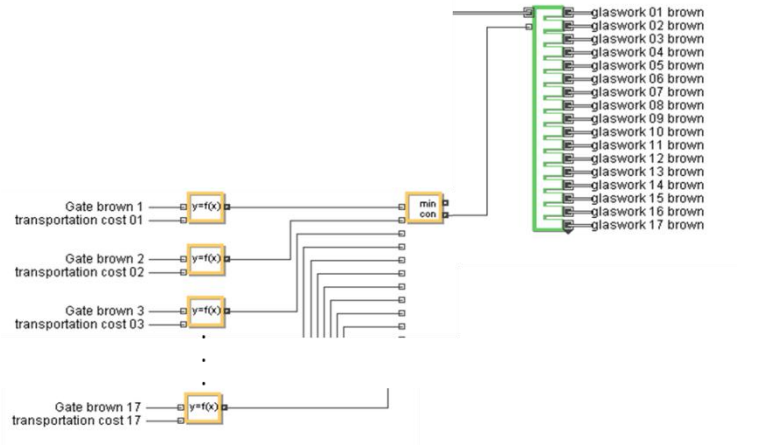

Fig. 3 : Selection criterion for the delivery of the glassworks

A gate follows the selection of a glasswork. This gate checks whether a contract amount has not been fully met so far. Since the quantities do not refer only to one calendar week, but to an entire year, the contract amounts are distributed evenly over the entire period. This will help to ensure that the cullet will be distributed equally among all the glassworks. In the simulation model the maximum delivery quantity that may be delivered up to the current calendar week to the glassworks, increases linearly with a tolerance of five percent above. The maximum delivery quantity may not exceed the contract amount. We have to check, whether the maximum delivery quantity is already reached in the current calendar week. If the glass recycling plants have not obtained the possible quantities in the last weeks, it is possible that they catch up these quantities in the current week. In the figure 4, a gate block is shown, which closes when the maximum delivery quantity was met by the glass recycling plants. For this a decision block compares, whether the delivered quantity, which all glass recycling plants have delivered to the current glasswork, is larger than the maximum delivery quantity. As long as the maximum delivery quantity does not exceed the contract amount, the maximum delivered quantity is calculated as follows: contract amount / contract duration * current week * (1 + tolerance).

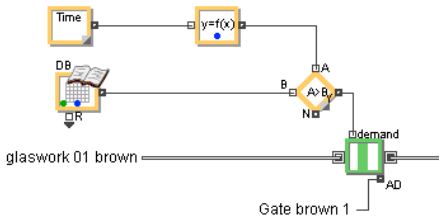

Fig. 4 : Gate to control, whether the contract amount already met

If a glass recycling plant supplies a glasswork, some metrics are collected. It shall be calculated how much the glass recycling plant has already delivered to the glasswork and the quantity that all glass recycling plants have delivered to the considered glasswork. Continue for the current glass recycling plant the cumulative transportation costs and the cumulative revenues and the resulting profit are collected. In the calculated profit the storage costs are not included, because they cannot be attributed to a specific glasswork. Moreover, the cumulative transport costs and revenues increase, which are caused or generated from all glass recycling plants for the delivery of the current glasswork. After the calculation of the metrics the cullet leaves the hierarchical block.

When a new glass recycling plant has to be added in the simulation model, in the hierarchical block only some database links and the transport costs have to be adjusted. When a new glasswork is added to the simulation model, the Select Item Out block, which is illustrated in the figure 3, has to be extended. These adjustments are carried out for each glass color.

When an entity leaves the hierarchical block of a glass recycling plant, which means that the cullet is delivered to a glasswork, the entity flows into another hierarchical block. Such a hierarchical block exists for each glasswork. In the hierarchical block, the entity flows to an exit block and the delivery of the glasswork can be considered as finished. The exit block captures all incoming entities, so it is known, which delivered quantities the glasswork received and from which glass recycling plants the quantities arrived. Furthermore in this hierarchical block the duration of the contracts and the contract amounts will be determined. In a Lookup Table block, the contract amounts depend on the calendar week.

If the simulation model should be expanded to include a new glasswork, the hierarchical block of a glasswork has to be copied and the duration of the contracts and the contract amounts have to be adjusted. When adding a new glass recycling plant, for each type of glass the exit block has to be extended to the new glass recycling plant.

Now the proposed model will be extended. The decision, whether a delivery from a glass recycling plant to a glasswork accrues, was so far only affected by the transport costs of the considered glass recycling plant. Now the decision should depend on the transport costs of all glass recycling plants. This extension is implemented in the simulation model. In the hierarchical block of the glass recycling plants for each glass color another gate block is added (see figure 5). This gate opens when the local minimum, which is passed from the Max & Min block, corresponds to the global minimum. That means that a delivery between the glass recycling plant and a glasswork will take place only when the combination of a glass recycling plant and the glasswork, relates to the minimal transport costs. Here, however, only the relevant combinations are considered, that means the glass recycling plants are able to deliver the cullet and the glasswork has a demand for the cullet.

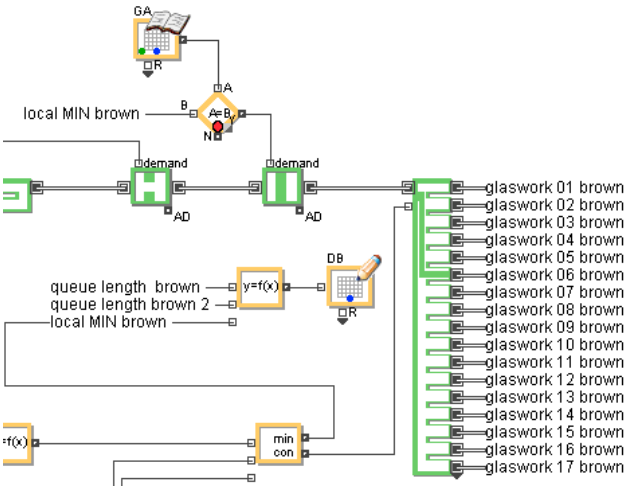

Fig. 5 : Adjustments for the extended simulation model

Now that the course of the process was modeled, plotter can be used to demonstrate some metrics graphically and the process can be analyzed. For example, the available cullet per quarter is plotted. In this way, the changes in each quarter become visible. Furthermore, changes to inventories and the storage costs are presented. This offers the possibility to identify, where there is a surplus of cullet. In another diagram is shown for each glasswork, how much cullet has been requested in the period of the current glasswork and how much

cullet was delivered to the considered glasswork. Thus identified, where there have been shortages.