BATCH PLANT MANAGEMENT IN NEED OF MORE SUPPORT

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Abstract

The complex multi-purpose, multi-product character of batch manufacturing plants implies a major need to integrate information from operational activities in the plant and to gain more insight into the relative importance of every activity with respect to the main objective of the enterprise. At Delft University of Technology a management decision support tool is being developed which aims at acquiring a deeper insight into the connection between the operational activities of the plant and its objectives. Moreover, it determines the relative importance of the objectives with respect to the main one. With this knowledge, plant managers are supported in their decisions on which activities they should emphasize for process and product improvement and innovation.

Keywords

Batch manufacturing, integration, objectives analysis, management decision tool, multi-criteria analysis

Introduction

The fast-changing demand for new products and the noticeable presence of competitors require a flexible production plant with good capabilities to exploit new opportunities and to take advantage of market changes.

The multi-purpose, multi-product character of most batch-wise operating plants guarantees to some extent the desired flexibility. However, continuous improvement of the plants' activities and well-structured information to take strategic and tactical decisions in an efficient and effective way is necessary to guarantee the plants' continuity in the longer term.

Technological solutions, like Manufacturing Execution Systems (MES) or the integration of software systems on several levels respond to this request for information ((Young, 1995), (Rickard et al., 2000) and (Das et al., 2000)). However, the mainly unilateral focus on the technological side has saddled companies with enormous data streams, whose usefulness is not always evident. Deriving information from these large amounts of data streams can only be reached when it is made explicit which information, where, when and why is needed. Only when the answers to all these questions are known, a technological solution can provide the request for information in an industrial plant. The organisational and psychological aspects of integrating people can and should not be forgotten (Shobrys et al., 2002).

This paper discusses a management decision support tool that supports plant management in their strategic and tactical decisions. The purpose of the tool is twofold. On the one hand, the tool supports management in their continuous search for improvements. On the other hand, when a specific problem should be solved, the tool will help them to take well-founded decisions by weighing the several solution strategies with respect to their contribution to the overall objective of the plant. The tool supports plant management in their choice for the right technological solution, and should therefore be used in addition to existing methods.

The Management Decision Support Tool (MDST)

In spite of the different products that are manufactured in a batch wise mode, the specific properties of batch manufacturing involve the possibility to define general models, as shown in the S88 Batch Control Standard and the S95 Enterprise-Control System Integration Standard of ISA (ANSI/ISA 1995, 2000, 2001). In accordance with these standards, the MDST includes three general models in which the emphasis is on similarities of batch manufacturing environments, although they may produce a quite divergent range of products.

Within the tool three elaborate models are available:

1. A general objective tree, modelling the objectives of a batch plant in a hierarchical way,
2. A general activity model, modelling the activities of a batch plant in several hierarchical decompositions,
3. A general relational model, connecting the operational objectives of the plant to the operational activities.

The models are validated and verified in several stages by experts from science and industrial practice. The users of the models can adapt the models to the specific batch plant characteristics. From case studies, this seems to be hardly necessary, since the models are quite comprehensive.

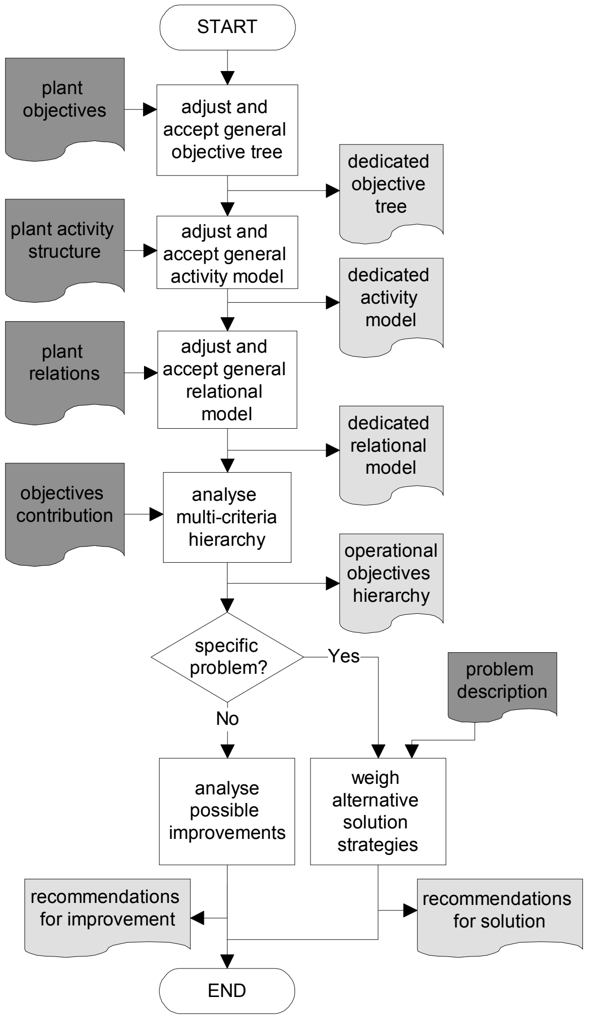

Figure 1: Flow diagram MDST

The flow diagram in Figure 1 shows the activities through which the user will be guided while executing the MDST. The dark grey documents depict the information that is requested from the user. The light grey documents depict the output of the MDST for the user. The activities in the flow diagram will be explained in more detail in the next paragraphs.

Adjust and accept general objective tree

The overall objective of a plant is often broadly formulated. To be manageable, this objective should be translated into several more concrete sub objectives. By this translation an hierarchical structure of objectives is acquired.

Every objective is defined as a factor that is desirable to change into a certain direction. An objective is operational when the factor within the objective is operational, i.e. when this factor can be measured in practice. There should be a clear distinction between *objectives*, that which should be changed, and the *means*, the instruments to make these changes.

A wide-used method to model objectives is the objective tree. Starting from the root, the main objective, objectives are split from strategic objectives, through tactical into operational ones.

A good objective tree follows certain rules:

1. Every sub objective contributes directly to the realization of the upper level objective,
2. The objective tree contains no means nor instruments, only real objectives.

In the first stage of the method the user will adjust, by adding specific plant information, the general objective tree into a dedicated one that applies to the plant involved.

Figure 2 shows the upper part of the general objective tree. Every branch is decomposed into several other branches.

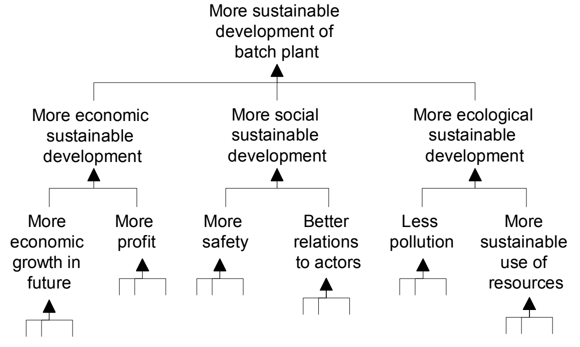

Figure 2: Upper three levels of the objective tree

Adjust and accept general activity model

For the activity modeling the IDEF0 standard (Integration Definition for Function Modeling 1993) is used. An IDEF0 model consists of an hierarchical chain of diagrams which describe in increasing detail the activities and their interactions. Within an IDEF0 model activities are drawn as boxes, their interactions as arrows. Four kind of arrows are distinguished; Input, Control, Output and Mechanism (ICOM).

1. *Input*: Data or objects, being transformed by the activity into the output.
2. *Control*: Conditions, required to produce the correct output.
3. *Output*: Data or objects, being produced by the activity.
4. *Mechanism*: Resources, performing the activity.

In the MDST general activity model, the emphasis is on the activities to be executed, independent from the way they are organized in specific departments.

Figure 3 shows the first three decompositions of the MDST general activity model.

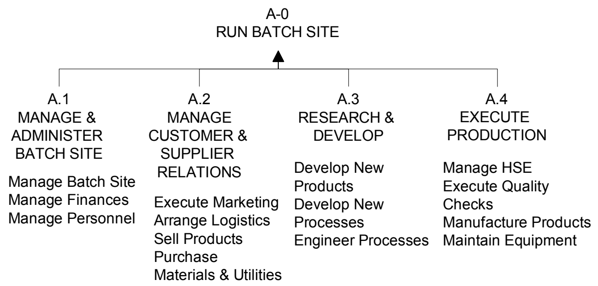

Figure 3: Upper part of the general activity model

Adjust and accept general relational model

Means connect the operational activities in a plant to the operational objectives of the plant. Means are the instruments that an activity possesses to change the operational factor of an objective.

In the MDST the most common relations between the objective model and the activity model are pre-defined. Users can easily adapt these assumptions to their own ideas or situation.

Analyse multi-criteria hierarchy

The limited resources of the plant should be deployed in a well-considered way. For this it is important to know which operational objectives *at this very moment* can provide the highest extra contribution to the overall objective of the plant.

Since the objective tree is quite comprehensive, a good presentation to the users is significant. For a good support within the plant it is important that people from several departments related to the subject, will decide on the relative importance of the objectives.

The pair-wise comparison method of Saaty (Saaty, 1980) is used to determine the relative weights of the objectives. Taking an objective from one of the main branches, the user should decide for every pair (A,B) of child objectives about the importance of A in relation to B, with respect to the degree in which their parent objective could be achieved. Based on the relative importance of the objectives a selection criterion decides which objectives are taken into account in the further analysis. Sensitivity analysis is provided to assess the sensitivity of the final results for choices made in this weighing analysis.

From all arrangements of different stakeholders one total ordering is achieved. This total ordering is submitted to all stakeholders for an additional approval to reach a consensus.

The stakeholders are asked to choose, on a scale of seven, between two sub objectives from the same parent objective which of the two, they think, is presently more important to focus on to achieve the parent objective.

Depending on the choices of all stakeholders a total score is obtained for every objective in the list, which yields a total order of the objectives. The objectives that have a score of less than 75% of the highest score will be left out for further analysis.

From case studies, this percentage has been empirically shown to be appropriate to make the weighing analysis not too time consuming. However, the number can easily be changed by the user of the MDST, when more or less accuracy is desirable.

The results of the MDST so far can be used for two purposes. They may support plant management in the continuous search for improvement, or they may support them in the assessment of different solution strategies for a specific problem situation. Both cases will be shortly described below.

Analyse possible improvements

By comparison of the information from all models and the results from the hierarchical multi-criteria analysis it is rather straightforward to deduce activities, management should focus on, to improve the more important operational objectives. The activity model is used to decide where improvements could be searched. Improvements can be made by improving the input of the activity (more often, more adequate), and the relational model will show the consequences of such an improvement. Improvements can also be made by improving the activity itself (new techniques, new methods, new software tools, etc.).

Using the MDST for continuous improvement requires adaptation of the models and the multi-criteria analysis when relevant changes are implemented in the plant.

Weigh alternative solution strategies

Using the MDST in a specific problem situation, several solution strategies could be weighted on their impact on the overall objective of the plant. With the hierarchical multi-criteria analysis the most important criteria on which the solution strategies should be screened result from the ordering of the operational objectives.

Case Study 1: A Flour Plant

The first case study was executed at a flour plant where grain specialties and coarse mill products are manufactured, intended for the production of bread and other food products. These products are manufactured partly continuous, partly in a batch-wise mode.

Plant management is constantly searching for improvements in the plant. The MDST is supporting them in this continuous improvement process. The market situation has recently changed, and the MDST has indicated that, instead of focusing on the highest production rate, it is more profitable now to focus on stricter delivery times, since customers make high demands on delivery times, and change easily to other manufacturers if they are dissatisfied.

Since planning and scheduling are the two activities that have a high impact on the degree in which this objective could be achieved, the activity model shows that improving the interactions between those two activities, as well as improving the interactions with the other operational activities in the plant, would surely be important in the near future.

Two projects resulted from these recommendations:

- A current PhD project is focussing on how to estimate beforehand the benefits of the integration between planning and scheduling.
- The purchase of a new logistic system is investigated to improve the logistic information supply.

Case Study 2: A Paper Plant

The second case study was executed at a paper plant, where a specific problem situation existed. The CHP (combined heat and power) plant of the paper plant was at the end of its technical and economic life span and no longer satisfied the current environmental regulations. Plant management is looking for a good solution to provide the production process in the future with the required energy supply.

There are several possible solution strategies that may guarantee the energy supply of the paper plant.

1. The life span of the current CHP plant can be extended by investment in the reduction of the NO_x emissions and repairing and replacing parts of the installation.
2. A new CHP plant can be built.
3. The exploitation of the CHP plant can be taken over by an external party, such as an energy supplier.
4. In the neighbourhood of the plant both a power station and a waste incineration plant are situated. Energy and heat for the paper plant could be delivered by these installations.

At the time of our research, plant management had a vague idea of the demands make upon a good solution. Energy supply should have a high reliability against small costs, etc. The MDST was used to formulate the criteria and more importantly, to determine their relative weight with respect to the continuity of the paper plant. The most important criteria were investment costs, personnel costs, maintenance costs, reliability and flexibility of the energy supply.

Future research and recommendations

In both case studies, plant management valued the MDST as a useful tool to obtain a better overview of all relations among objectives and activities, which was of great help before decisions on specific technological solutions were made.

Future research will be in evaluation and improvement of the three models provided with the MDST by several new case studies and in the development of an MDST software tool that can easily be used by plant managers.

Acknowledgement

The research described in this paper is part of the multi-disciplinary project “Batch processes - cleaner and more efficient” carried out at the Delft University of Technology in co-operation with five batch processing companies and TNO TPD Delft. The Dutch Ministry of Economic Affairs and the Ministry of Education, Culture and Science financially support the project in the framework of the E.E.T. program (Ecology, Economy and Technology). The authors gratefully acknowledge the financial support and the scientific cooperation with parties involved in the project.

References

ANSI/ISA-88.01-1995: Batch Control Part 1: Models and Terminology

ANSI/ISA-88.00.02-2001: Batch Control Part 2: Data Structures and Guidelines for Languages

ANSI/ISA-95.00.01-2000: Enterprise–Control System Integration Part 1: Models and Terminology

ANSI/ISA-95.00.02-2001: Enterprise–Control System Integration Part 2: Model Object Attributes

Das, B.P., J.G. Rickard, N.Shah and S. Machietto (2000). An investigation on integration of aggregate production planning, master production scheduling and short-term production scheduling of batch process operations through a common data model. Computers & Chemical Engineering 24. 1625-1631.

Rickard, Julian G., M. Celeste Colantonio, Sandro Macchietto and Nilay Shah (2000). Integration in hierarchical structures for batch process operations. Computers & Chemical Engineering 24, 1159-1165.

Saaty, T.L., (1980), The Analytic Hierarchy Process, McGraw-Hill Book Co, New York.

Shobrys, Donald E., Douglas C. White (2002). Planning, scheduling and control systems: why cannot they work together. Computers & Chemical Engineering 26, 149-160.

Standard Integration Definition for Function Modelling (IDEF0), 1993, Publication 183, FIPS PUBS.

Young, Stephen L. (1995). Technology … The enabler for tomorrow’s agile enterprise, ISA Transactions 34, 334-341