Mass-Customized Production in a SME Network

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Abstract
The most promising feature of a manufacturing system oriented to mass customization is to have at disposal a layout and a governance such to allow: a) to include a new product within the family of products under manufacture; b) and to apply the required modification of the manufacturing process in front of the market-requested product innovations, in such a way to minimise the cost for product inclusion. The inclusion of a new product in a SME network implies to approach two complementary problems: 1) a ***post-ponement problem***, that means to recognise the new characters of the innovated product such to specify its difference with respect to the set of other products already processed, and to adjoin the new working sequence in the existing processing program (to be possibly modified at least) already applied by the SME network; 2) an ***order-fulfillment problem***, that means to include the a-priori estimated production flow required for the new product, within the programmed flows pattern in the existing SME network, by adding the minimum possible innovations to the network itself. The paper will discuss the proposed solution phases, and illustrate a set of integrated procedure to be applied in order to obtain a mass-customisation strategy of practical utilisation for managing SME networks.

Keywords
post-ponement, order fulfilment, mass customisation.

1 Introduction

Manufacturing system oriented to mass customization implies use of layout and governance such to allow an easy and fast inclusion of a new product within the family of products under manufacture, and a simple modification of the

manufacturing process in front of the market-requested product innovations, such to minimise the cost for product inclusion.
This task is particularly important in a Network of Small-Mid Enterprises (SME), where a large effort is necessary to coordinate

1. the definition of the necessary modifications of the working sequence (which should be applied in the different SMEs of the network, depending on their specialisation and the phases of the product working sequence they are able to implement),
2. the innovation of the existing pattern of production flows among the various SMEs.

Then, the inclusion of a new product in a SME network implies to approach two complementary problems:

(i) a ***post-ponement problem***, i.e. recognise the new characters of the innovated product such to specify its difference with respect to the set of other products already processed, and adjoin the new working sequence in the existing working sequence;

(ii) an ***order-fulfillment problem***, i.e. include estimated production flows of new product within the existing flows pattern but with the minimum possible innovations to the network itself.

A sketch of the two joined problems is illustrated in the following Figure 1.

Planning the inclusion of a new product in the mass-customised SME network can be obtained by the following phases:

1° Phase: Detecting the request of the new product, in terms of expected features;

2° Phase: Specification of the new product in terms of new “product tree”:

1° Step: Recognition of new expected functions, different from those which can be obtained by existing products and production activities of the different SMEs in the network;

2° Step: Selecting new product components through a comparison with already existing product trees;

3° Phase: Definition of the new working sequence:

1° Step: Transforming the new tree of components into a working sequence;

2° Step: Given the new working sequence, selecting the required resources to be included in some SMEs of the network, such to assure the execution of the new working sequence;

4° Phase: Inclusion of the new product into the SME network:

1° Step: Integrating the layout of the existing SME network and the production capabilities of each SME with the new resources required at the previous step;

2° Step: Given an a-priori estimation of the new expected demand, assigning production flows on the various SMEs in the network.

The paper will discuss the proposed solution phases, and illustrate a set of integrated procedure to be applied in order to obtain a mass-customisation strategy of practical utilisation for managing SME networks.

The developed solution strategy can be validated by applying real data contained in the web portal developed within the EU-funded CODESNET (COllaborative

Demand & Supply NETwork[1]) project. Owing to space constraints, description of some industrial applications will be done during the APMS'07 Conference.

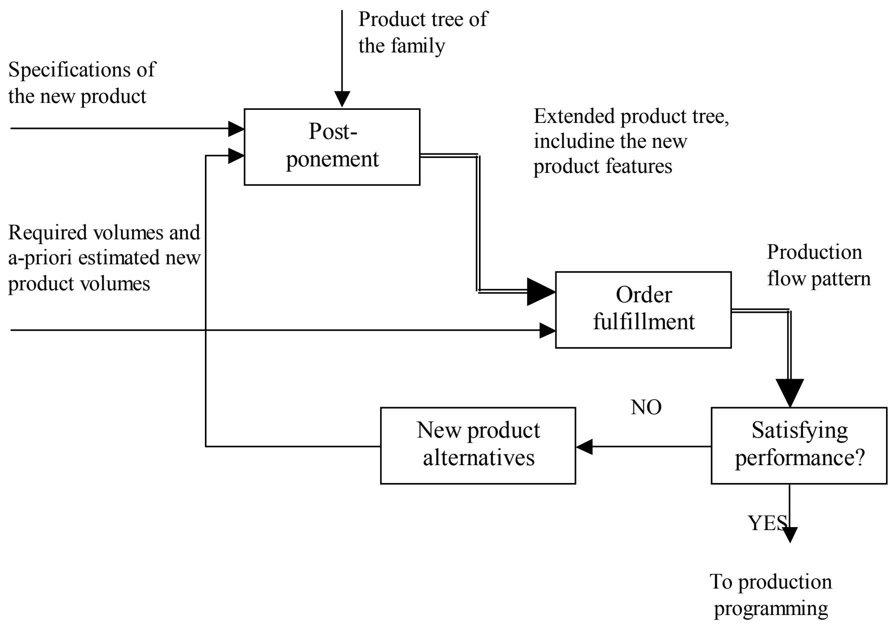

Figure 1. Loop connection of the two joined problems of "post-ponement" and "order fulfillment"

Known Results:
Several research efforts have been dedicated to the two complementary problems of post-ponement and order fulfillment in a mass customization industrial system. Usually, the two problems are separately approached, with the scope of defining procedures sufficiently simple for the following two scopes: for the former, to generate a wide mix of product configurations, possibly by delaying the product differentiation on the final part of the manufacturing lines [1, 2, 3]; for the latter, search for strategies minimizing due date even in case of large variety of products [4]. The integration of both for assuring an assignment of working sequence phases to the line stages maximizing the line utilization (then, minimizing delivery delays) even for a wide mix, has still to be defined and validated.

[1] *CO-DESNET is the acronym of the Coordination Action (CA) project n° IST-2002-506673 / Joint Call IST-NMP-1 on COllaborative DEmand & Supply NETworks, supported by the European Commission, Information Society Directorate General, Communication Networks, Security and Software Applications, under the coordination of Politecnico di Torino (see the web portal address www.codesnet.polito.it).*

2 Practice-oriented problem solution

The approach outline sketched in Figure 1 contains the following organisation of solution phases for the joint problem of post-ponement & order fulfilment in a mass customization system:

1st phase: recognize a new product to be manufactured;

2nd phase: characterize the new product in terms of multi-attribute product tree [5, 6]

1st step: identify all new functions required to the new product, not yet supplied by existing products;

2nd step: select new components through a comparison with existing product trees.

3rd phase: Define the new working sequence [7]:

1st step: transform the new product tree into a sequence of manufacturing operations;

2nd step: Given the new working sequence, select the resources required to manufacture.

4th phase: Include the new product into the manufacturing system:

1st step: integrate the existing manufacturing system with newly required resources (see 2nd step 2nd phase) [7];

2nd step: given the expected average demand of the new product, assign production flows to the manufacturing system network [8].

In details, the four phases have to be accomplished according to the following actions.

1st phase: recognize a new product to be manufactured;

Data: the enterprise receives the demand for a new product, whose innovation with respect to the existent mix is identified in terms of: a) product “mission”, stated by new functionality; b) product “structure”, in terms of new components.

Action: the enterprise detects the demand for new product, compare required functionality with its product mix data base (each product being described by a specific product tree).

Remark: comparisons of several product trees could be time-consuming: then, new procedures based on pattern recognition could be necessary.

2nd phase: characterize the new product in terms of multi-attribute product tree:

Data: the enterprise, detected the innovation characters of the newly requested product, specify it in terms of new product tree.

Actions:

1st step: Identification of all new functions required to the new product, not yet supplied by existing products, will be performed through a comparison of two/many product trees of the same “product family”. To this aim, the new product must be recognized as belonging to a given product family according to the following:

> Rule 1: Two products belong to the same product family if: a) both have the same "mission"; b) the parameters describing the functionality of one differ from those of the other at most for a given bound; c) the product tree structure of one differs from the other of at most a given number of components.

2nd step: Selection of the new components through a comparison with existing product trees will be done according to the following:

> *Consequence of Rule 1:* Necessary and sufficient condition to assure a correct comparison between two products is that both present the same "mission".

3rd phase: Define the new working sequence:

The scope of this third phase is to design the working sequence for the new product with attention to the as small as possible number of changes from existing sequences.

1st step: Transformation of the new product tree into a sequence of manufacturing operations can be obtained according to the following

> Rule 2: The optimal allocation of the manufacturing operations required for a new product is stated as the problem of selecting both the best patterns of product components and the minimum cost working phases, among those characterising the product family.

Note that this is a combinatorial problem of reduced complexity, because the number of feasible alternative in practice does not appear to be high.

2nd step: Given the new working sequence, the selection of the resources required to manufacture is a standard problem of manufacturing/assembling system design, often denoted "machine layout problem", as in [1].

4th phase: Include the new product into the manufacturing system:

This last phase is devoted to estimate at which level new product orders can be satisfied: estimation of this level is based on the a-priori evaluation of the new product demand, in terms either of an average value over a mid-long time span, or a known variable evolution depending on the market demands (e.g., seasonal periodicity). Such an evaluation is the basis of a standard "order fulfilment" problem.

1st step: The integration of the existing manufacturing system with newly required resources (result of the second step of the previous phase) consists of a completion of the graph of manufacturing centers included in the production system, such to make it able to perform all the working operations necessary to process both the old products and the new one. Then, this step is just a completion of the "resource selection" problem above mentioned.

2nd step: Given the expected average demand of the new product, the assignment of production flows to the manufacturing system network aims to estimate the loading conditions of any manufacturing center in the system, such to give an evaluation of the system utilization and of the production costs there involved.

Starting point is the new product tree and the related working sequence, obtained at 1st step of the previous phase.

To the new working sequence and product tree as well as to the set of working sequences of the other products in the mix, a graph of production flows corresponds. Within said graph, both "old" production flows and the ones for processing the new product must coexist. The following Figure 2 shows an example of the mentioned graph.

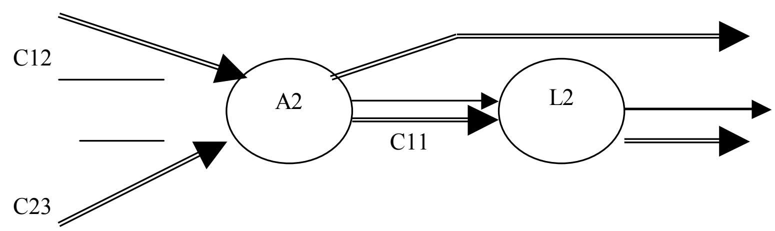

Fig. 2. Graph of production flows in a simple manufacturing system.

→ denotes a production flow for the new product components;

⇒ refers to production flows of the "old" mix in the system.

The following rule has to be applied:

Rule 3: The minimum cost to include a new product demand into an existing system, provided that the required new resources have been put inside, is obtained by solving a standard Aggregate Production Planning [9] problem, i.e. by optimising production flows on the graph of manufacturing centers through minimization of production costs given the centers capacities.

It is a LP problem, whose solution tries to minimise distance between demands and produced volumes, in each time bucket of the planning horizon.

From this flows optimisation problem a further result concerning the overall objective of deciding if to include or not a new product in the production stream, follows:

Rule 4: Decision of either including or not a new product in the previous mix of an enterprise depends on the joint solution of two problems:

i. select an alternative of product components and related working operations of minimum cost, among those contained in a given product family;
ii. optimise production flows over the network of manufacturing centers such as to minimise production costs.

Remark: Note that the best (minimum cost) decision is that of including a new product if it implies the minimum possible perturbation in the manufacturing system, in terms of a non-congested utilisation of the actual *capacity margin* of the production centers.

This remark should suggest the system manager in selecting heuristic criteria and rules for taking into considerations new product, market pushed, and evaluating the cost involved if they will be included in the actual manufacturing operations.

3 Some concluding remarks

The approach sketched in Figure 1, and detailed through the four phases above, can receive two types of interpretations:

a. from a theoretical point of view, the four solution phases come from a *decomposition* of a unique complex combinatorial optimisation problem, i.e. that of selecting an organised set of new components (the new product tree) according to which to modify the production flows and loads in such a way to minimise the production costs related to manufacturing all the components for the whole (previous and new) set of products;

b. from a practical point of view, the four solution phases summarise the sequence of steps that a production manager must apply in order to evaluate the convenience of including or not a new product into the existing mix.

Applications under development concerns the production of bicycles for disabled people (tricycle, with special features for sport or out-road use). New features are sometime requested, to make the cycle easier to use and lighter.

Obtained results in selecting the new features and in identifying how to modify the existing production line, according to the four phases – four rules above presented, seem to be really promising. Evaluation data will be presented at the APMS Conference.

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