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Production Management Model for Short Life-Cycle Goods

Abstract
One distinctive feature of a production cycle model for short life-cycle goods is its determined time for starting the sale of products. As shown by the author's investigation, there is also a possibility of creating a production management model for this group of products. The process applied to that end was based on the inverted tree approach (graph theory). The model thus created model indicates the times when particular actions should start, their expected duration times, as well as causal relationships. The model is a dynamic structure responding to changes in the factors determining the functioning of an enterprise.

Key words: *production management, graphs, production cycle.*

Introduction

Graph theory is a field of knowledge offering a broad range of applications. A novel approach is using the theory to build a production management model based on the concept of an inverted tree (with many entries and one exit), as this type of model reflects the real-life determinants affecting the production of short life-cycle goods. The investigation conducted involved clothing companies that produce such goods. Clothing manufacturers deciding to start production invariably expose themselves to considerable risk, which can be reduced by obtaining more information on customer expectations, fashion trends, conditions for acquiring materials necessary for making the models designed, as well as on the manufacturer's technical and technological capacity for actually producing the garment. One assumption made during the investigation was that the product analysed would not be a single design but a series of garments comprising a fashion collection [4]. It was also necessary to assume a process-based approach to production management that, in the opinion of many authors, boosts enterprise effectiveness [3, 6]. With these assumptions in mind, the production process was broken down into four main sub-processes (product creation, setting up product manufacturing, manufacturing and sale) and their subdivisions. The production management model presented is based on this breakdown.

Building a production management model

Production management must always arise from a plan. Every plan involves a performance imperative. An organisation striving to comply with the imperative becomes less flexible and less perceptive of what is going on around it. On the other hand, the increasingly turbulent environment requires organisations to show flexibility so that unexpected events representing opportunities can be used, and those posing threats avoided [8]. The changes in the functioning of domestic enterprises are well illustrated by events that took place at the turn of the 20th century, which demonstrated how the transition of 1989 contributed to the formation of a new economic reality in Poland [5]. After the domestic market was opened, the inflow of imports increased. As a result, stronger competition in the market reduced the range of selling opportunities. These circumstances necessitate an investigation into ways of improving the effectiveness of production management that provide companies with more favourable market positions.

A production management model for short life-cycle goods was built following the stages below:

- Stage I. Empirical aggregation of actions comprising the production process.
- Stage II. Using the Altshuller method for verifying causal relationships between particular actions.
- Stage III. Making a schedule of the actions and determining their times.
- Stage IV. Building a model based on graph theory.

The fact that the author had researched the area for many years helped verify the constituents of the process, and the causal relationships between them were found using the Altshuller method. For the sake of illustration, let us show the method applied with respect to the sub-process representing the creation of a fashion collection.

Evaluation of the attractiveness of clothing designs (5) is the critical part in the string of events presented in ***Figure 1***, see page 8. The acceptance of the designs means that the next steps can be taken, i.e. the sample room team can prepare a sample of the model designed; otherwise, the model proposed has to be redesigned. This procedure is repeated until the group of specialists appointed by the enterprise board decides that the outcomes are satisfactory (the number of designs meets the manufacturer's needs).

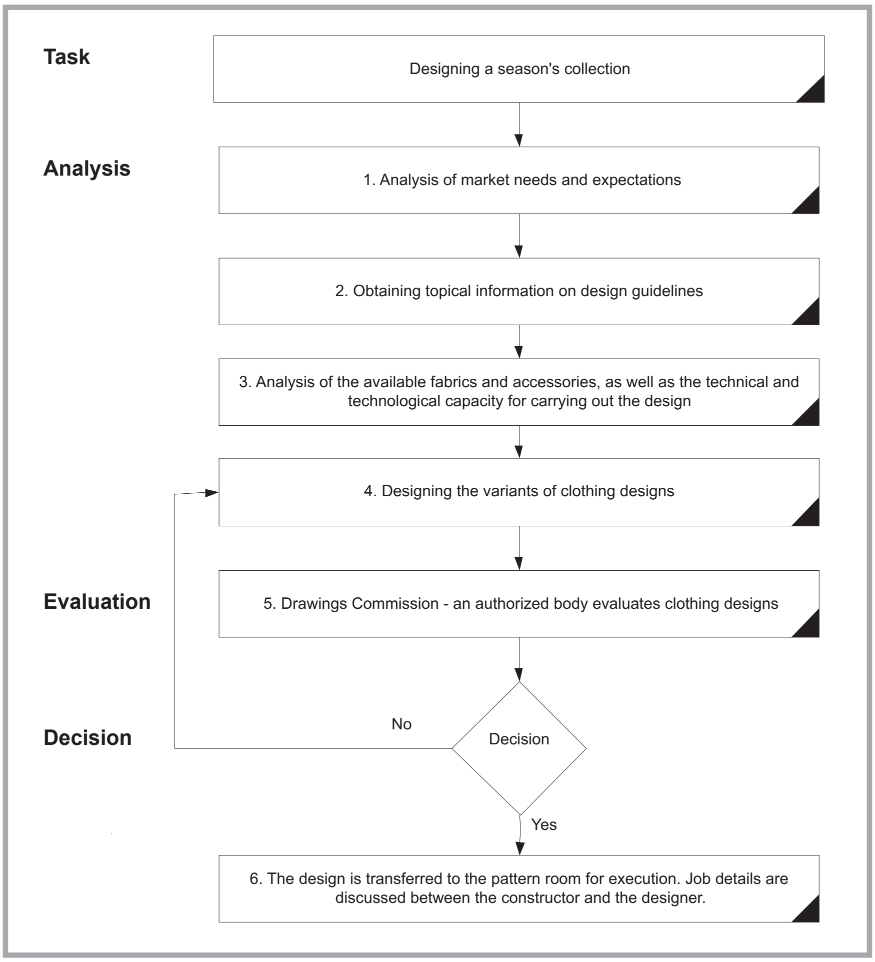

Figure 1. *Algorithm illustrating a fashion collection design process.* ***Source:*** *developed by the author.*

The Altshuller method applied to evaluate the results of all strings of events allowed to schedule the process correctly. The duration times of the strings were determined empirically and then verified using special catalogues, which are in the possession of every clothing manufacturer. The actual duration times of identical actions may vary between particular manufacturers, as they operate in different technical and technological environments. Therefore, a production management model should follow from an investigation conducted in a concrete enterprise. Because process scheduling is a widely discussed topic in literature [1, 2], for the sake of keeping this article succinct, we wish to note that the schedule produced in the course of this investigation provided only a basis for constructing a production management model.

The number of points for starting the construction of the model corresponded to the number of entry points to the process. The points are the leaves from which each branch, consisting of many events (vertices) and actions (edges) denoting their execution, originates. The edges do not provide any information on their duration times, indicating only the sequence of events. At the next stage of the tree development, particular branches converge to ultimately form the root, i.e. the final event. With these rules in mind, two assumptions were formulated to build the model:

- the start time of each string of actions depends on the process's external and internal determinants,
- the duration of an action is a deterministic value expressed in terms of specific units.

Let us consider whether the second assumption is not a simplification possibly leading to the creation of an unrealistic model. We need to bear in mind that in the case of short life-cycle goods, the time for performing each elementary action can be allowed to deviate from the schedule only to a limited degree because product selling must start at a predetermined point in time. Therefore, the deterministic time assumption actually relates to a certain expected time, the length of which is estimated based on long experience and many measurements. A starting point for future research could be the adaptation of the model to a situation where the elementary actions have non-deterministic (i.e. described by a random variable) execution times.

The production management model was built along the following lines:

1. Each process action is represented by an edge with a label indicating its duration.
2. There is one vertex for one intermediate state of the process. A vertex is a place where all edges symbolising actions immediately preceding the state described by the vertex end, and where an edge representing an action leading to the next state has its beginning.
3. The tree leaves are equivalent to the initial states of the strings of actions.
4. The root of the tree denotes that the process is complete and the product is ready.
5. Chronologically later process stages are closer to the root than the earlier stages because the tree is oriented towards the root.
6. Each vertex u can be assigned pairs of numbers, p(u) and q(u), denoting the earliest and latest acceptable times of starting actions originating in the vertex.

Let us now explain the exact meanings of the notions and terms used in this article. The earliest acceptable action start time p(u) is the time when the state u appears, assuming that the preceding actions were performed on schedule.

The latest acceptable action start time q(u), represented by an edge originating in vertex u, allows to complete the entire process on schedule, provided that all the following actions are performed on time. For each vertex u of the production management model, the following inequality exists:

$$p(u) \leq q(u)$$

If strong inequality $p(u) < q(u)$ is met, then some extra time is available to the state u, which can be used to make up for any earlier delay in the string of actions. The acceptable length of this delay is given by $q(u) - p(u)$, which is not likely to affect the process completion time, unless the times of the next actions grow longer. However, if the equality $q(u) = p(u)$ takes place, any delay in the string of actions preceding state u may defer the process completion time. Therefore, the extra time, r(u), available to state u (i.e. the difference between the latest and earliest acceptable start times for an action) can be defined as follows:

$$r(u) = q(u) – p(u)$$

Based on the above, other assumptions can be formulated:
- if r(u) = 0, state u will be termed sensitive,
- if r(u) > 0, state u will be termed resistant.

To simplify the formulas, a state in the process represented by a vertex (e.g. u) will be treated as identical to that vertex, therefore the term 'state *u'* will be used. Analogously, an action originating from state *u,* with state *v* as its end, will be equated with the *u–v* edge and called the *u–v* action for the sake of clarity. The time of its execution will be denoted as t(*u–v*). These assumptions allow to form a production management model as a tree. Let us present its portion corresponding to the product creation subprocess (***Figure 2***).

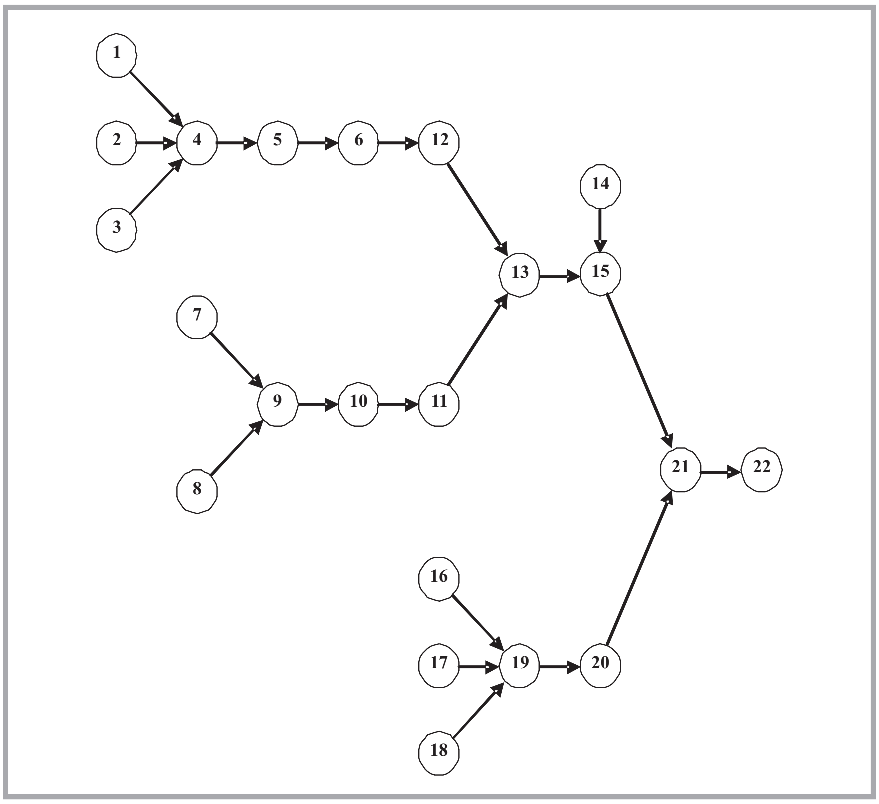

Figure 2. *Production management model – the product creation subprocess.* ***Source****: developed by the author.*

The designer does his job (4), which is central to the design making subprocess, based on the leaves (actions 1, 2, 3 in ***Figure 1***). The drawings accepted (5) are transferred to the sample room (6). At the same time, visually attractive fabrics are sought, selected and purchased for the sample room (7 − 11). The fabrics and markers prepared (12) are used for making cutouts (13), which are then assembled with accessories (14) to make a sample of the model (15). Parallel to that, abridged model documentation is prepared so that manufacturing costs can be calculated (16 − 20). The finished models are evaluated in terms of their appearance and functionality (21). The ones accepted are priced and added to the fashion collection (22). If the production process were designed as part of B2B services involving the delivery of corporate clothing (employees meeting with customers shape their employer's image), then body measurements (23 – 26 in ***Figure 3***) would precede the making of the markers.

The decisions giving the green light to the production of particular models (subsequent to consumer focus groups, shows at fairs, etc.) initiate the following processes:

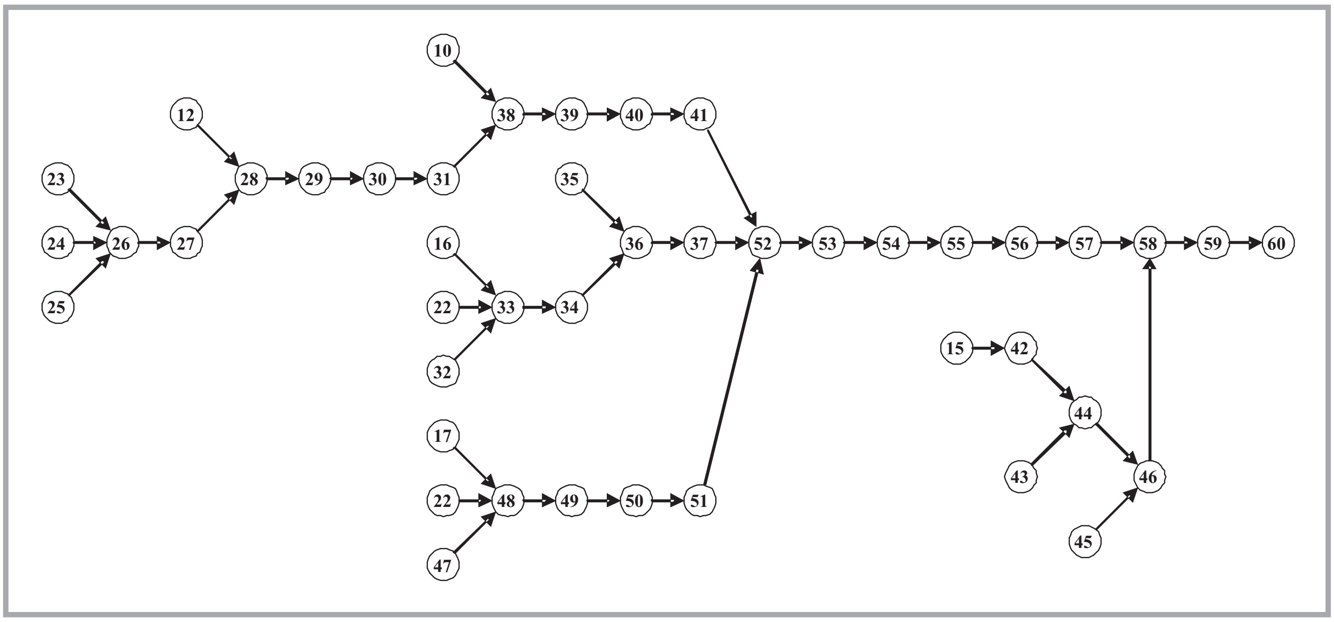

Figure 3. *Production management model.* ***Source****: developed by the author.*

- market grading (27 - 31),
- delivery of necessary materials (32 - 37),
- pattern making (38 - 41),
- preparation of technical and technological documentation for the sewing room (42 - 46),
- operational planning (47 - 51),
- product manufacturing (52 - 60).

The production management model discussed is illustrated graphically in ***Figure 3***, but without repeating the string of actions shown in ***Figure 2*** (the product creation subprocess). Let us concentrate our discussion on the product manufacturing subprocess, which is determined by only several vertices. Vertex 52 stands for assembling the 'job order' (i.e. the putting together of all materials, accessories, the earlier made sample, as well as technical and technological documentation for the manufacturing process), checking the order's completeness and then delivering the complete set to the manufacturing team. Vertices 53 − 57 represent the cutting room operations (spreading the fabric into stacks, dividing the stacked fabric into sections, making the patterns either automatically or manually, applying the stiffening inserts ((if necessary)), checking the cut-outs for quality and bundling them together into units of input delivered to the sewing room).

The cutouts and technological documentation for the assembly meet at vertex 58, being the string of operations performed in the sewing-room (the operations may vary depending on the model of clothing and sewing room equipment). For instance, it takes several tens of operations to assemble the cutouts of an overcoat. Given that the construction of the product manufacturing subprocess has already been discussed in another original study by the author in [7], it does not seem necessary to repeat it. Vertex 59 is the inspection of the finished product quality, and vertex 60 represents its delivery to the warehouse. Taking into account that the main goal of the investigation was to build a model of the production management process, the aggregation of elementary jobs into sub-processes seems rational.

Conclusions

A production management model based on an inverted tree concept (graph theory) allows an innovative, graphical representation of the management process to be applied to the production of short life-cycle goods. Although an inverted rooted tree has not been used in management theory so far, there are good reasons for constructing it, as it can help to:

- identify the sensitive graph routes, i.e. those determining process duration,
- develop a unique measure of the process resistance to change (PRI), enabling an immediate evaluation of the production management model for the production process designed or after each process modification caused by changes arising during its execution,
- develop a method for analysing changes in the management of the production of short life-cycle goods that allows its user to have active control over the process.

The amount of material concerning the issues above is quite extensive, therefore it will be presented in other articles that will be published in this periodical.

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