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Evaluation of flexibility for the effective change management of manufacturing organizations

K. Georgoulias [a], N. Papakostas [a], G. Chryssolouris [a,*], S. Stanev [b], H. Krappe [b], J. Ovtcharova [b]

[a] *Laboratory for Manufacturing Systems and Automation (LMS), University of Patras, Rio, Patras 26500, Greece*
[b] *Institute for Information Management in Engineering (IMI), University of Karlsruhe, Karlsruhe 76131, Germany*

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ABSTRACT

In this paper, we propose selected flexibility measures which can quantify flexibility and eventually integrate it into the change management processes of manufacturing organizations, aiming to increase effectiveness and competitiveness of the European industry. These measures can be utilized either stand-alone or integrated into a change management system to influence the change direction. A classification model supporting flexibility-related aspects is also discussed. A case study presenting a recommended integration of flexibility into a change management process is described. Additionally, a service-oriented architecture on IT level that can be adopted in order to combine the flexibility calculation with the change management is presented. The final objective is to investigate the integration of quantified flexibility indicators into the change management processes of a manufacturing organization.

1. Introduction

For many decades, cost and production rates were the most important performance criteria in manufacturing, and manufacturers relied on dedicated mass production systems in order to achieve economies of scale [1]. Delivery reliability has also been a primary concern of many companies [2] along with their aim to sustain a satisfactory product quality [3,4]. Nowadays, manufacturing organizations understand that these criteria have been further diversified. The competition has increased and the customer base is more mature. Cost and production rates are not considered adequate criteria anymore. The concept of customer satisfaction has been an underlying part of marketing and it is widely recognised as a predictor of behavioural variables, such as customer loyalty, repurchase intentions and others [5–8]; thus, becoming a primary objective of modern manufacturing firms. Customers today not only do they demand high quality and functionality of a product but also more and more individual product features, short delivery times and the use of the latest technologies [9].

Chryssolouris comments: “As living standards improve, it is increasingly evident that the era of mass production is being replaced by the era of market niches. The key to creating products that can meet the demands of a diversified customer base, is a short development cycle yielding low cost, high-quality goods in sufficient quantities to meet demand. This makes flexibility an increasingly important attribute to manufacturing” [1]. The ability to adapt to dynamic market demands and to ever shortening product life cycles is now a norm for many industries [10].

The turbulent market environments dictate frequent reconfigurations to adapt to emerging demands. To efficiently adapt, the manufacturing systems, in question, have to be flexible. Flexibility has to be considered in the “change decisions” of the stakeholders. However, to consider flexibility, companies must have a way of evaluating flexibility quantitatively [1]. Towards this objective, different approaches have been studied. A method, integrating the Real Options Analysis into Net Present Value calculations for measuring flexibility, in investment decisions, is described in [11]. Approaches to a flexible design for manufacturing systems have been studied [12], while the economic terms for cost effectiveness have also been considered [13]. Furthermore, flexibility in supply chains has been studied [14].

In change management, quantitative flexibility indicators can be exploited to provide the directions towards which the change should take place, when investigating the upgrade of a machine, the investment decision to increase flexibility or the reconfiguration to adapt to emerging production requirements. Additionally, these decisions can be reinforced by the utilization of simulation models in the design or operation phases. Different planning solutions can be tested and compared during simulation, whilst different scenarios (e.g. order forecasts or technical planning solutions) can be simulated [15].

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* Corresponding author. Tel.: +30 2610 997262; fax: +30 2610 997744.
E-mail address: xrisol@lms.mech.upatras.gr (G. Chryssolouris).

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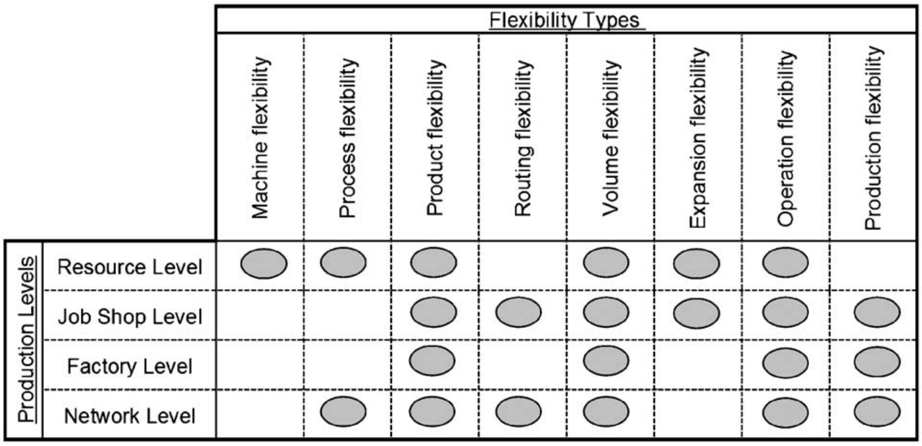

Production Levels	Machine flexibility	Process flexibility	Product flexibility	Routing flexibility	Volume flexibility	Expansion flexibility	Operation flexibility	Production flexibility
Resource Level	●	●	●		●	●	●	
Job Shop Level			●	●	●	●	●	●
Factory Level			●		●		●	●
Network Level		●	●	●	●		●	●

Fig. 1. Correlation of production levels with flexibility types.

2. Flexibility classification of manufacturing systems

2.1. Flexibility types and production levels

High flexibility or low sensitivity to a change provides a manufacturing system with three principal advantages. It is convenient to think of these advantages as arising from the various types of flexibility that can be summarized in three main categories as in Chryssolouris [1]:

- Product flexibility enables a manufacturing system to make a variety of part types using the same equipment. Over the short term, this means that the system has the capability of economically using small lot sizes to adapt to the changing demands for various products (this is often referred to as production-mix flexibility). Over the long term, this means that the system's equipment can be used across multiple product life cycles, increasing investment efficiency.
- Capacity flexibility allows a manufacturing system to vary the production volumes of different products to accommodate changes in the volume demand, while remaining profitable. It reflects the ability of the manufacturing system to contract or expand easily. It has been traditionally seen as being critical for make-to-order systems, but is also very important in mass production, especially for high-value products such as automobiles.
- Operation flexibility refers to the ability to produce a set of products using different machines, materials, operations and sequences of operations. It results from the flexibility of individual processes and machines, that of product designs, as well as the flexibility of the structure of the manufacturing system itself. It provides breakdown tolerance—the ability to maintain a sufficient production level even when machines break down or humans are absent.

Furthermore, to classify manufacturing systems, based on their flexibility-related aspects, an appropriate classification model needs to be identified. The aim is not only to study flexibility at a machine level but also at other levels of the enterprise. Thus, to examine the possibility of an indirect aggregation of flexibility indicators, starting from a machine level and ranging up to a production network, a classification model has to be utilized, to view the manufacturing organization in a hierarchy mode.

An example is the five-layer hierarchical model of production control, the AMRF hierarchy, dealt with in [16,17]. It presents and discusses the following five levels: (i) facility, (ii) shop, (iii) cell, (iv) workstation and (v) equipment. An analysis of traditional small batch manufacturing systems has provided the construction of this hierarchy. In another work, the concept of a task within a control architecture, called intelligent systems architecture for manufacturing (ISAM), is discussed [18].

In another approach, the following coherent classification model is provided in [1]:

- factory level
- job shop level
- work center level
- resource level

The highest level in hierarchy, the factory, corresponds to the system as a whole. A factory can be divided into job shops, which are sets of work centers commonly producing a family of products. A work center consists of resources capable of performing similar manufacturing processes. For example, a turning work center may include some or all of the lathes of a job shop. It should be noted at this point that there is no need for all individual resources to be at the same location in the factory, since a work center is only a logical grouping of resources. A resource is an individual production unit such as a machine, a human worker or a manufacturing cell (a group of machines and auxiliary devices (e.g. robots) that work together to perform an operation). Not only similarities but also differences can be found when it is compared with the five-layer hierarchical model discussed before. We initially identify that the equipment level is not present here, mainly because the latter model is focusing on the manufacturing processes and the resource level encapsulates the equipment pieces. It can be perceived that the resource level here can also be a manufacturing cell employed to perform an operation. The AMRF hierarchy eyes a wider approach, also considering information management, data sources, administrative management (such as accounting and procurement), system interfaces and more. It can also be identified that both of the hierarchy models adequately facilitate the efficient scheduling of manufacturing tasks and the assignment of tasks to production elements.

However, when it comes to flexibility, the need for the supply and manufacturing chain perspective of the enterprise to be addressed, can also be identified. Therefore, another level should be added, that of the network. This level addresses the production network of the enterprise and the outside partners of the enterprise, namely suppliers and subcontractors. Additionally,