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Design and planning of manufacturing networks for mass customisation and personalisation: Challenges and Outlook

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Abstract

Manufacturers and service providers are called to design, plan and operate globalized manufacturing networks, addressing to challenges such as ever-decreasing lifecycles and increased product complexity. These factors, caused primarily by mass customisation and demand volatility, generate a number of issues related to the design and planning of manufacturing systems and networks, which are not holistically tackled in industrial and academic practices. The mapping of production performance requirements to process and production planning requires automated closed-loop control systems, which current systems fail to deliver. Technology-based business approaches are an enabler for increased enterprise performance. Towards that end, the issues discussed in this paper focus on challenges in the design and planning of manufacturing networks in a mass customization and personalization landscape. The development of methods and tools for supporting the dynamic configuration and optimal routing of manufacturing networks and facilities under cost, time, complexity and environmental constraints to support product-service personalization are promoted.

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Keywords: Manufacturing Systems and Networks; Product-Services; Design, Planning and operation

1. Introduction

The changes in the economic, political and technological landscape during the last thirty years, have drastically affected manufacturing. The traditional localized and centralized manufacturing transformed into a globalized and decentralized paradigm. Stable markets, at the same time, become highly volatile and unpredictable [1]. The role of customer changed from that of a product buyer to an integrated entity in the product design and development.

Currently, manufacturers and service providers are presented with challenges such as reduced product life cycles, increased product, service and system complexity, and immense pressure from global competition [2]. These challenges are partly generated by the highly volatile demand and exploding product variety introduced by the mass customisation and product personalisation paradigms. Their impact on the design and operation of modern globalized manufacturing networks is evident [3]. Consequently they also heavily affect the operation of individual facilities.

The emergence of new materials, new forms of production and key enabling technologies make new diversified product features and processes feasible, as well as allow the interconnection between IT systems, humans and engineering / manufacturing phases.

The management of the co-evolution of product, process and production on a strategic and operational level is a huge challenge however, the manufacturing domain in general lacks of unified solution approaches [4].

Towards this end, technology-based business approaches comprise a major enabler for the realization of robust manufacturing systems and networks that offer high-value value-added, user-oriented products and services. Design, planning and control support systems with inherent robustness are necessary in order for companies to withstand the antagonism through sustainable practices.

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1.1. Review Methodology

The review approach is based on a search among academic journals, articles and books, primarily in the Scopus and Google Scholar databases, using as keywords the main fields of interest, namely: evolution of manufacturing paradigms, issues of mass customization and personalization environments, the role of simulation for manufacturing, methods and technologies related to product and production complexity, inventory management and capacity planning, among others.

Academic peer-reviewed publications related to the above fields were selected, ranging over a period of 30 years, from 1984 to 2014, with only a few notable exceptions.

Sciences that were included in the search were: engineering, management, business, and mathematics. The review was carried out in three stages: (a) search in scientific databases (Scopus and Google Scholar) with relevant keywords, (b) identification of relevant papers by abstract reading and (c) full-text reading and grouping into research topics.

Indicatively, the frequency of results from a search with the keywords "mass customization" or "product personalization" in the abstract, title and keywords of the article as obtained from the Scopus database, is depicted in Fig. 1. This figure also visualizes the increase of interest on these topics by the scientific community.

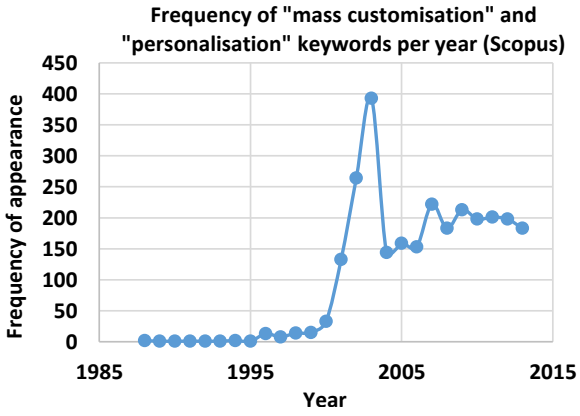

Fig. 1. Frequency of appearance of the keywords "mass customization" and "personalization" in the abstract, title and keywords of the article (obtained from Scopus)

2. State of the Art: Challenges and Practices

Globalization in manufacturing activities, apart from its apparent advantages, introduces a set challenges. On one hand, a globalized market offers opportunities for expanding the sphere of influence of a company, widening its customer base and production capacity. Information and Communication Technologies (ICT) and the Internet has played a significant role to that [5]. On the other hand, regional particularities greatly complicate the transportation logistics and the identification of optimum product volume procurement, among other. Indicatively, the difficulty in forecasting product demand, was highlighted as early as in 1986 by the following observation from Intel labs: when investigating the match between actual call off and the actual forecast, estimated that supply and demand were in equilibrium for only 35 minutes in the period between 1976 to 1986 [6][7].

Enterprises started locating their main production facilities in countries with favourable legislation and low cost of human labour [8], thus, the management of the supply chain became extremely complex, owing primarily to the fact that a great number of business partners have to mutually cooperate in order to carry out a project, while being driven by opportunistic behaviour. Thus, manufacturing networks need to properly coordinate, collaborate and communicate in order to survive [9].

On a manufacturing facility level, the impact of supply chain uncertainties and market fluctuations is also heavy. The design and engineering analysis of a complex manufacturing system is a hard task and its operation becomes even harder when flexibility and re-configurability parameters must be incorporated [10]. The process is iterative and can be separated into smaller task of manageable complexity. Resource requirements, resource layout, material flow and buffer capacity are some of these tasks [11]. Even when decomposed and relaxed through, production planning, assembly line balancing and sequencing are challenging tasks [12].

Especially in the context of production for mass customization businesses, issues such as task-sequence dependent inter-task times between product families are usually ignored, leading to inexact and in many cases non-feasible planning and scheduling. Even rebalancing strategies for serial lines with no other interdependencies is a difficult task, with ample room for improvement in order for the inconsistencies between process planning and line balancing to be minimized [13].

From a technological perspective, the increased penetration of ICT in all aspects of product and production life-cycle enable a ubiquitous environment for the acquisition, processing and distribution of information. With the introduction in manufacturing of the concepts of Cyber-Physical Systems (CPS) and Internet of Things (IoT) [14], new horizons are presented for improving awareness, diagnosis, prognosis and control.

Also, the relatively new paradigm of agent-based computation provides great potential for realising desirable characteristics in production, such as autonomy, responsiveness, distributiveness and openness [15].

2.1. Evolution of Manufacturing Paradigms

Historically, manufacturing paradigms, driven by the change of the environment in which they operate, change in character and evolve in patterns over time (Fig. 2). The various patterns witnessed up to now can be roughly correlated to movements between three stages: (i) craft shops that employ skilled artisans, (ii) long-linked industrial systems using rigid automation and (iii) post-industrial enterprises characterised by flexible resources and information intensive