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Manufacturing Networks Design through Smart Decision Making towards Frugal Innovation

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Abstract

The ever-increasing complexity of the advanced manufacturing environments together with the global competition, dictate the investigation of new approaches for manufacturing networks design and configuration. In addition to that, the newcomer concept of frugal innovation is moving towards a new business model by adapting local market requirements and providing cost-efficient and high customer-value solutions. Towards that end, a methodology for manufacturing networks design via a smart search algorithm is proposed, targeting the adoption of frugal innovation in a new manufacturing network. The proposed methodology is validated using data from an industrial case study.

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Keywords: Design; Manufacturing Networks; Frugal; Manufacturing.

1. Introduction

The contemporary manufacturing industry is characterised by immense competition, divergent regional markets, high demand volatility, and heterogeneity. Towards that end, manufacturing global supply chains are shaped into regional blocks, i.e. European, Asian and North-American [1]. This leads to regional characterisation of customer demands and product requirements. This combination of global production and distributed customer networks forms the basis of frugal innovation, which aims at exploiting the concept of intelligent use of resources, turning the related constraints into advantages and a driving force towards product innovation [2]. To address these challenges, the Original Equipment Manufacturers (OEMs) are searching for better approaches to create well-structured manufacturing networks with higher efficiency, moving towards a more close-to-customer approach. Thus, properly configured and easily adaptable manufacturing networks are needed, which would be capable of handling the complexity and enormity of the supply chain structures. The selection of optimum manufacturing network configurations that satisfy these challenging objectives however, is a proven data-intensive problem [3]. To support the decision process, this research work proposes a method for the design and operation of highly efficient modern manufacturing networks operating under demand fluctuations, economic and environmental constraints. In addition to that, a multi-criteria ranking method is utilized to rank the suitable suppliers and support the design of the manufacturing networks.

2. State of the art

The manufacturing environment is characterized by dynamic changes and ever raising complexity due to the fact that globalization and customer demand impose new requirements to industries [4], while states are creating legislation for a more socially and environmentally responsible production. Adding to this, the rising logistics costs, mass customization and regionalism are all trends pushing towards distributed manufacturing in order to achieve greater efficiency and sustainability [5]. Distributed manufacturing is going to play an important role in niche markets, where products created by local suppliers are more favourable to the public. Regionalism also affects production design, as adapting to local market requirements is of high importance for companies. This is a part of a bigger paradigm which is emerging, called Frugal innovation. Frugal products are low- to mid-end products or services sold mainly in emerging markets. They can be defined in terms of the attributes: Functional, Robust, User-friendly, Growing, Affordable and Local, and can be found in most industries [6]. Globalization and rising incomes in developing countries may also instigate frugal innovation. Such services and products

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need not be of inferior quality, but must be provided at a low and affordable price [7].

Distributed manufacturing can be defined as a system of autonomous agents; mutually dependent on each other, but at the same time are characterised by geographical dispersion [8]. These agents are companies that create a distributed manufacturing network (DMN), which is complex to design, plan and operate.

The configuration of a production network system follows the same logic in decision making and coordination of manufacturing activities on a global basis, as production systems in the development of production as well as in functions of production in plants or in plant areas (micro level)[9]. Decentralized manufacturing systems, also called as distributed manufacturing systems, have already shown many of their benefits. As shown in [10] and [11], the decentralized systems can handle unexpected market requests more efficiently, and therefore are better suited for DMNs. There have been many frameworks for manufacturing networks design, namely the game theoretic approach [12], the agent-based where a survey can be found in [13] and an architecture for outsourcing SMEs in [14], the holonic [15] and a multi-criteria method for network design[16], among others .

The main challenge during manufacturing networks design is to select the optimum suppliers based on their suitability and availability. Therefore, there is a need for multi-criteria supplier ranking and selection methods so that the chosen suppliers can be the most suitable for each circumstance. The multi-criteria ranking will give the opportunity to consider multiple and conflicting criteria that will support the supplier selection based on any new product configuration. There has been a large number of methods for dealing with this problem, which are further analysed in [17]. A commonly used method is the Analytic hierarchy process (AHP) [18], where the method provides a means of decomposing the problem into a hierarchy of sub-problems so that they are subjectively evaluated. The subjective evaluations are converted into numerical values and are processed to rank each alternative on a numerical scale. Another approach is the ELECTRE III [19], which is based on pairwise comparisons between alternatives characterised by outranking relations, that is then distilled by two antagonist procedures one ascending and one descending.

Addressing the aforementioned challenges of frugal innovation and the data-intensive problem of manufacturing networks configuration and design, the proposed methodology will aim at generating optimum manufacturing network configuration. The usage of a multi-criteria smart search algorithm supported by a multi-criteria supplier ranking and selection algorithm will reduce the solution space of the generated alternatives and will lead to high-performance manufacturing networks, addressing challenges of the existing literature review that have not yet been adequately tackled. Moreover, the proposed approach will increase the proportion of multiple and regional suppliers selecting the optimum ones and targeting frugality's main objectives of optimum cost and time.

3. Design and configuration of manufacturing networks

3.1 *Description of methodology*

This paper proposes a framework for manufacturing networks design and configuration, aiming at reducing the solution space of the network configuration problem and at generating optimum alternatives. The proposed method consists of two main steps. The first one is the multi-criteria supplier ranking and selection algorithm. The second one is a multi-criteria smart search algorithm (SSA) for the design and planning of the manufacturing networks.

The new product configuration is based on the regional customer demands and requirements, which trigger the algorithm of multi-criteria supplier ranking and selection. New regional and frugal components of the product are

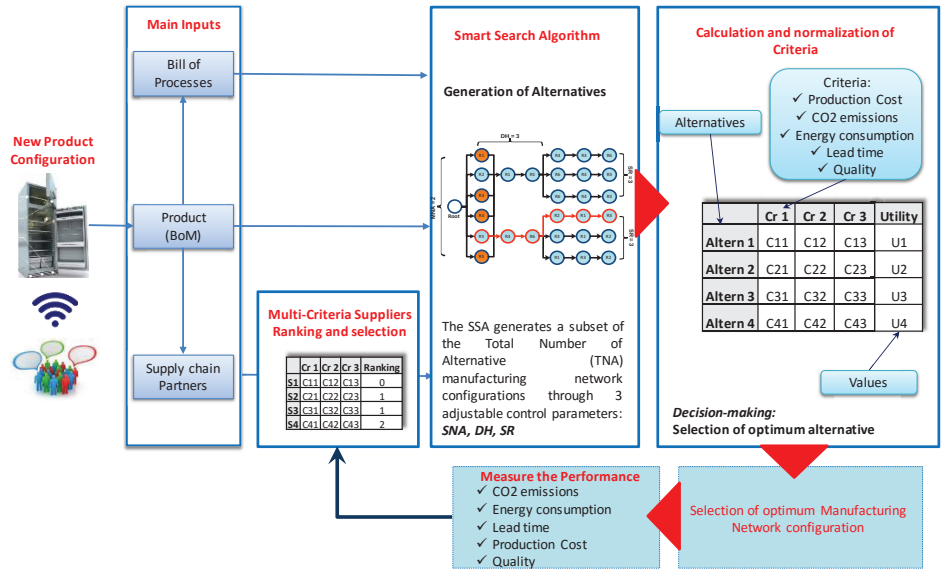

Fig. 1 Workflow of the proposed methodology