A literature review of optimization problems focused on scalability aspects for manufacturing systems

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1 Context

During the early decades of the twentieth century, the industrial environment was characterized by a relatively stable and high demand volume, low product variety and long product life cycles, leading to the emergence and widespread adoption of the concept of mass production. This latter relies on the standardization of manufacturing processes in order to efficiently produce a large quantity of similar products. Dedicated manufacturing systems are strategically aligned with the mass production paradigm, since they are designed to cost-effectively produce a single item at a high production rate. However, by the end of the twentieth century, as market demand became more dynamic and less predictable, the limitations of dedicated manufacturing systems became more apparent and the need to explore more adaptable manufacturing systems has arisen. This has led to the development of flexible manufacturing systems, characterized by their inherent generalized flexibility, enabling them to produce a wide range of products with changeable volumes. Nevertheless, the high initial investment cost and relatively low productivity of these systems make them unsuitable for many industrial sectors. To overcome the lack of flexibility in dedicated manufacturing systems and the high costs associated with flexible manufacturing systems, Koren et al. [2] introduced the concept of reconfigurable manufacturing systems which are characterized by customized flexibility. They are designed from the outset to respond rapidly and cost-effectively to a product family's changing requirements in terms of volume and functionality.

In order to efficiently address the demands of today's industrial environment, a modern manufacturing system should have a dynamic modular structure, facilitating the quick integration of new technologies. Additionally, it should provide real-time diagnostic capabilities to continuously assess and enhance system performance. A system with such a structure has the capability to modify its functionality to meet the requirements of a product family. Moreover, it should be able to adjust its capacity to cope with fluctuating demand, a quality commonly recognized as scalability. This latter, as highlighted by Koren et al. [3], has a direct impact on the company's profitability and its ability to survive in a turbulent business environment.

2 Scalability

According to Putnik et al. [4], scalability is defined as the ability of a manufacturing system to adjust its production capacity rapidly, incrementally and cost-effectively in order to respond to market demand. In the literature, scalability in manufacturing systems has received the attention of numerous studies. However, a limited number of these studies address scalability within the context of dedicated systems, mainly because of their inherent rigid structure.

Indeed, in order to increase the capacity of a dedicated production line, an entire new line needs to be added, resulting in doubling the system's production capacity. This could potentially lead to under-utilization of resources and financial loss. Similarly, scalability in the context of flexible manufacturing systems has not attracted the interest of many research studies because, even though these systems offer the benefit of incremental increase in production, their initial high cost remains a limiting factor for scalability. However, the primary focus of existing research on scalability revolves around reconfigurable manufacturing systems.

Scalability is a key feature of reconfigurable manufacturing systems, generally achieved by reallocating tasks to machines or by rearranging, removing and adding manufacturing resources. Issues of scalability management and performance measurement have been addressed by researchers at various decision-making stages, from the strategic to the operational one (see, *e.g.*, Cerqueus and Delorme [1]). Strategically, the studied problems involve designing production lines and making investment choices aimed to ensure that the implemented degree of scalability aligns with organizational goals. This requires making crucial decisions on layout design, resource selection and line balancing. In the tactical stage, researchers explore the challenges associated with determining a suitable arrangement of available resources, including machinery, equipment and manpower, to guarantee responsive scalability in the face of fluctuating demand. In the operational stage, challenges related to production planning are tackled to ensure efficient scalability. This involves determining optimal batch sizes and establishing a schedule that meet market requirements within a given planning horizon.

In this context, our objective is to conduct a literature review focused on scalability optimization problems. By employing various criteria, we intend to categorize the identified research publications comprehensively. The classification will be presented during the conference, offering insights into potential gaps, challenges and opportunities for future research.

References

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