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An integrated approach for warehouse analysis and optimization: A case study

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ABSTRACT

The paper focuses on the analysis and optimization of production warehouses, proposing a novel approach to reduce inefficiencies which employs three lean manufacturing tools in an integrated and iterative framework. The proposed approach integrates the Unified Modeling Language (UML) – providing a detailed description of the warehouse logistics – the Value Stream Mapping (VSM) tool – identifying non-value adding activities – and a mathematical formulation of the so-called Genba Shikumi philosophy – ranking such system anomalies and assessing how they affect the warehouse. The subsequent reapplication of the VSM produces a complete picture of the reengineered warehouse, and using the UML tool allows describing in detail the updated system. By applying the presented methodology to the warehouse of an Italian interior design producer, we show that it represents a useful tool to systematically and dynamically improve the warehouse management. Indeed, the application of the approach to the company leads to an innovative proposal for the warehouse analysis and optimization: a warehouse management system that leads to increased profitability and quality as well as to reduced errors.

1. Introduction

Nowadays, factors like globalization, competition, rapid market changes, short product life cycles, high productivity and reduction of time-to-market make the impact of logistics on production by far wider than in the past [1–5]. Such a complex scenario has led to a considerable interest in the design, planning and control of warehousing systems as new research topics ([6–10], Gu et al., 2010; [11,12]). Warehouses may be defined as material handling stations dedicated to receiving, storage, order-picking, accumulation, sorting and shipping of goods [13]. This definition covers a wide variety of systems, and may be broadly categorized by three types of warehouses [14]: (i) distribution warehouses, (ii) production warehouses and (iii) contract warehouses.

This paper considers production warehouses, a class that covers the vast majority of warehouses and may be defined as production sites facilities for storing raw materials, semi-finished products, and final products [14]. Moreover, considering the traditional classification of strategic, tactical, and operational problems, we focus on the strategic design of production warehouses, that has been shown to be a sector in need for investigation, as opposed to the strong research oriented on single sub-problems at an operational level that seems to be dominant in the literature [11].

The available literature on production warehouse strategic design and performance evaluation/optimization may be classified based on three main issues [15,16]: (i) contributions addressing warehouse design decisions, typically concentrating on order picking routing or product location strategies; (ii) papers proposing analytic or simulation models and (iii) publications on benchmarking and performance evaluation. The interested reader may refer to the comprehensive reviews by Baker and Canessa [17], Gu et al. [16] and Rouwenhorst et al. [11] for a discussion on the first two topics. In spite of the importance of warehouse design and their management, the technical literature on warehouse performance assessment is meager, with two main streams [15]: (a) contributions proposing frameworks for designing or analyzing warehouses and (b) those which directly address performance assessment. The reader interested in the latter topic is addressed to

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[15], where the authors tackle the warehouse coordination problem by analyzing the warehouse as a single system and quantifying its performance as a whole by a data envelopment analysis approach. On the contrary, many authors agree on the lack of systematic approaches on warehouse analysis and optimization [17,18]. This paper fills this gap proposing an integrated approach for warehouse analysis and optimization which employs several tools borrowed from lean manufacturing.

Lean manufacturing, originating from the Toyota production system, is the most widely known approach for industrial improvement [19]. Basically, the major goal of lean production is to reduce costs by eliminating any possible source of waste within the company. The seven sources of waste identified by the lean manufacturing are: over-production, waiting time, transportation, over-processing, inventory, motion, and scrap [20]. Hence, lean manufacturing is a multi-dimensional approach which comprises a variety of management practices and tools [21]. However, these tools are not integrated but are usually employed on an isolated basis. Moreover, they are typically applied to improve the internal logistics of the company and not the warehouse.

The research community has only recently started the application of lean principles to the warehouse [22,23]. Among the lean manufacturing tools, one of the most commonly cited in the related literature is Value Stream Mapping or VSM [24], thanks to its ability to provide a compact display of the system under examination. For this reason, there are several application examples of VSM to discrete manufacturing systems (see e.g. [25–27]). However, only few papers employ VSM for lean warehousing (see for instance [28–30]). Moreover, these contributions do not consider VSM in an integrated fashion with other tools for the systematic analysis and optimization of the warehouse.

Summing up only the integration of lean tools allows to analyze the overall warehouse management problem from different point of view solving it in a more logical approach.

Based on the lack of joined tools found in the related literature, this paper proposes a lean warehousing approach for analyzing and reducing waste in production warehouses. The presented methodology integrates the Unified Modeling Language (UML) formalism, the VSM lean manufacturing tool, and the so-called Genba Shikumi philosophy. In particular, the UML formalism is adopted to describe and analyze the warehouse activities and the corresponding responsibilities; this detailed representation is employed by the VSM tool to highlight in which area any possible waste is located; hence, the Genba Shikumi philosophy is adopted to rank the analyzed waste and determines the most significant ones to eliminate. This scope is obtained by reapplying the VSM and UML tools to respectively redesign the system without the described anomalies and detail its flows and activities. The physical implementation of the designed changes follows in the so-called final reengineering phase.

The iterative nature of the presented integrated approach brings to the so-called "*kaizen*", that is the continuous improvement which the lean philosophy is based on.

To enlighten the methodology, we employ a real case study, an Italian producer of interior design objects. The proposed technique is applied to improve some key performance indicators (KPI) of the company production warehouse, enlightening the approach effectiveness and leading to an innovative proposal for the warehouse optimization, with particular reference to the key order picking process.

The remainder of the paper is structured as follows. Section 2 presents an overview of lean manufacturing techniques motivating the presented approach, which is described in detail in Section 3, where its merits are also discussed with respect to the related literature. Hence, Section 4 presents the case study in order to validate the presented approach and discusses the obtained results, describing a possible reengineering proposal and the consequent future mapping of the case study. Subsequently, Section 5 presents the conclusions and possible future developments. The paper is concluded by the reference section.

2. Summary of lean manufacturing techniques and paper motivation

Lean manufacturing includes numerous tools and methodologies [31]. Among these, we recall those somehow connected with the methodology proposed in this paper.

1. VSM – VSM [21] is a tool used to visually map the flow of production and to show the current and future state of processes in a way that highlights opportunities for improvement. Dharmapriya and Kulatunga [28] apply VSM to optimize warehouse operations and use the simulated annealing heuristics to determine an optimal layout. Moreover, Gopakumar et al. [29] employ discrete event simulation and VSM for studying the dock allocation problem in a food distribution center, while Chen et al. [30] investigate the use of VSM with radiofrequency identification in the warehouse.
2. Genba – Genba [32] is a philosophy that recommends managers to spend their time on the plant floor (rather than in their office), i.e., in the place where real action occurs; it is a companion approach of VSM that focuses on the waste identification and removal, i.e., the ideal system, rather than on the actual one.
3. Jidoka – Jidoka [33] consists in partially automating the manufacturing process (note that partial automation is typically much less expensive than full automation) and automatically stopping when defects are detected.
4. Bottleneck analysis – it consists in identifying which part of the manufacturing process limits the overall throughput and improve the performance of that part of the process [34].
5. Kaizen – it stands for a proactive strategy for achieving continuous improvement [35].
6. Key performance indicator (KPI) evaluation – it is a technique related to kaizen that consists in the continuous analysis and monitoring of metrics designed to track and encourage progress toward critical goals of the organization [36].
7. Muda removal – it consists in the reduction or elimination of anything in the manufacturing process that does not add value from the customers' perspective [37].
8. PDCA – PDCA (Plan, Do, Check, Act) is an iterative methodology for implementing continuous improvement of processes and products [38].
9. Poka-Yoke – it is the design error detection and prevention into production processes with the goal of achieving zero defects [39].
10. Root cause analysis – it is a problem solving methodology that focuses on resolving the underlying problem instead of applying quick fixes that only treat immediate symptoms of the problem [40].
11. Visual factory – it consists in the utilization of visual indicators, displays, and controls throughout manufacturing plants to improve the communication of information [41].
12. Responsibility based planning and control – it is the practice of involving engineers in the planning process in order to ensure deadlines are met, backup plans are available, and tasks are completed [42].

It is to be noted that all these lean tools are rarely integrated into a streamlined, high quality system [43]. Recently, the