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# Cloud-based integrated shop-floor planning and control of manufacturing operations for mass customisation

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**Abstract**

The shift of traditional mass producing industries towards mass customisation practices is nowadays evident. However, if not implemented properly, mass customisation can lead to disturbances in material flow and severe reduction in productivity. This paper discusses the design and development of a Cloud-based production planning and control system for discrete manufacturing environments, referred to as i-MRP. The proposed approach takes into consideration capacity constraints, lot sizing and priority control in a 'bucket-less' manufacturing environment. The i-MRP system offers simultaneous shop scheduling and material planning, where material and capacity constraints are considered together in a continuous time environment. A number of feasible alternative shop schedules and material plan combinations are formed and are evaluated on the Cloud platform where the i-MRP engine is hosted. The Cloud platform enables mobility, since it is device and location independent, as well as it minimises the cost of IT infrastructure ownership, which is especially important for SMEs. The performance of the i-MRP system has been studied in an SME from the textile sector, using real production data. The system demonstrates high performance in cases of short production times, high value inventory and frequent, small deliveries by suppliers. The i-MRP can be easily integrated with legacy IT systems as an interfaced functional module under the Software as a Service (SaaS) architecture.


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## 1. Introduction

At the heart of currently used closed-loop Manufacturing Resource Planning (MRP-II) and Enterprise Resource Planning (ERP) systems in manufacturing enterprises, lies the fundamental Material Requirements Planning (MRP) logic [1][2]. Such IT systems entail major investments and involve extensive efforts and organisational changes in companies that decide to employ them. They integrate all business processes of the entire enterprise and tie the financial and marketing functions to the operations function, incorporating assets such as human resources, project management, product design, material and capacity planning [4].

Still, the classic time-phased material planning procedure is at the core of these systems as far as the production planning function is concerned [2][2]. Despite the vast and increasing adoption of such commercial MRP-based systems [5], a growing number of authors criticize their poor performance in relation to implementation costs. Recent studies, such as Lapiedra et al., [6], showed that few manufacturers were able to implement MRP-based systems successfully. In a survey conducted in [7], it was revealed that only 37% of the implementations achieved predicted budgets, and 66% of the companies realised less than half of the projected benefits. Moreover, while accurate percentages of unsuccessful implementations vary from study to study, nearly 20% of the times they are characterised as failures [7], with only a small number of companies achieving a Class A MRP operation [8]. The main reasons for that are commonly attributed to the fact that MRP-based systems do not produce detailed shopfloor schedules, since standard MRP method merely specifies the job release and completion dates in the context of time buckets [9]. Also, most of them assume infinite production capacity, thus using inflated, constant, and thus unrealistic lead times.

## 2. Literature Review

The integration of capacity limitations into the MRP planning process was one of the major areas of research in the past. Since the pure MRP logic is deployed in today's MRP-II,


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ERP and Supply Chain Management (SCM) systems, when they are used for production planning and control, their outputs suffer from the same false assumptions. The majority of the less recently published models and algorithms on capacity-sensitive production planning are complex and difficult to use in industrial practice. They employ either complex mathematical programming, as in Rahmnani et al., [10] and Wu and Shi [11], or heuristics in order to calculate workload-dependent planned lead times, as in Dobson and Karmarkar [12] and Aouam and Uzsoy [13]. Due to the fact that when the number of variables and constraints is raised the computational time increases rapidly, they operate under a lot of simplistic assumptions and restrict their use only to small problems. In addition, their performance under a dynamic production environment may be unreliable. As they are not easily understood by the planner, confidence in their results is limited [14]. Finally, the complications that product customisation introduces to the modern shop-floor, heavily its production planning and control functions, thus, the robustness of the deployed MRP-based solution is a catalytic factor for high performance.

These limitations have led to a lot of recently published research on the performance of different finite-capacitated production planning systems based on standard MRP. Pandey et al. [14] presented a capacitated material requirements planning algorithm that has been found to be superior to the existing standard MRP system in terms of mean job tardiness and inventory holding cost per part. However, the lot-sizing problem is not addressed and only a single resource for each part type is assumed to be available. Ho and Chang [15] proposed an integrated MRP and Just-In-Time (JIT) framework, modelled as an integer linear program in combination with forward and backward heuristics for finding detailed shop floor schedules with the objective of minimizing the total production cost without, however, providing any information related to actual implementations. Furthermore, they neither addressed the lot-sizing problem, nor did they deal with the refinement of the scheduling problem using multiple criteria. Koh et al. [16] presented the development and implementation of a generic model for simulating MRP-controlled finite-capacitated manufacturing environments in order to study the effects of uncertainty and production fluctuations on the performance of a company. The output of the infinite capacitated MRP planning acts as the main input to the simulation model. This link is problematic due to the fact that the simulation model does not recognize dependence relationships among the parts and hence it simply processes a part whenever the required resources are available. Iranpoor et al., [17] studied a general flexible flowshop scheduling problem minimising earliness and tardiness penalties deriving from the less or excess quantity produced. The model used deterministic processing times and fixed penalty costs for pre-defined production quantities. A capacitated master planning problem with inventory constraints over discrete multi-period horizons is presented in [18]. The paper focused solely on the determination of optimum pricing policies and schedules for a master facility planning level, thus the time components were aggregated, and possibly non-realistic. Another recent study, considered a drum-buffer-rope-based production planning method as a control mechanism that exhibited high potential as a decision making tool especially for turbulent manufacturing environments [19]. However, a constraint of the method is the acquisition of real-time accurate monitoring data that require specialised high-investment equipment found only in state of the art shop-floors.

Literature on capacity-sensitive MRP fails to provide a comprehensive solution to all discrete manufacturing environments especially for finite short to medium-term horizon. Their application is usually limited to a number of constraints, such as the number of machines and processing stages, input from an interfaced MRP system, and bucketed planning horizon convention to name a few.

The proposed i-MRP production planning and control system incorporates a flexible workload and facility modelling, capable of representing the entirety of discrete manufacturing systems. In comparison to commercial solutions, it requires low implementation efforts, involves minimum organisational changes for its deployment, and is based on an easily maintainable. Moreover, the system considers finite production capacity in a bucket-less environment, thus it provides a detailed schedules without inflated constant time components. Finally, a Cloud infrastructure is designed for hosting and exposing the application as a service. This servitisation model offers benefits such as mobility and low investment costs, and allows the easy maintenance, synchronisation and version-control of material and production planning information.

## 3. Concept and design of the i-MRP system

This section presents the basic structure of the proposed i-MRP system. The i-MRP production planning and control tool is itself not MRP-based and supports the integration of shop scheduling and material planning under constraints imposed by the finite capacity of a manufacturing system. Items with relatively small cycle times and/or high inventory value, which is usually the case in textiles, can pass under its control.

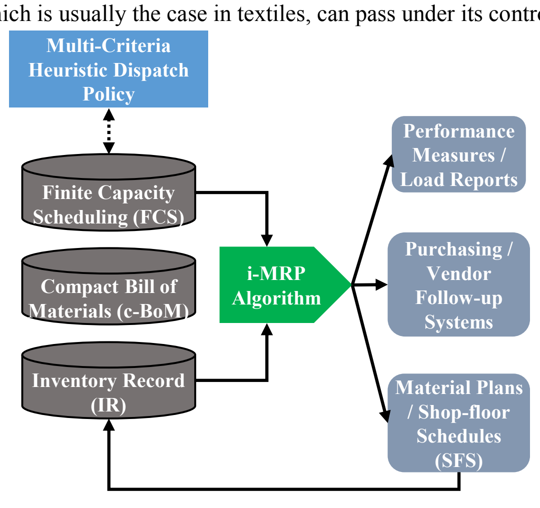


Figure 1. i-MRP system main inputs and outputs

The i-MRP tool has been primarily developed for the textile industry, but, it can be also implemented in other multi-