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Optimization Algorithms for Collaborative Manufacturing and Logistics Processes

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ABSTRACT. *This paper comprises the starting point of research, with the presentation, of a taxonomy for classifying manufacturing and logistic collaborative processes, which is based on SCOR views (Supply Chain Council, 2012), regarding with source (S), make (M), and delivery (D) plans, and their combination (SM, MD, SMD). In a second part, this paper focuses on the state of the art carried out within the scope of models and algorithms proposed to support enterprises in the decision-making of calculating plans from a collaborative and automated perspective. Identified Plans and Algorithms are classified according to the presented taxonomy. An analysis of the models and algorithms proposed, so far, in the literature is presented.*

KEYWORDS: *Logistic Collaborative Processes, Supply Chain, Algorithms, Decision-making, Optimization.*

1. Introduction

Over the last years, collaboration has increased its attention in both scholars and practitioners, due to the associated competitive advantages, specially, for SMEs, in front of large manufacturing industries. Nevertheless, SMEs have higher difficulties to acquire collaborative tools; therefore, there is a gap for the identification and contribution of models, algorithms and tools to support SMEs in the establishment of manufacturing and logistic collaborative processes. Motivated by this, there is a need to identify and provide to SMEs specific models, algorithms and tools to support them in the optimisation of Source (S), Make (M) and Delivery (D) plans, typically identified in manufacturing networks (Supply Chain Council, 2012). This paper focuses, first, on describing the taxonomy, used to classify the collaborative plans identified, which will be subsequently employed to review and analyze them (Section 2). The second part of the paper presents the analysis of Plans identified in the literature that propose optimisation approaches (Algorithms) to deal with Collaborative Manufacturing and Logistics Processes (Section 3). Finally, Section 4 provides future research work, and the main conclusions are discussed in Section 5.

2. Taxonomy for Classifying Manufacturing and Logistic Collaborative Processes

The proposed Taxonomy used for analysing Collaborative Plans, considers the following features: (i) Type, (ii) Sub-Type, (iii) Aggregation Level, (iv) Algorithms Type, (v) Input Data, (vi) Output Data and (vii) Collaboration Level. The *Plans Type* refers to the Plans Characterisation, based on SCOR views: Sourcing, Production, and Delivery requirements, and their combination: Source (S); Make (M); Deliver (D); Source and Make (SM) Plan; Make and Deliver (MD); Source and Make and Deliver (SMD). *Plan Subtype* refers to a second level of Plans Categorisation, describing more precisely the identified plans so that the plans have different inputs, outputs and objectives. Different *levels of planning* are considered depending on the degree of detail of the information available to calculate the plan, and the horizon and period of planning: Aggregated Plan; Master Plan; Scheduling; Sequencing Plan. *Algorithms* are classified concerning its calculation mechanism, which is related with the calculation time and the proximity to the optimum: (i) Optimiser, e.g., Dynamic Programming; (ii) Heuristic, e.g., Nearest Neighbour or Lagrangian; (iii) Metaheuristic, e.g., Genetic Algorithm; (iv) Matheuristic, e.g., Cross-Entropy Progressive Hedging. *Input Data* is considered as needs and resources and objectives of the production, replenishment or delivery processes. Each algorithm will handle with different Input Data and will result on different *Output Data*, which is related with the plan solution and the amount to be produced, ordered or supplied.

3.1. Source Plans

Source (S) Plan deals with the goods procurement to meet the demand. S/Inventory Planning deals with the inventory management in the procurement of raw materials in the supply chains, to meet optimal inventory parameters that must be maintained to meet expected service levels for demand fulfilment. In this category, Valencia and Cáceres (2011) propose Genetic Algorithms, and Deng *et al.* (2014) proposes a Simulated Annealing algorithm. S/ Procurement Planning deals with the procurement management of a buyer who needs to purchase a variety of goods from its suppliers demand. Fu *et al.* (2010) propose linear programming algorithms and Ab Rahman *et al.* (2015) presents a genetic algorithm. S/Material Requirements Planning translates a production schedule of a finished product into a known quantity and timing needs for components based on bill-of-material and lead-time information. Billington *et al.* (1983) and Mula *et al.* (2006) propose linear programming algorithms. S/Replenishment Planning calculates inventory replenishment policies taking into account the variations in customer demand and replenishment order lead times. In this category, Disney and Towill (2002) presents a dynamic programming algorithm and Pibernik (2005) proposes a branch and bound algorithm.

3.2. Make Plans

Make (M) Plan deals with the transformation of a product into a finished state to meet the demand. The plans subtype identified for M are M/Finished Good Inventory Planning models that deal with the inventory management of finished goods to meet the demand, a Dynamic Programming algorithm is used (Graves and Willems, 2000), as well as in (Hall and Potts, 2003) to deal with M/Production Scheduling, to identify start and end times of individual products, machine assignments and lot sizing, given due dates, demands, and operational constraints. M/Production Planning deals with the allocation of assets to tasks, and production, inventory and work force levels in order to satisfy the demand, optimisation algorithms such as Simplex are used (McDonald and Karimi, 1997). M/Production Sequencing deals with the order of jobs on a shared workstation, a Tabu Search algorithm is proposed by (Franz *et al.*, 2014).

3.3. Deliver Plans

Deliver (D) Plan deals with the provision of finished goods to meet the demand. The identified subtype plans for D are D/Demand Planning to manage demand

forecasts as input to service-planning processes, production, and inventory and revenue planning, to deal with this plan Gelper *et al.* (2010) present robust Holt-Winters smoothing method for forecasting. D/Distribution Planning concerns the design of the distribution network; deterministic, metaheuristic (Arntzen *et al.*, 1995) and stochastic approaches (Santoso *et al.*, 2005) are used to address this plan. D/Order Promising matches customer orders against available manufacturing resources, and replies with promised quantities and due dates (Pibernik, 2005). D/Transport Planning concerns the movement of components to manufacturing enterprises for accomplishing production requirements (Sakawa *et al.*, 2001).

3.4. Source and Make Plans

Source and Make (SM) Plan deals with the procurement of goods and transforms them into finished goods to meet the demand. The plans subtype identified for SM are S/ Materials Requirements Planning and M/Production Planning, specifies the quantity to produce in every period, the planned ordering of components (MRP), and the stock levels, delayed demand, and capacity usage. S/Inventory Planning and M/Production Planning deals with a planning model where sourcing considerations are important, given that products can be manufactured at several facilities. For both plans optimisation algorithms such as Simplex are proposed (Mula *et al.*, 2006).

3.5. Make and Deliver Plans

Make and Deliver (MD) Plan deals with the transformation of products into finished goods and delivering them according to the received orders. The subtype plans identified for MD are M/Production Planning and D/Distribution Planning, which deals with the designation of production and distribution quantities of each item for each time period at each site, while taking capacity constraints and distribution lead-time into account. M/Production Planning and D/Transport Planning deals with two phases, (i) the efficient allocation of the production capacity at the various production sites, and (ii) the procurement transport activities for accomplishing production requirements. Most of the studied plans apply Simplex optimization algorithm (Rizk *et al.*, 2008), while also Lagrangian (Jayaraman and Pirkul 2001) and Genetic (Aliev *et al.*, 2007) algorithms are suggested, among others.

3.6. Source, Make and Deliver Plans

Source and Make and Deliver (SMD) Plan deals with the procurement of goods, transforms them into finished goods and provides finished goods to meet the

demand. The identified subtypes are (i) S/Inventory Planning and M/Production Planning and D/Distribution Planning models deals with the configuration of the production-distribution system with the lowest supply, production, transportation, inventory, and facility costs to meet the demand. Most of them are solved through Simplex (Rizk *et al.*, 2008), non-Linear Programming (Benjamin, 1998) or Lagrangian Heuristic (Barbarosoglu and Ozgur, 1999); and (ii) S/Replenishment and M/Production Planning and D/Distribution that deals with sourcing considerations for replenishments, production facilities, and distribution centres with decisions about allocation of final goods to production lines. Simplex (Alemany *et al.*, 2010) and Multi-objective Linear Programming (Sabri and Beamon, 2000) are proposed.

4. Conclusions

This paper presents a summary of a taxonomy used to classify and analyze Collaborative Manufacturing and Logistics Processes. Considering the classification of Plans Type provided in the taxonomy, a literature review is performed in order to identify models and algorithms, which address replenishment, production and distribution plans. As a result of the performed analysis a good understanding of the different optimisation approaches existing in the literature is obtained. By implementing the taxonomy previously described, this research work should be able to propose a concrete solution to support the selection of optimization and simulation algorithms by facilitating the matching between the companies' requirements and scholar proposals. This should also allow identifying the rooms of improvement of existing models in terms of Supply Chain collaborative processes.

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