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Characterizing Productive Processes with Lack of Homogeneity in the Product and its Impact on the Master Planning and Order Promising[1]

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Abstract: Manufacturing environments with Lack of Homogeneity in the Product (LHP) are characterized by the fact that units of the same product can present differences in some attributes relevant to customers. This aspect becomes a problem when customer needs to be served with homogeneous units of one same product. Though LHP is present in many sectors, particular characteristics introduced by LHP in transformation activities, products and orders have not been previously studied in a systematic approach. This paper provides a conceptual framework for characterizing LHP manufacturing processes and analyzes the LHP impact on the master planning and the order promising, stressing the new aspects introduced by LHP as compared with traditional environments.

Keywords: Conceptual Framework, Master Planning, Order Promising, Lack of Homogeneity in the Product.

1.1 Introduction

The Lack of Homogeneity in the Product (LHP) is defined as "the lack of uniformity required by the customer in the products" (Alarcón et al. 2011). LHP appears in those productive processes which include raw materials that directly originate from nature and/or production processes with operations which confer

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heterogeneity to the characteristics of the outputs obtained, even when the inputs used are homogeneous. LHP is present in certain industries like ceramics, textile, wood, marble, tanned hides, leather goods, horticulture and oil. All these industries have in common that are obliged to include one or several classification stages along the productive process whose localization along the process and classification criteria depend on the specific industry. For instance, in the horticulture sector, important criteria for sorting and grading fresh fruit are size, weight, ripeness, damages, color, shape and firmness (Verdow et al., 2010). In the ceramics sector, the classification criteria are based on (Poyatos et al., 2010): aspect (qualities), tone and gage.

LHP impacts the management system in various ways: the existence of several subtypes of the same item increases the number of references and the information volume to be processed. Furthermore, LHP manufacturing systems have to deal with a new kind of uncertainty: the future homogeneous quantities available of one same product. This uncertainty proves to be a problem when customers' orders should be promised, reserved and served from planned production quantities for which the real homogeneity distribution will not be known until their production were finished. This uncertainty will lead to differences between planned and real homogeneous quantities that can make impossible to serve previously committed orders in the terms of homogeneity, quantities and dates promised. Improperly LHP management can impact very negative in revenues, costs and customer satisfaction. In view of the scarce research in the LHP management field (Alarcón et al, 2011; Roma and Castán, 2009) and being conscientious that LHP affects several sectors, the main objective of this paper is to provide a framework for characterizing LHP productive processes (section 2). The application of the framework to a specific productive process will provide decision-makers with the LHP key aspects to properly manage their specific LHP situation. After identifying those LHP characteristics, sections 3 and 4 offer an analysis of their implications in the master planning and the order promising processes. Assessing the impact that each LHP aspect has on both processes, will allow the choice of the LHP characteristics that merit consideration in the decision making for each case.

1.2 Framework for Characterizing LHP Productive Processes

The **research methodology** for deriving the present framework has been the productive process analysis of different sectors presenting LHP (wood, ceramic, marble, horticulture, pearl, skin and textile) as regards three blocks: transformation activities, products and order proposal characteristics. Based on this analysis, the abstraction of common aspects related to the three blocks of the conceptual framework that are relevant for the properly LHP management have been derived. Figure 1 shows an overview of the whole paper: the three blocks composing the

framework and their relationship with the master planning and the order promising processes that are described in the next sections.

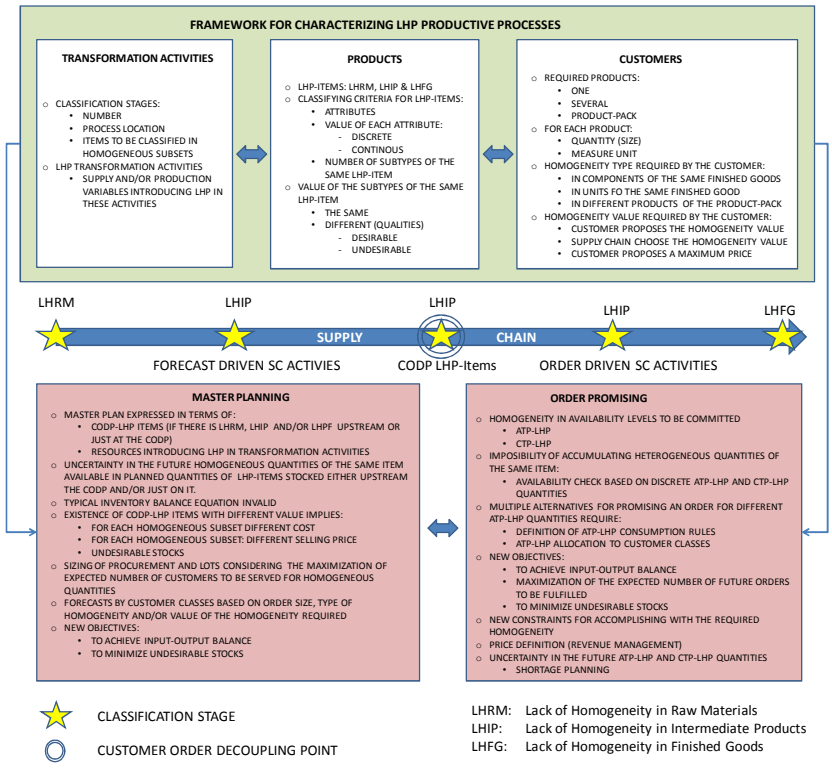

Fig. 1.1 Framework for characterizing LHP productive processes and their relationship with master planning and order promising

1.2.1 Transformation Activities: Classification Activities as the Key

To describe any manufacturing process is necessary to identify transformation activities that take place from the input material to finished goods. Transformations are business processes that contribute directly to the creation and movement of products by a company (Verdou et al., 2010). Traditionally they have been classified in engineering, production, assembly and distribution (transport, handling and storage) activities. However, for LHP contexts the identification of **classification activities or sorting stages** becomes crucial. In fact, the key LHP element will be the number and **situation of classification stages** along the productive process as

well as **items classified** in each one of them. Furthermore, with the aim of anticipating the homogeneous quantities available in production plans, it will be necessary to identify the **transformation activities that introduce heterogeneity** in the process and the **variables** that cause it. It will be important to define the relationship between the heterogeneity origin and the productive resources (on the same machine, between machines, in time). This helps us to know the degree of detail for modeling resources in the master planning.

1.2.2 Products

With the aim of being more exhaustive in the determination of the **LHP origin**, we extend the LHP definition provided by Alarcón et al. (2011) introducing the terms Lack of Homogeneity in Raw Materials (**LHRM**), Lack of Homogeneity in Intermediate Products (**LHIP**) and Lack of Homogeneity in Finished Goods (**LHFG**) to differentiate if the classified items are either raw materials or intermediate products and components or finished goods, respectively. Furthermore, this classification will allow the identification in the heterogeneity origin: raw materials (LHRM) or productive process (LHI and/or LHFG without LHRM) or both them (LHRM and/or LHI and/or LHFG), allowing the location of the **uncertainty** in the supply and/or the production process, respectively. For each sorted item, the **classification criteria** and the **values** they can take (discrete or continuous) should be identified. This provides us the **number of subtypes** of the same LHP-item that can have the same and/or different value. Usually, different values imply the existence of several qualities. For instance, in the ceramic sector, the same production batch results in various qualities (first, second and third one) with a decreasing value. In addition, within each quality different shades and sizes are found with the same value.

1.2.3 Customers

Because LHP management problem arises from the homogeneity requirement imposed by customers, it is crucial to identify the customizable parameters of order proposals affecting LHP. As in most companies it will be essential to know from the customer order, the **requested products** (one, several or a product-pack), the **unit measure** for each product (that can be dependent on the customer class: units, pallets or trucks), the **quantity** and the **due date**. But LHP introduces a new customized aspect in order proposals: the **homogeneity type required** by the customer among the ordered products. The customer may require uniformity between **components of a product** (pearls on a necklace) or between **units of the same product** (ceramic tiles) or between **different products of a product-pack** (chairs

and a dining table). In addition, the customer **can specify the value of the homogeneity attributes required** or, in case there are subtypes of the same item with different value, the **maximum price** willing to pay. Note that the **order size** becomes a very relevant factor for LHP because the larger the orders size, the more difficult will be to meet the uniformity requirement among all their units.

1.3 LHP Impact on Master Planning and Order Promising

Two of the key processes that attempt to provide the customer with the degree of uniformity required in his/her orders are the **order promising process** and the **master planning**. These two processes are strongly **connected** in the border established by the **customer order decoupling point** (CODP). The CODP location along the productive process is a strategic decision (Olhager, 2010) that defines the manufacturing strategy adopted (make-to-stock (MTS), assemble/configure-to-order (ATO/CTO), and make-to-order (MTO)). The CODP separates the forecast-driven parts of a supply chain from the order-driven parts in such a way that only the items upstream the CODP and just at the CODP are stocked (i.e. planned against forecasts). Besides, the master plan should be expressed in terms of CODP items (Ball et al. 2004): raw materials and components in MTO; intermediate product and subassemblies in ATO, and finished goods in MTS. Based on the CODP items quantities in the master plan, the on hand inventory and the committed orders, the order promising process calculates the uncommitted available quantities to be promised to customers (ATP). Therefore, it can be understood the close relationship between the master planning and the order promising on the boundary defined by the CODP (Christou and Ponis, 2009).

As it is described below, for LHP manufacturing environments it is crucial not only the CODP location but also its relative position as regards the classification stages. This aspect represent the starting point to analyze LHP implications in the master plan and order promising that, in turn, will constitute the basis for choosing the LHP characteristics relevant to be modeled.

1.3.1 CODP and Classification Stages: CODP LHP-Items

Because the master plan and the ATP quantities are expressed in terms of CODP items, the start point to properly manage LHP is to determine if CODP items are classified based on some criteria: i.e. the existence or not of CODP LHP-items. From the application of the previous described framework (section 1.2), the location of classification stages along the productive processes and the classified items are known. Based on this information, the **relative position of classification stages** regarding the **CODP** can be derived. **CODP LHP-Items** will appear when

there are some classification stages before or just at the CODP. That is, CODP-LHP items will appear when there are FHRM, FHIP o FHFG before or just at the CODP. The existence of CODP LHP-Items implies to deal with **different subtypes stocked of the same item, not** being possible to **accumulate their stocks for serving customer orders** at the CODP because of their heterogeneity. Additionally, if there are subtypes of the same item with different value, the existence of **undesirable stocks** will appear for references with low or null value.

1.3.2 LHP Master Planning

The objective is to derive a master plan that should feed up the order promising process with precise information about the expected homogeneous quantities of each subtype (**LHP Master Plan**). For properly LHP modeling, the master plan should be expressed in terms of CODP items that in LHP context can imply dealing with **CODP LHP-items**. If it is known the **impact on LHP of productive resources** upstream the CODP (supply and/or production **variables** introducing LHP in transformation activities carried out by these resources), the master plan should be defined with a detail degree regarding **resources** that allows anticipating as much as possible the future homogeneous quantities available of an LHP-Item. For instance, in ceramic sector, batches of one same product processed in different production lines and time periods are most likely to not be homogeneous then, the master plan should specifies the quantities to be produced by each production line of each plant in each time period (Alemany et al., 2010)

LHP modeling in the master plan supposes the appearance of a new kind of uncertainty: **uncertainty in the future homogeneous quantities** of the same item available in planned quantities of LHP-items stocked either upstream the CODP and/or just on it. Because heterogeneous quantities of the same LHP-item cannot be mixed, the **typical inventory balance equation** becomes **invalid**.

The existence of CODP LHP-items with different value supposes a **not uniform sharing of cost among the expected homogeneous quantities.** This fact can lead to **different selling prices** for each subtype based on their value in such a way that selling prices should be greater for subtypes of the same item with scarce availability and high demand. Furthermore, **undesirable stocks** for LHP-items with low or null value and low or null demand can appear along the supply chain.

For maximizing the expected customer orders fulfilled, it should be recommendable **to size the planned items quantities** trying to serve an **integer number of customer orders**. This means, that the typical constraint of accomplishing the aggregate forecasted demand for an item does not ensure the fulfillment of all its orders, due to the impossibility of mixing heterogeneous quantities to serve the same customer order. In this sense, it will be useful to obtain **forecasts for each item per customer classes** which will be defined based on the **order size, type of homogeneity and/or value of the homogeneity required**. Uncertainty inherent to

LHP environments and undesirable stocks can lead to define **additional master plan objectives** related to the balance achievement between homogeneous availabilities and uniformity requirements generated by sales (**input-output balance**) as well as **minimizing undesirable stocks.**

1.3.4 LHP Order Promising

Because ATP is derived from the Master Plan, dealing with CODP LHP-items in master plan implies the existence of **multiple ATP-LHP homogeneous quantities** for those items than cannot be accumulated to serve an order. In case there is not enough ATP for promising orders it will be possible to compute the uncommitted quantities of materials and productive resources (Capable-To-Promise: CTP) upstream the CODP to produce additionally quantities of CODP items modifying the master plan. Furthermore, if CODP items are not finished goods, the order promising process should compute CTP quantities for each resource downstream the CODP to ensure there is enough capacity to finally produce finished goods from the CODP items by the Final Assembly Schedule. In this case the **CTP-LHP** management will be necessary if either there is LHMP and/or LHIP downstream and/or upstream the CODP or it is known the impact of the part of the productive process on the heterogeneity characteristic of finished goods upstream or downstream the CODP. If the impact of productive resources on LHP is known, to ensure as much as possible that orders are reserved from homogeneous quantities of one same product, **it should be not allowed to serve an order by accumulating heterogeneous ATPs-LHP subtypes** not only from the same item but also from different time periods or from different resources. When there are different ATP-LHP homogeneous quantities from which to serve an order, the final choice will affect subsequent promises. In this case, formulating **consumption rules** for guiding the choice of specific **ATP-LHP from** which to serve the order complemented with **ATP-LHP allocation to customer classes** can constitute different approaches to increase order promising efficiency. Implementation of such LHP consumption rules can imply the definition of **additional objectives and/or constraints** different from the typical ones, with the aim of guiding the best choice of reserving ATP-LHP from multiple alternatives. These new objectives should be related with the **reduction of undesirable stocks** when promising orders, the **maximization of the expected number of future orders to be fulfilled** and the **input-output balance**. A key element for achieving this input-output equilibrium is the **selling price definition** that is typical of revenue management.

Finally, **uncertainty in the future homogeneous quantities** will originate differences between the previous planned homogeneous quantities and the real ones. In order to minimize the committed orders that cannot be served due to this uncertainty, effective methods for **shortage planning in LHP environments** should be developed.

1.4 Conclusions

Improperly LHP management may have very negative effects on SCs' competitiveness: 1) appearance of undesirable stock; 2) uncertainty in the homogeneous quantities can lead to produce more than necessary increasing stocks; and 3) the customer service level may prove deficient (even when high stock volume) if the heterogeneity is not managed in a suitable manner. The master planning and the order promising processes play a crucial role in the proper LHP management. However, the special LHP characteristics to be considered in both processes are strongly dependent on the specific manufacturing process. Therefore, to help in the properly LHP management, in this paper the characterization of LHP productive processes and their impact on the master planning and the order promising have been described. The result is special LHP characteristics suitable to be considered for its right management. Because incorporating LHP characteristics implies an increase of the decision-making complexity, future research lines are focused on modeling LHP aspects and assess under which circumstances to model the complexity inherent to LHP implies substantial improvements.

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