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A proposal for scheduling and delivery orders under VMI environment

A. Santoja, P. Gómez-Gasquet[1], R. Cortés[1]

[1] Centre d'Investigació de Gestió i Enginyería de Producció, Universitat Politècnica de València, Camí de Vera s/n, 46022, València, Espanya, pgomez@cigip.upv.es

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1. Introduction. The VMI as a Challenge and Opportunity

Vendor managed inventory (VMI) is a widely applied stock management method in SCM in which the inventory is controlled, planned and managed by the supplier, on behalf of the organization which consumes the product, based on an expected demand and on previously agreed inventory levels. Thus, is the supplier who, according to the customer inventory levels, generates a purchase order defining quantities and delivery dates (Marques et al., 2010).

As a general rule, when such a stock management system is introduced, the objectives are diverse. One of the most important is to avoid excessive inventory levels in the different elements of the supply chain and the Bullwhip effect caused by demand variability (Campuzano-Bolarín et al., 2010). In addition, it is reasonable to expect a reduction of the administrative costs, due for instance to duplicity of administrative errors in the transmission of information.

In order to implement a VMI system, there must necessarily exist a high level of confidence in the business relationship between customer and supplier. The provider must have at any time updated information on the customer´s demand and inventory levels. However, this is not the only key factor for success that must exist. Leadership commitment and acceptance of the project by purchasing and sales departments involved are also essential concepts. Finally, an electronic data interchange system for the structured transmission of data between the two organizations must be defined and adapted to the management systems of the companies.

As a consequence of the implantation, besides the aforementioned stock and costs reduction, a higher degree of customer loyalty in the commercial relationship is attained. However, the most important consequence is a general improvement in the service level obtained after removing communication barriers and clearing the way to information flow throughout the process of stock management and order processing (Kharazi and Jandaghi, 2011).

Still, this saving in administrative costs and the improvement in the service level provokes very often the overlook of the fact that VMI systems represent an important chance to improve the internal operations management for the companies involved. The adaptation of the logistics and operations management processes to the VMI system, is a source of opportunities for both the customer and the supplier.

In the case described in this paper, the company QMC was able to identify the opportunity to improve some specific aspects on its operations management, relating to the products that as “vendor” would manage through VMI. (Thron et al., 2006)

The work has been structured in four sections. Besides this introduction, Section 2 describes the problem of the enterprise that we will resolve. Section 3 describes the proposal. Section 4 analyzes the experimental results and, finally, Section 5 briefly discusses the need, expected contribution and further research steps.

2. The problem of QMC

QMC produces a range of complementary products for a company, which is a world leader in its sector. The range consists of approximately 50 references, with very similar characteristics, whose main difference is the color of the product.

The product is manufactured in batches, in a configuration to be treated as a two-stage flow shop. The first stage of the flow shop consists of a set of 7 mixers that can be considered parallel machines. The jobs are processed by means of these mechanical mixers that stir the different materials contained in a process tank. The mixers and the tanks can only handle a minimum and a maximum volume, directly related to the power of the main mixer engine and the volume of the tank. In the first step of our analysis, we propose a simplification of the problem omitting the fact that the machines are non-identical.

The second stage of the flow shop consists of a canning line. This is a semi-automatic canning line in which the product is decanted from the process tank to the final packaging. At the end of the canning process the machine is completely tainted by the product and sometimes it is necessary to clean it up depending on the product that is to be processed next. The clean-up process usually takes a constant time period and it needs the use of a cleaning solvent. A clean-up process will not always be necessary (depending on the job which is to be processed next in the machine). Therefore, the production schedule affects directly to the setup times and the costs (Artigues, 1997)(Allahverdi et al., 2008), because of the waste of cleaning solvents. Previous to the implementation of the VMI management system, for approximately 200 lots / year produced, an average of 76 setups per year was performed, representing a total setup cost over € 7,500 / year. Due to this second machine acts as a bottleneck in this paper we consider only this one and ***model the shop as a single-machine.*** Some interesting related papers are been reviewed like (Gupta and Smith, 2006), (Koulamas and Kyparisis, 2007), (Baptiste and Le Pape, 2005) or (Schutten et al., 1996).

Finally, the possibility of improving transport costs as a result of VMI management was also identified. Until the introduction of the VMI it was pointless try to optimize truck loading, since the shipments had to meet necessarily the customer orders, both in quantities and delivery dates. However, having the capacity to decide on these two factors (quantities and delivery date) while defining the PO, makes it reasonable to propose a procedure to optimize the truck loading to reduce costs, maintaining the agreed service level. Previous to the implementation of the VMI management system, an average of 28 shipments per year was performed, involving a cost of over € 11,000 per year.

3. The Process Proposed: From VMI to Delivery Orders he problem of QMC

Once the characteristics of the present case as well as the potential benefits of implementing a VMI system are identified, three alternatives algorithms based on heuristics have been defined. All of them start from a common premise: the availability of updated information about the inventory levels of the client company. In order to ***minimize the annual overall cost***, various processes have been designed and all of them consider the following set of decisions: when to generate productions orders, which jobs must be processed, which sequence must be carried out and finally, according to the volume of manufactured goods, the type of distribution facility. It should be emphasized that cleaning setup times to remove the remains of paint on the filling machine are taken into account.

Firstly, before proceeding to the design of the different algorithms, regarding the demand of the client company and based on the concept of Economic Order Quantity (EOQ), the standard lot sizes for each reference are set. In addition, two inventory levels for each product are considered to determine the set of jobs that can be manufactured and supplied each period. The graph below explains the jobs grouping based on their inventory level.

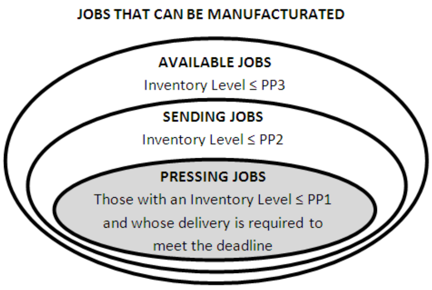


Fig. 1-1. Classification of jobs according to its inventory level.

PP1 Level: It is the inventory level, which once reached, indicates the necessity of launching a production order for such reference. It is also known as Reorder Point in the EOQ Model. PP2 Level: It is the PP1 Level plus a slack percentage. References whose inventory level reaches the PP2 level can be produced and sent to the client company. PP3 Level: It is defined and used in “Minimum Setup Times with Storage Possibility” process.

The decision-making processes proposed below are performed with a weekly periodicity. All alternatives algorithms are based on selecting and sequencing production orders only when an urgent job is detected. Another common aspect to all three procedures is the use of a “***Basic Sequencing Algorithm (BSA)***” for canning line which is defined at the end of this section. A definition of the three alternatives is presented below.

The first process, named “***Last Call***” (LC), consists in generating a manufacturing sequence including all jobs in PP1 or PP2 level but only when at least an urgent job exists. Once jobs have been selected, the next step is to determine the filling sequence as follows: if the number of jobs is less than four all combinations are evaluated and the one entailing fewer setups is chosen. Otherwise, the BSA algorithm is applied. Finally, all manufactured products are delivered to the client company in the current period.

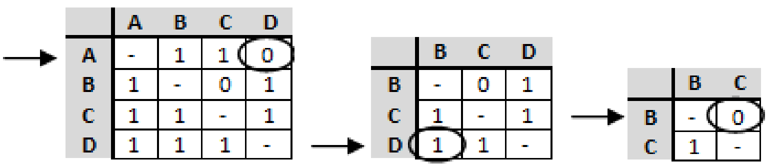
The next process, called “***Minimum Setup Times***” (MST), has been designed with the objective of taking the maximum advantage of setups. In this case, the decision of which references should be manufactured is tightly linked to the decision of sequence. In periods where there is an urgent job, it proceeds this way: firstly, an initial manufacturing sequence that only includes the urgent jobs is created. In order to determine the sequence, the process is the same one as in “Last Call”. Once it is obtained this initial sequence, jobs that have already reached PP2 level are tried to insert in the initial sequence, giving priority to those whose inventory level is closer to PP1 and have not been included yet. The decision to include an additional job is linked to the change in the number of setups of the initial sequence. The aim is not to increase the final number of setups over 40% of the strictly necessary setups to manufacture the urgent jobs. Finally, all manufactured products are delivered to the client company in the current period.

The last process is a variant from the previous process and is named “***Minimum Setup Times with Inventory Option***” (MSTwIO). In this case, a new inventory level called PP3, which is 10% above the PP2 level, is created. This new level is established in order to increase the range of available jobs.

The process to be followed is exactly the same as the one stated in the original “Minimum Setup Times”, the only difference is in the supply since it can only be delivered to the client company those references whose inventory level has reached at least the PP2 level. The remainder will be stored by the supplier company until those reach the PP2 level.

In all of the explained processes, the available capacity of the canning line has been taken into account so that if its capacity is insufficient to produce all planned jobs according to the algorithm, then priority to jobs whose inventory level is more critical is given since supplier must always meet the deadline.

Finally, the “***Basic Sequence Algorithm***” (BSA) for canning line consists in a binary matrix that indicates the setup requirements among all the jobs to be sequenced, the procedure is as follows: (A) Arbitrarily, select an *initial job* “i”; (B) In the line of the selected job, choose the one that requires no setup whenever it is possible; (C) Delete the row and column of the first job; (D) Repeat the previous steps with the new matrix, but now take the selected job in step 2 as *initial job*; (E) Continue this procedure until all the jobs are sequenced; (F) Repeat the whole procedure but select as *initial job* a different one.



First evaluated sequence: A-D-B-C

Fig. 1-2. An example of BSA matrix.

The aim is to obtain the sequence that involves a lower number of setups, so that this process is repeated as many times as number of jobs to be sequenced exists, choosing every one of them as initial job. The selected sequence will be the one which involves fewer setups. It should be noticed that the packaging machine must be cleaned to restore it basic condition when all the jobs are completed, so there is always a Final Cleaning Setup.

4. Experimental Analysis and Results Reached

In order to evaluate each of the three processes, an experimental analysis has been designed (Kolmogoroff, 1950). In this case, the means of evaluation used to analyze the performance of the proposals is the ***average annual cost***, the value of which depends on a set of explicative variables. After an analysis of the experimental environment, the most potentially influential variables on result were found to be: the algorithm applied (LC, MST, MSTwIO), the percentage margin which defines the PP2 level, the capacity available of the canning line and the capacity of the truck which will be used for delivery.

Several levels have been selected for each one of these variables as shown in the table below:

VARIABLE	Levels
Algorithm (A)	LC
	MST
	MSTwIO
Capacity (B) (minutes/period)	High (2,205)
	Medium (1,575)
Truck (C)	Type 1 (12,096)
(Load in Kg)	Type 2 (9,072)
PP2 Level (D)	10% (1,1)
(% Slack over PP1)	15% (1,15)
	20% (1,2)

Fig. 1-3. Factors and levels for Experimentation.

Once all variables are defined, all possible combinations must be taken into account in order to analyze correctly their interrelation and influence on the variable in question. For each combination of factors or experimental set, the system has been simulated for the equivalent period to 10 years but considering only 9 years, calculating the average annual cost. Nine repetitions have been performed by each combination (10 runnings in total). Once these results are obtained, a categorical multi-factor design is created using Statgraphics tool. In order to establish conclusions, the ANOVA statistical test was used. In addition, different tests to verify the fulfillment of all the ANOVA hypotheses (normality, homoscedasticity, linearity, absence of correlation and absence of multicollinearity) were applied. It must be emphasized the use of LEVENE test to check the homogeneity of variances because of the appearance of some difficulties related to this condition.

The ANOVA table breaks up the variability of cost in contributions owing to the different explicative variables. In this case, according to the test results, the factors affecting the cost are the A-C and A-D combinations.

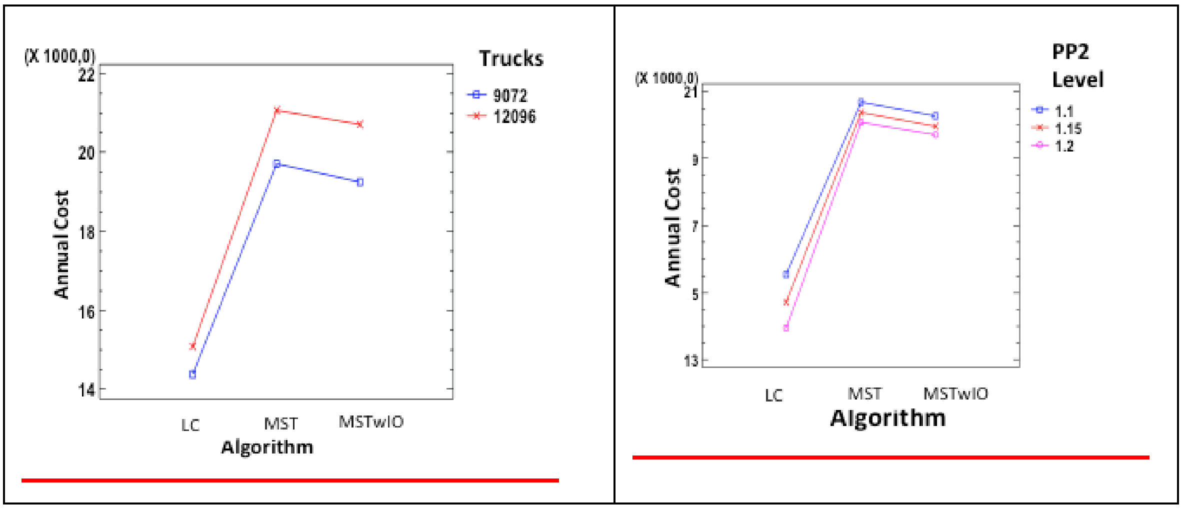


Fig. 1-4. Factor interactions.

The algorithm that offers the best result in terms of cost in any case is “Last Call”. Regarding the Capacity of Truck, the one offering best results is Type 2 (9072). Finally, the factor defining Level PP2 achieving a lower cost is 20% (1.2). As for the production capacity of the canning line, after the ANOVA analysis, the conclusion is that it is not an influential factor over cost, which is a very positive aspect since it is not a controllable factor and its value depends on several circumstances unrelated to the process. The rest of the variables analyzed are controllable and invariable for their value can be determined in advance.

After this, the new proposal is analyzed, taking into account the behavior of the system in the event of its implementation and also comparing these results with the ones obtained by the original production configuration.

In the table below is shown the percentage of some types of cost, both considering the new proposal and the original configuration:

Selected Sets	**Original Configuration**	**LC|2205/1575|9072|1.2**	**Reduction**
Production Cost	11,15%	17,39%	-0,74%
Setups Cost	35,95%	47,35%	13,65%
Supply Cost	52,90%	35,26%	56,96%
TOTAL COST	**100%**	**100%**	**35,43%**

Fig. 1-5. Cost reduction using the proposal.

As shown, the improvement is roughly 35% and the most of the saving is reached in the supply operation with a reduction over 50%. In the following graph, the amounts in kilograms produced per period are compared in both configurations.

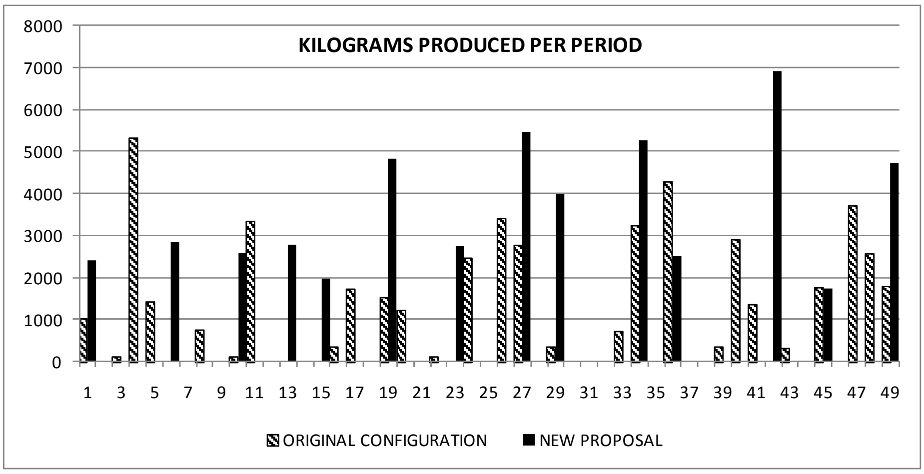


Fig. 1-6. Manufactured kilograms comparative.

If the proposed configuration were implemented, there would be a notable reduction in the number of periods where a production order would be needed, roughly to a half. This improvement is mostly due to the decisional process applied as well as the new defined lot sizes.

5. Conclusions

This paper presents a new process to address the activities of selecting jobs from remaining orders; sequencing the chosen jobs; and deciding about the most suitable capacity of the trucks that transport the jobs to the final client under a VMI environment. The results show how new opportunities emerging because of the increase on demand visibility can be exploited. Under the new this paradigm both the manufacturer and the customer can improve substantially their operations management.

Once the new process is analyzed in order to adjust the parameters, it can be observed that with the original configuration, production is very low in certain periods, which results in both a waste of resources and time in setup changes. With the new configuration more than 80% of cases the amount is over 2,000 kg per period, which constitutes a great advantage in terms of better use of equipment since as production is higher, manufacturing sequences can be improved according to the setups required as well as taking better advantage of the means of transportation. The results show how the new proposal overcomes until a 50% the previous one.

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