



INTEGRATION OF PRODUCTION AND SUPPLY IN THE LEAN MANUFACTURING CONDITIONS ACCORDING TO THE LOT FOR LOT METHOD LOGIC - RESULTS OF RESEARCH

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ABSTRACT. Background: The review of literature and observations of business practice indicate that integration of production and supply is not a well-developed area of science. The author notes that the publications on the integration most often focus on selected detailed aspects and are rather postulative in character. This is accompanied by absence of specific utilitarian solutions (tools) which could be used in business practice.

Methods: The research was conducted between 2009 and 2010 in a company in Wielkopolska which operates in the machining sector. The solution of the research problem is based on the author's own concept - the integration model. The cost concept of the solution was built and verified (case study) on the basis of conditions of a given enterprise (industrial data).

Results: Partial verifiability of results was proved in the entire set of selected material indexes (although in two cases out of three the costs differences to the disadvantage of the lot-for-lot method were small). In case of structure of studied product range, a significant conformity of results in the order of 67% was achieved for items typically characteristic for the LfL method (group AX).

Conclusions: The formulated research problem and the result of its solution (only 6 material items) demand a lot (orthodoxy) in terms of implementation conditions. The concept of the solution has a narrow field of application in the selected organizational conditions (studied enterprise). It should be verified by independent studies of this kind at other enterprises.

Key words: lot for lot, selection of product range, simulation of inventory costs.

INTRODUCTION

The contemporary world has at its disposal a number of technical and organizational solutions in the area of company and supply chain management. However, the requirements of present times clearly show that all these achievements of the management science and practice are still insufficient. The needs of a contemporary customer confronted with the possibilities of meeting these needs by organizations create a number of problems which stem not only inside the company, but

mainly in the general conditions of world economy. Therefore, more and more attention is paid to rational use of resources and adaptive solutions which allow a quicker response to changing market environment. The savings generated by correct use of resources will certainly contribute to the increase of the organization's effectiveness. The ubiquitous reduction of cycles (time parameter) at acceptable cost level remains a valid direction of actions in business practice. From the perspective of market needs, the best method of action is the one which satisfies such need the quickest.

The remedy to these challenges of our times can be the lean manufacturing concept. It attaches great significance to economical commitment of resources (elimination of waste) in connection with the activities aiming at improvement of the organization (kaizen). Undoubtedly, the positive effects of lean manufacturing can be felt very quickly within a single organization (local optimization). However, it is not before we apply this concept holistically to all links of supply chain that the entire potential can be seen (systemic solutions). This requires though that the solutions are developed and used above the functional and organizational divisions.

ENVIRONMENT AND SCOPE OF APPLICATION OF THE LOT-FOR-LOT METHOD

The integration of production and supply in the lean manufacturing conditions requires that the concept of the solutions conforms to the requirements of lean concept [Fertsch 2010]. Two key criteria should be considered to this end:

- minimizing the products supply cycles,
- elimination of inventories.

In case of classical methods of determining the size of lots in planning of material requirements [Orlicky 1975], each method to a greater or lesser extent can influence the length of supply cycles. But only one solution allows to eliminate the inventory - the lot-for-lot method (LfL).

In the lot-for-lot method, the quantity is exactly equal to the net requirement (no more, no less), hence any inventory is impossible. The ordering/ supply cycle is determined by the moment the demand occurs. An unquestionable advantage of this method is adaptation of supply size to needs in terms of time and quantities. A disadvantage is high transport costs (ordering costs) and high changeover costs (costs of starting the manufacturing). The first problem is solved by negotiating favourable transport rates, the other by reducing the changeover times (SMED method).

The lot-for-lot method is used [Orlicky 1975]:

- in supply: for expensive bought-in items and/or items with highly discontinuous requirement,
- in production: for expensive parts made to order (one-off production) or sporadic starts for low repeatability parts (used to eliminate the dead, non-rotating items).

Hence, according to the ABC classification [Cyplik 2005], which reflects the importance of individual items mostly in terms of value, the lot-for-lot method applies to group A - items with high cost contribution (in case of this criterion the situation is clear).

The value of an item which assigns it to group A can be reached by volume or by price. In addition to the most favourable case - large volume and high price - two more cases are possible [Krzyżaniak 2003]:

- regular requirement/large volume at low price;
- irregular requirement/small volume at high price.

Thus, according to the XYZ classification, which reflects the importance of individual items mostly in terms of amounts (size of e.g. purchase), the items A from the lot-for-lot method can be assigned to group X (large volumes) or to group Z (small volumes).

OVERCOMING THE LIMITATIONS OF THE LOT-FOR-LOT METHOD

The author was interested only in bought-in items purchased from outside suppliers (supply). Taking this into account, in further study the application of the lot-for-lot method was limited to groups AX and AZ. Group AX (large value, large volume) fits perfectly the conditions of lean manufacturing. It can be equated to cyclical manufacturing of product range in lines (replenishment of inventory) to which the product range was allocated according to the characteristics of value streams (product families) [Rother and Shook 1998; Rother and Harris 2001, Harris and Harris and Wilson 2003]. In such case, there

will be rather no obstacles to lean manufacturing in the Just-in-Time conventions implemented operationally using the lot-for-lot method due to high volume. The problems appear when the resultant lot size for the lot-for-lot method is unsatisfactory (too small). This situation will certainly take place in case of items from group AZ. It is then necessary to overcome the existing limitations.

The limitations of the lot-for-lot method can be divided into two categories:

- theoretical (conventional) limitations resulting from the logic of the LfL method,
- actual limitations connected with the business reality.

The theoretical limitations include, i.e.:

- absence of safety margin (a physical reserve of material at the manufacturer's),
- absence of quantitative flexibility of supply (lot size = net needs),
- absence of time flexibility of supply (delivery time = occurrence of need).

The actual limitations include, i.e.:

- supplier's production capacity (logistic maximum),
- lower order limit (logistic minimum),
- purchase budget,
- ordering costs (de facto transport costs).

When forming the lot, also in the lot-for-lot method, taken into account are the economic and organizational actors which are related to the conditions of companies and the features of material items. There are three ways to eliminate the aforementioned limitations:

- using a substitute material (with different lot sizing),
- changing the lot size (vertical lot accumulation),
- changing the delivery time (speeding up).

The first solution has only a potential significance, but is given here for completeness of our considerations. The second solution - vertical lot accumulation - is promising and offers a few options. The third solution is unacceptable, it clearly contradicts the assumptions. Bringing the delivery date forward negates the JiT/LfL logic as it destroys

the need-supply relationship and results in creation of an inventory.

SELECTION OF PRODUCTS FOR INTEGRATION

The research was conducted in a company in Wielkopolska which operates in the machining sector. The production process involves standard steps for this type of industry: forging/ casting, machining and assembly. The company currently has a wide spectrum of products (diversified range) manufactured in one plant (concentration of production at a single location). The restructuring of the company evolves towards streamlining the organization and implementation of the lean manufacturing approach [Domański and Cyplik and Hadaś and Pruska 2011].

The set of final products of the company was reviewed for the research. 1104 different final products were identified on the basis of production documentation which was made available. Products families were identified on the basis of design and technological similarity, and the families are represented by the most standard product in each group (structure and technology). This selection of product range was described in another publication [Domański and Hadaś 2008]. The selection allowed to narrow down the spectrum of analysis to 17 representative products. With such sample, the research horizon was set to one year broken down to weeks (52 timing units). The stream size in a given week is a sum of all products constituting the stream. In order to reduce the labour intensity, the research was then limited to one quarter of the year. Second quarter was chosen for representativeness of the results (weeks 14 to 26). The next step was disaggregation of needs within product families. The requirements for individual materials were determined for each of 17 streams according to the MRP (material requirements planning) logic by multiplying the production plan for a stream by repeatability of a given material in a representative product. He total of 431 different materials was identified. According to the assumptions, only materials purchased

from eternal suppliers were considered. This narrowed down the research to 245 purchase items. The ABC and XYZ classification was made on this sample of 245 items. The value analysis ABC gave 8 material indexes which generate 81% of turnover. The material items from group A constitute 3.3% of all indexes. The quantitative analysis XYZ gave 30 indexes for group X and 171 indexes for group Z, which represent 12.2% and 69.8% of all materials. The quintessence of these analyses was the cross analysis ABC/XYZ. The final selection included 6 material items, 3 from the group AX and 3 from the group AZ.

The summary of the selection stage included a comparison of these 6 material positions with the structures of 17 representative products for material-final product relations. The aim was to test the uniqueness (material is used exclusively for one single product) and the versatility (material is used for more than one product). The result was 100% uniqueness - no shared materials in products (there was always "one material - one product" relationship).

The results obtained using the LfL method according to the zero inventory variant [Głowacka-Fertsch and Fertsch 2004] were compared with the results of another lot sizing method. We arbitrarily chose the FOQ (Fixed order Quantity) method.

Table 1. LfL vs FOQ - comparative analysis, synthesis
 Tabela 1. PnP vs SWP - analiza porównawcza, synteza

Material index	Group	LfL Method	FOQ Method
Material 223	AX	better	worse
Material 225	AX	worse	better
Material 75	AX	better	worse
Material 222	AZ	better	worse
Material 77	AZ	worse	better
Material 226	AZ	worse	better

Source: own study

The synthetic research results show a proportional distribution of effectiveness of both methods. Please note domination of the LfL method in the group AX and its incidental nature in the group AZ. It is hard to formulate more general conclusions because of the small

sample size (only 6 indexes). However, it can be assumed that the environment for the LfL method is rather large volumes (quantitative). This requires however a deeper research on a different industrial plant.

CONDITIONS OF APPLICATION OF THE LOT-BY-LOT METHOD AS A LEAN INTEGRATION TOOL

As a complement and complement of the research results, the author decided to look for a coefficient and mathematical function which could determine the conditions of using the lot-by-lot method without the need for a scrupulous calculation of the MRP table [Fertsch 2003].

Two categories of inventory management costs were considered [Krzyżaniak 2003]:

- inventory replenishment costs K_g (gathering, renewal),
- inventory keeping costs K_u (storage, warehousing).

Two cases are possible when these categories are compared with each other:

- (1) $K_g < K_u$,
- (2) $K_g > K_u$.

The sought after conditions of application are the case when $L < P$, that is:

$$K_g < K_u \rightarrow \text{LfL method.}$$

In any different case when $L > P$:

$$K_g > K_u \rightarrow \text{another lot sizing method.}$$

After mathematical transformations we obtain:

$$K_g < K_u$$

$$(P / WD) \cdot kg < 0,5 \cdot WD \cdot c \cdot u_o / : u_o$$

$$(P \cdot kg) / WD \cdot u_o < 0,5 \cdot WD \cdot c / \cdot WD$$

$$(P \cdot kg) / u_o < 0,5 \cdot WD^2 \cdot c / : P$$

$$kg / u_o < 0,5 \cdot WD^2 \cdot c / P$$

The left side of the inequality can be treated as a certain logistic characteristic of lot sizing method (α ME), described by the following relationship:

$$\alpha\text{ME} = \text{kg} / u_0$$

where:

- P - planned demand (purchases) in the considered period,
- WD - lot (order) size,
- kg - unit gathering costs,
- c - purchase cost,
- u_0 - coefficient of inventory keeping costs.

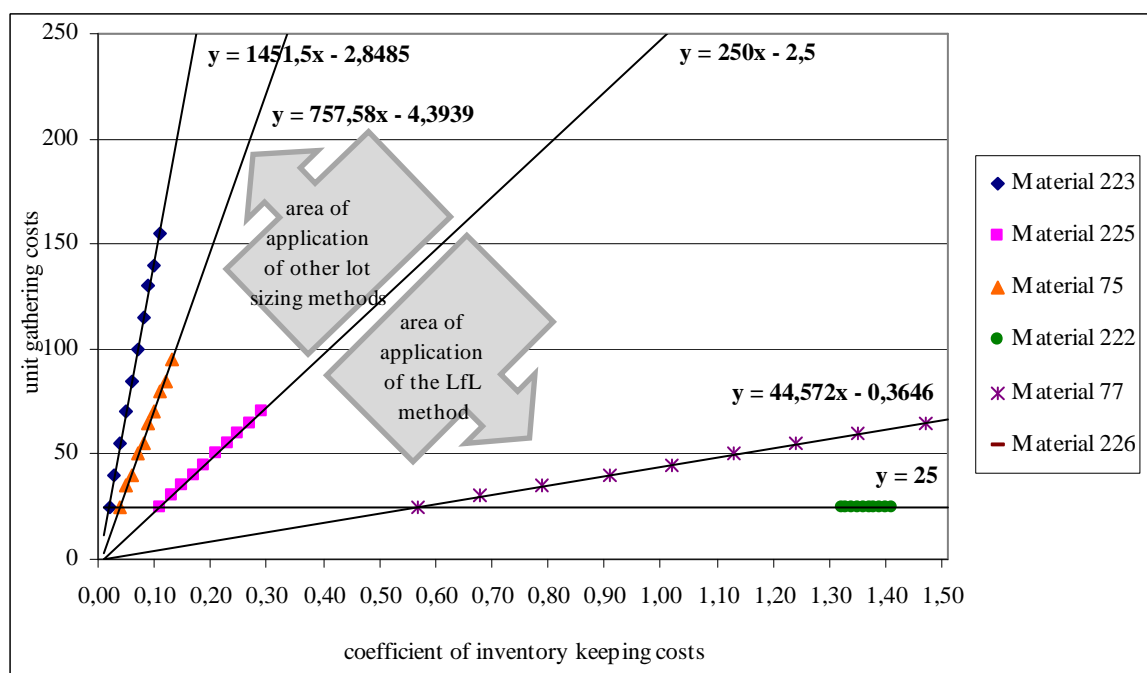
The right side of the inequality represents the characteristics of material index (α MA), described by the following relationship:

$$\alpha\text{MA} = 0,5 \cdot \text{WD}^2 \cdot c / P$$

The conditions of application sought by the author are the case when:

$$\alpha\text{ME} < \alpha\text{MA}.$$

The inventory replenishment costs were simulated in an Excel spreadsheet. The results were stored in the matrix arrangement: supply size vs unit gathering cost. Inventory keeping costs were simulated in another Excel spreadsheet. The results were also stored in the matrix arrangement: supply size vs coefficient of inventory keeping costs. The final Excel spreadsheet included the simulation of the inventory cost comparison. The results show the area of application of the LfL method and the areas where other (remaining) supply lot methods should be used. Only variable costs were considered. This choice is a result of the fact that the size of simulated supply is related to generation of a certain level of variable costs. Curves were plotted for individual material indexes (first 10 values were used as independent variables). Then, the analytical form of the function was obtained using the trend line (a linear character was assumed) - formulas for individual indexes (Fig. 1).



Source: own study

Fig. 1. Area of application of the lot-for-lot method and the area of application of alternative methods
Rys. 1. Obszar stosowania metody partia na partię oraz obszar zastosowania metod alternatywnych

Each function is a so-called limit curve, with the area of application of the LfL method on one side of the curve and the area of application of other lot sizing methods on the other side. The correctness of equations can be checked by making substitutions in the formulas: when x is a certain inventory keeping cost, we calculate y - unit gathering cost.

CONCLUSIONS

Lean manufacturing as one method of action is by no means a universal recipe. It can be successfully implemented in practice only under specific organizational and production conditions. Certainly, lean manufacturing well fits the reality of contemporary production. Better use of resources and perfection of enterprises by organizational improvement is a cost effective (low-budget) option, though often difficult to carry out and maintain in a longer timeframe.

The solution of the research problem is based on the lot paradigm - a specific stream of goods flowing between the interested spheres: supply - production. The accepted method of solving the problem - lean manufacturing - has imposed the flow synchronization character - the Just in Time model implemented operationally using the lot-for-lot method. The author hopes that this idea and viewpoint will be developed by others into next specific utilitarian solutions (tools and implementations).

The Just in Time practice or the lot-for-lot model are treated as solutions which do not create inventories. This is true and false at the same time. If we assume that the supplied amount is equal to the requirement in a unit of time, then theoretically there is no inventory. The catch is hidden in the determination of length of a period of time (assumed timing unit). In reality, not all pieces will be used in an instant, this will happen gradually as time flows. Hence, in such case we can say that there is a temporary inventory and related inventory keeping cost. The remedy to avoid this paradox is to strive for as short timing units as possible.

The paper also attempts to test the sense of using the lot-for-lot method also from the perspective of taking the inventory keeping cost into consideration. The simulations have shown the frames of application is this concept. Realistically, it must be admitted that this method can be used only for a few initial values of the function because gradually the inventory costs are becoming increasingly important.

The paper tries to fill the existing tool gap. Identification of pro-integration factors within specific configurations, knowing the direction and force of these factors, and establishing the system to measure the integration are among the current problems and phenomena of contemporary business. The paper sketches the road to look for answers in the area of integration for both scholars - theoreticians of management - and practitioners who deal with improving the supply and production processes in the context of operational activities.

ACKNOWLEDGEMENT

This paper has been the result of the study conducted within the grant by the Ministry of Science and Higher Education entitled "Modelling of economic order quantity in the supply chain" (project No. KSL 1/15) pursued at the Poznań School of Logistics in Poznań. The paper is at the same time a continuation of research of PhD dissertation "The model of production and supply integration in the industry according to lean manufacturing conception" [Domański 2013] defended at the Faculty of Engineering Management of Poznan University of Technology in 2013. The first author of the paper wishes to thank Mr Marek Fertsch, Ph.D. Eng., professor at Poznan University of Technology and Poznan School of Logistics, for his support in editing the dissertation and assistance in the finalization of its defence.

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INTEGRACJA PRODUKCJI I ZAOPATRZENIA W WARUNKACH SZCZUPEŁEGO WYTWARZANIA WEDŁUG LOGIKI METODY PARTIA NA PARTIĘ - WYNIKI BADAŃ

STRESZCZENIE. Wstęp: Przeprowadzone badania literaturowe oraz obserwacje praktyk biznesowych wskazują, iż integracja sfery produkcji ze sferą zaopatrzenia stanowi narzędziowo mało zagospodarowany obszar nauki. Autor zauważa, iż publikacje dotyczące integracji koncentrują się najczęściej na wybranych aspektach szczegółowych i mają raczej charakter postulatyczny. Obserwuje się jednocześnie brak propozycji konkretnych rozwiązań użytecznych (instrumenty) możliwych do biznesowego stosowania.

Metody: Prace badawcze prowadzono na przestrzeni lat 2009-2010 w jednym z wielkopolskich przedsiębiorstw zaliczanych do branży obróbki mechanicznej. Rozwiązanie problemu badawczego nastąpiło w oparciu o autorską koncepcję - model integracji. Opierając się na warunkach wybranego przedsiębiorstwa (dane przemysłowe), dokonano budowy i weryfikacji kosztowej koncepcji rozwiązania (studium przypadku).

Wyniki: W całym zbiorze wyselekcjonowanych indeksów materiałowych wykazano połowiczną sprawdzalność wyników (choć w dwóch z trzech przypadków różnice kosztowe na niekorzyść metody partia na partię były niewielkie). W przypadku struktury rozpatrywanego asortymentu, dla pozycji typowo charakterystycznych dla metody PnP (grupa AX), uzyskano znaczącą zgodność wyników rzędu 67%.

Wnioski: Sformułowany problem badawczy i wynik jego rozwiązania (zaledwie 6 pozycji materiałowych), stawiają duże wymagania (ortodoksyjność) co do warunków wdrożenia. Koncepcja rozwiązania ma w obranych warunkach organizacyjnych (badane przedsiębiorstwo) wąski obszar stosowania. Należałoby to potwierdzić niezależnymi badaniami tego typu w innych przedsiębiorstwach.

Słowa kluczowe: partia na partię, selekcja asortymentu, symulacja kosztów zapasów.

INTEGRATION VON FERTIGUNG UND VERSORGUNG IN DER SCHLANKEN PRODUKTION GEMÄß DER LOGIK NACH DER METHODE LOSGRÖßE AUF LOSGRÖßE - FORSCHUNGSERGEBNISSE

ZUSAMMENFASSUNG. Einleitung: Die durchgeführten Literaturstudien und die Wahrnehmungen von Business-Praktika ergeben, dass die Integration der Fertigung mit der Beschaffung hinsichtlich der eingesetzten Tools einen relativ wenig erforschten Wissenschaftsbereich der Logistik darstellt. Der Autor ist der Ansicht, dass die die Integration anbetreffenden Veröffentlichungen sich meistens auf ausgewählte, detaillierte Aspekte konzentrieren und eher einen postulativen Charakter besitzen. Gleichzeitig beobachtet man einen Mangel von konkreten, einsetz- und brauchbaren Lösungen (Tools) für praktische Anwendung.

Methoden: Die Forschungsarbeiten wurden im Zeitraum 2009-2010 in einem der großpolnischen Unternehmen für mechnische Verarbeitung durchgeführt. Die Lösung des Forschungsproblems erfolgte anhand eines Autorkonzeptes - mithilfe eines Integrationsmodells. In Anlehnung an den Ist-Zustand des ausgewählten Unternehmens (industrielle Echt-Daten) wurde ein Lösungskonzept und dessen Kostenanalyse in Form einer Fallstudie erarbeitet.

Ergebnisse: In der ganzen Gruppe der ausgesonderten Material-Indexe zeigte man eine halbwertmäßige Prüfbarkeit der Ergebnisse (obwohl in zwei von drei Fällen die Kostendifferenzen zuungunsten der Methode Losgröße auf Losgröße nicht groß bemessen waren) auf. Angesichts der Struktur des behandelten Sortiments erzielte man fuer die fuer die LaL-Methode (Gruppe AX) charakteristischen Positionen eine weitgehende Übereinstimmung der Ergebnisse in Höhe von 67%.

Fazit: Das formulierte Forschungsproblem und das Ergebnis dessen Lösung (lediglich 6 Materialpositionen) stellen hohe Herausforderungen (Orthodoxie) an die Voraussetzungen der Einführung dar. Das Lösungskonzept findet unter den betreffenden, organisatorischen Bedingungen (das analysierte Unternehmen) ein eher schmales Anwendungsgebiet. Dies sollte mit unabhängigen Forschungen dieser Art in anderen Unternehmen noch bestätigt werden.

Codewörter: Losgröße auf Losgröße (LaL), Aussonderung des Sortiments, Simulation von Vorratskosten

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