Analyzing the Impact of the Strategy of Modularity in Production Systems for Products

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Abstract

This article discusses the potential effects of modularized product design in production systems within the manufacturing environment. The main effect was analyzed and discussed the combination of the following assumed variability of Factory Physics (HOPP & SPEARMAN, 2000). The discussions were conducted in this research proposals from the literature review and a case study in the electronics industry. This research play an important role in the area of operations management as it is a topic with wide field of research and gaps. The main results of the research allowed to point out that the modularization of the product can have positive and negative effects on the production system and the resulting directly depends on the configuration of the modules, the variability of demand and the characteristics of the production system itself.

1. Introduction

The design of the products can be done taking into account several internal and external factors on the organization. Among the external factors it is possible to cite the need or otherwise of the alleged clients offering existing competition the market segment that seeks to achieve and the supply chain. Since the internal factors are mainly related to skills or develop existing and including productive capacity related to the product you want to produce.

One of the paradigms that can to influence the design of products is the life cycle (Product Lifecycle Theory). The main assumptions underlying this theory is that technological innovation would be stimulated and stabilized by an increasing specificity of ynergistic organizations technologies and markets (SCHILLING, 2002). According Cebon, Hauptaman and Shekhar (2002) the progressive modularization of products not only offers a counterpoint to the paradigm of the life cycle of the product making question about it. In the case of modular products rather than experience a synergistic specificity the opposite occurs. This point is mainly because the product modules are configurable so flexible or so synergistically nonspecific.

The importance of the debate on the impact of modularization performed this research is justified by the increasing use of modular product architectures in the industries of technology and its importance as one of the paradigms of innovation. Therefore it is necessary to deepen the understanding and respect of modular systems with internal factors of the firm and more specifically the production system used. In productive systems of the characteristics that most affect their performance is the variability. Hopp and Spearman (2000) demonstrated that under certain conditions the main way to increase the productive efficiency of any system is to reduce the variability in each of the workstations of the system.

At first glance the modularity of product contributes in some way to reducing the effects of variability of the production system. This is what suggests the concept described by Hopp and Spearman (2000) called "variability pooling" which can be translated as a concept associated with the combination of different sources of variability. By using modules that can be combined for different products a result of lower variability in demands among other things contribute to the reduction of inventories. At this point of the discussion arise the following pertinent questions that should be discussed in academia: how this effect depends on the variability of the production system? To what extent is worth modularize the product to avail the benefit of reduced inventories? There are other significant effects either positive or negative that may be observed due to modularization strategy? It would be mathematically possible to relate the degree of modularization of the product with the most significant variables of a production system?

The complexity of the answer to these questions indicates the importance of studies in this area. Given this context this research aims in short understand the potential effects of product modularity in the production system particularly in aspects of product variability. This study seeks to understand how the number of modules impact on inventories in productive capacity and productive times. Which imply costs directly resulting from variability in the production system. Will be evaluated in this study the impact considering the difference between the condition of a certain level of modularization and complete product integration.

2. Discussion and hypothesis

This research adopts the method advocated by Goldratt (2002) distribution management product to assess the impact of modularization strategy in stocks. In this method detailed in Schragenheim (2007) is monitored the inventory goals according to three control zones of equal size: green, yellow and red. Some rules are set to increase and reduction targets and for monitoring the variation of the stock during the replacement making a simple process.

Schragenheim (2007) defines as buffer size the total stock of each product that the firm wants to keep the warehouses. The same author explains penetration as the buffer amount of missing parts of the buffer dividing the buffer size in areas of monitoring to prioritize replacements: i) green zone (less than 33% penetration of the buffer): the stock at the point of consumption is high - so there is more than enough pieces as protection; ii) yellow zone (between 33% and 67% penetration of the buffer): the stock at the point of consumption is adequate but still must be issued request for replacement; iii) red zone (between 67% and 100% penetration of the buffer): there is a risk of missing parts to suit the application so it should be considered for urgent action to restore the buffer; and iv) black zone (if the penetration of the buffer is greater than 100%): in this situation every hour can mean loss requests so urgent action must be taken to restore the buffer.

3. Procedures for collecting data

To analyze the effects of modularization of the product was considered a production system consisting of "n" workstations connected in series (E1.... En). Are shared in the same production system "i" different products. Each workstation is powered by raw materials for the manufacture of each product. And between each workstation there is a stock of semi-finished material for the manufacture of each product.

Considering that each product initially has a certain number of modules Mj then each product can be represented by the vector [PiM1 ... PiMj]. Where “j” is number of modules of each product “Pi” and the total number of modules is processed by the production system at any given time is given by Equation 1.

$$\sum_{k=1}^{i} \sum_{l=1}^{j} Pi \times j \qquad (1)$$

However it is considered that in practice the output from each module of the same product is not necessarily the same. Considering that the internal performance of quality and also external where the company produces separate modules for replacement can vary according to the module. In this case the total number of modules is processed by the production system at any given time is given by Equation 2. It is also important to consider that for communication between modules is necessary to use interfaces. The number of different interfaces required is then given by Equation 3.

$$\sum_{k=1}^{i} \sum_{l=1}^{j} PiMj \qquad (2)$$

$$\sum_{k=1}^{i} \sum_{l=1}^{j} PiM\,(j-1) \qquad (3)$$

4. Discussing modularization effects: a case in electronic components industry

4.1 Work-in-process impact

Even the strategy is to manufacture in order to produce the quantity of modules tends to result in an increase in the number of different items in stock. This occurs because the presence of additional modules apparent amount of external interfaces for communication between modules. Equation 4 indicates directly the additional different items in stock generated if we compare the products with a fully integrated version.

$$\sum_{k=1}^{i} \sum_{l=1}^{j} PiMj - \sum_{l=1}^{i} Pi \qquad (4)$$

Depending upon usage characteristics of the interfaces the amount of external interfaces can be considered directly as a necessary additional amount of inventory items. There is a greater need for in-stock items the production system ends up being harmed although this effect is not related to the variability itself. However the fact that there is variability in demand and production process efficiency may end up amplifying the effect of these additional items. It is worth noting that the firm may decide to outsource the production of the external interfaces. And in so doing although the manufacture becomes free from direct effects of these additional items not prevent any negative impact occurs in view of the need to manage the inventory of these items.

In addition there is a greater amount of items to be administered and possibly occur due to the addition of external interfaces the modularization of the products also directly results in a greater amount of items to be produced as shown in Equation 4.

A further quantity of items to be produced whereas the amount of components of products are practically identical implies the reduction of the size of the batch and increasing the amount of batches produced. The main result is greater flexibility in the production system which in the long term may be desirable. This argument is reinforced in Hopp and Spearman (2000) who argue that the effects of variability can be minimized by flexibility.

Moreover, the principle of combination of variability as discussed before suggests examine what would be the effect if different products share common modules. In this case, for example, more than one product can share the same module variability in demand for these products could be combined to the module that is common. This strategy would require that the resulting coefficient of variation of demand of this module is less than the coefficient in the case unless they share modules. The practical implication is that once the intermediate stocks could be reduced. In this way, P1 is a product consisting of modules P1M1 and P1M2 the product P2 consisting of modules P2M1, P2M2 and P2M3 and the product P3 which has modules P3M1, P3M2 and P3M3. Therefore the total of modules of this system is 2 +3 +3 = modules 8. The production demand for each module is defined by PiMj matrix 1.

$$D= \begin{bmatrix} 1100 & 1050 & 0 \\ 2200 & 2120 & 2080 \\ 550 & 540 & 550 \end{bmatrix} \qquad (1)$$

The total demand is given according to Equation (2): 1100 + 1050 + 0 + 2200 + 2120 + 2080 + 550 + 540 + 550 = 10190 pieces. Assuming that the modules P1M1, P2M1 and P3M1 can be standardized, then the matrix D can be replaced by matrix 2.

$$D'= \begin{bmatrix} 3850 & 1050 & 0 \\ 0 & 2120 & 2080 \\ 0 & 540 & 550 \end{bmatrix} \qquad (2)$$

Comparing the products P1, P2 and P3 configuration modularized and fully integrated version as described above it appears that there is an increase of inventory items due to the need for external interfaces. The amount of added items is 1 item to P1, 2 items to P2 and 2 items to P3 resulting in a total of 5 items (additional items 62.5%). Due to the standardization of the modules the number of different interfaces is increased to three items (additional items 50%). With increasing number of items sharing a same module this defect can be reduced.

Determining the volume already connected to these items depends on the performance impact inner and outer products P1, P2 and P3 being at least 1050 + 2*(2080) + 2*(540) = 3670 pieces. If the production system possessed only products P1, P2 and P3, this would represent an increase of 61.73% of parts in stock. This effect of the increase in the number of items in inventory also naturally decreases with the increase of items also considering the standardization of modules.

To consider the effect of the combination of variability before it is necessary to explore how variability would impact on demand. Two situations are analyzed: i) a scenario in which work only for manufacturing applications; and ii) the second scenario where the manufacturing that works with a minimum stock of each item. It is possible to analyse that the stage of producing make-to-order the only potential effect of the combination of variability is the modularization of components in the intermediate stocks. However, this effect can only be realized if the blocks currently used for product manufacturing are not standardized. Otherwise, the effect of combination of variability already occurs for the components of these blocks. The modularization if the modules are not standardized, it could serve as a driver to force the standardization of components used for the standardization of the modules inserted blocks. In this case, the effect of the combination of variability depends directly on how the production system controls its internal inventories. In the production scenario for minimum stock, the combination of the variability can be seen in the reduction of inventories of finished product (modules). The effect depends on the method of inventory replenishment.

To illustrate the use of this method and evaluate the impact on inventory reduction with the combination of 3 modules variability was considered related to 3 different products: P1M1, P2M1 and P3M1, as already previously defined nomenclature. The daily demand period is shown in Table 1 and the time of item´s replacement is 3 days.

Table 1: Product´s demand on analysis

Day	Demand P1M1	Demand P2M1	Demand P3M1	Day	Demand P1M1	Demand P2M1	Demand P3M1	Day	Demand P1M1	Demand P2M1	Demand P3M1
1	166	200	200	**27**	510	500	450	**53**	166	166	500
2	330	12	12	**28**	166	30	600	**54**	200	300	300
3	30	36	450	**29**	30	300	600	**55**	120	120	200
4	166	48	300	**30**	300	12	340	**56**	300	300	400
5	330	600	200	**31**	120	30	340	**57**	60	250	500
6	210	12	120	**32**	210	200	700	**58**	90	200	300
7	210	58	440	**33**	200	200	300	**59**	300	250	150
8	60	43	320	**34**	90	200	340	**60**	210	200	600
9	166	43	200	**35**	60	12	700	**61**	166	166	400
10	90	90	90	**36**	270	420	300	**62**	300	300	200
11	150	150	150	**37**	420	150	300	**63**	166	210	700
12	210	13	13	**38**	150	30	200	**64**	210	500	40
13	180	66	66	**39**	30	150	400	**65**	150	166	90
14	166	44	340	**40**	150	240	500	**66**	166	400	166
15	10	78	500	**41**	240	150	300	**67**	120	30	210
16	166	24	400	**42**	150	150	150	**68**	30	240	600
17	200	79	200	**43**	90	90	600	**69**	240	300	30
18	100	66	120	**44**	500	300	300	**70**	120	240	240
19	400	34	55	**45**	300	390	150	**71**	90	300	500
20	120	88	45	**46**	166	166	600	**72**	166	200	500
21	166	200	300	**47**	30	30	300	**73**	210	166	166
22	90	200	400	**48**	166	166	400	**74**	300	210	210
23	166	300	350	**49**	420	600	700	**75**	120	300	300
24	8	55	450	**50**	180	180	34	**76**	60	120	120
25	166	45	500	**51**	166	166	600	**77**	90	800	250
26	30	400	30	**52**	210	210	25	**78**	120	90	120

From the history of consumption of each item during the period analyzed are defined minimum stock levels. Using the rules for determining requests for restocking mentioned in Schragenheim (2007) has achieved the following levels of penetration in the buffer of each product, as shown in Figures 1, 2 and 3 which relate different possible configurations of the electronic product under review.

Figure 1. Engaging on buffer P1M1.

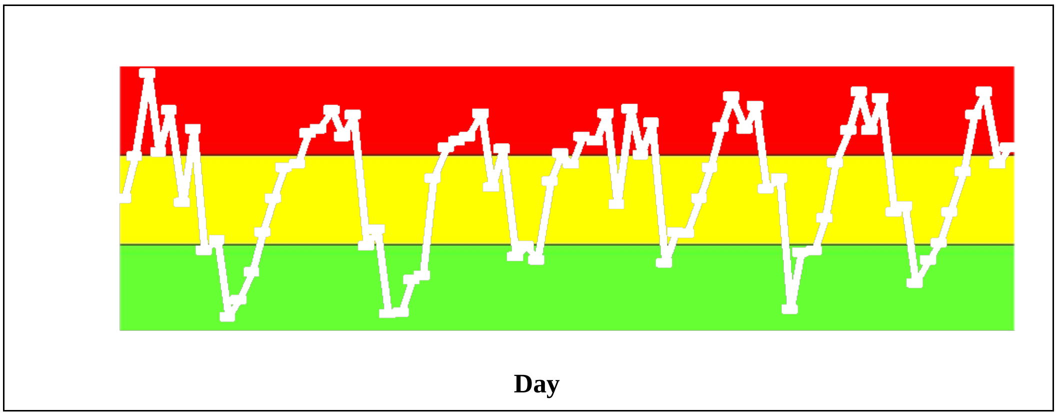


Figure 2. Engaging on buffer P2M1.

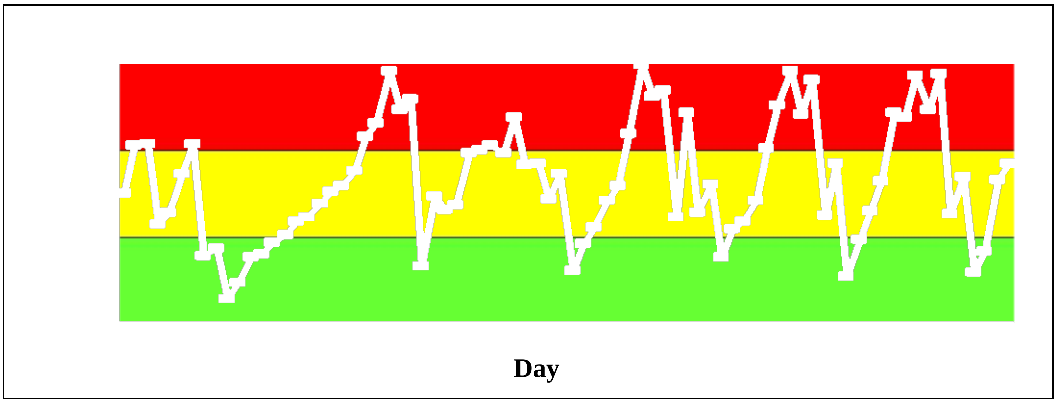
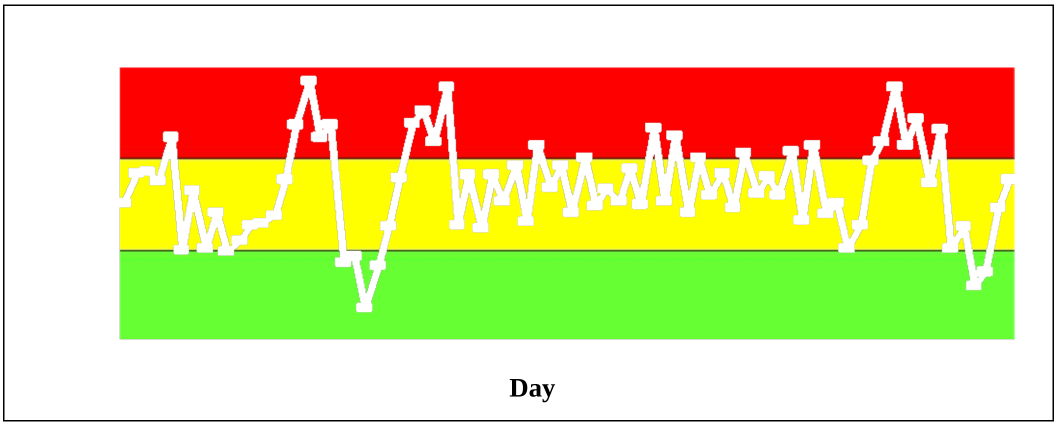


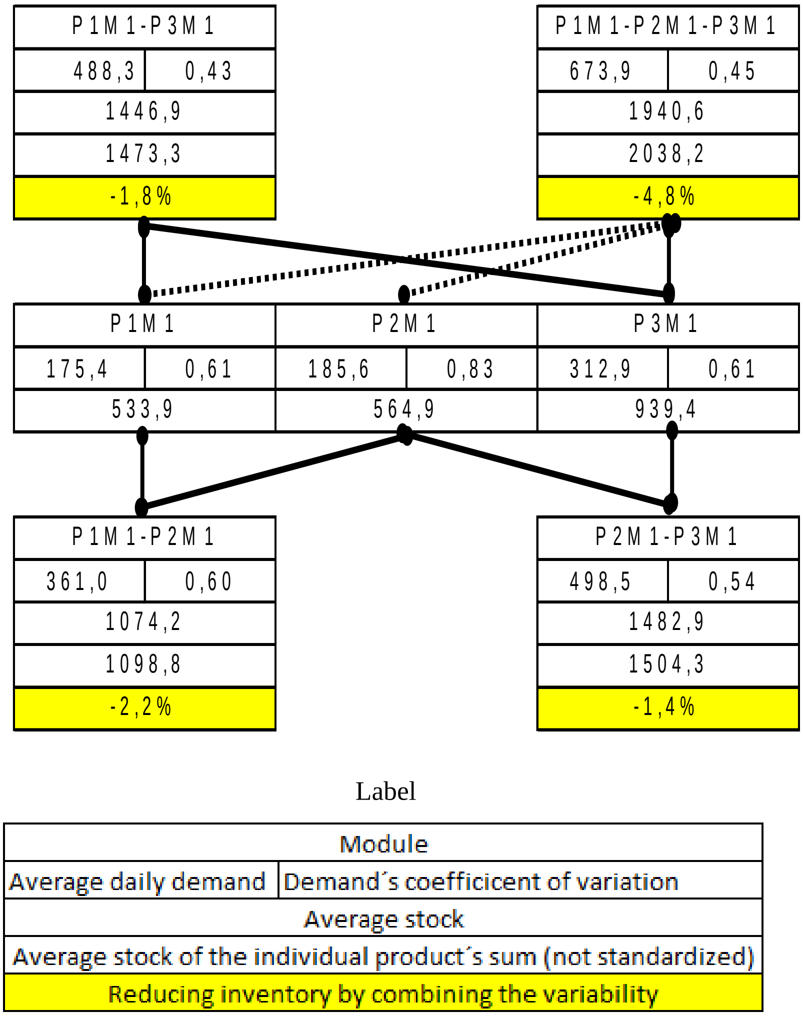
Figure 3. Engaging on buffer P3M1.



The result of the combination of variability was analyzed considering the following variables: average daily demand, coefficient of variation of demand, inventory, average product, average inventory from the sum of individual products and the percentage of inventory reduction achieved. These results were obtained verifying the result of combining the variability of demands in the following options: a) the module P1M1 is standardized with the P2M1 module (P1M1-P2M1); b) The module P1M1is standardized with the P3M1 module (P1M1-P3M1); c) the module P2M1 is standardized with the P3M1 module (P2M1-

P3M1); and d) all modules are standardized (P1M1-P2M1-P3M1). The scheme of Figure 4 shows the final results.

Figure 4. Summary of results obtained by standardizing modules simulated.



It is possible to show that by standardizing modules, the daily demand between standardized modules shall be added. That is the variability that occur between these demands are eventually combined. It should be mentioned that in inventory replenishment model was used assuming infinite capacity, ie the plant parts delivered in accordance with the calculated spare time. Thus, it was observed that in the case where more modules were standardized (P1M1-P2M1-P3M1), there was obtained a greater reduction of inventory levels. Another relevant aspect observed in the case study was that in all cases the coefficient of variation of total demand resulting from the combination of variability by modularization and standardization of modules became smaller compared to the coefficient of variation of the demands of each individual product.

5. Conclusion

The main objective of this article was to discuss the potential effects of modularized product design in production systems within the manufacturing environment. The research results to allow the modularization of the product can have positive and negative effects on the production system and the resulting directly depends on the configuration of the modules, the variability of demand and the characteristics of the production system itself.

The performance of production systems is the result of several factors, some of which are external to manufacturing. Some of the factors that may have great relevance are related to the design of products. The degree of modularization of products manufactured in the production system influenced in various ways some parameters of the production system. The main effect of the internal production system that was explored refers consequences of variability called combination. One of the conclusions of this study is that the use of modules can take advantage of the positive benefits of alleviating the negative effects of variability, since it is possible to standardize the use of the modules of different products.

During the development of this research relevant limitations were evident. The main limitation lies in not proposing to allow a definitive conclusion on the comparison of the final performance of the production system with and without the use of product modularization strategy. This is because there are positive and negative effects, whose dynamics involved precludes any conclusion in part without the use of some analysis tools, such as computer simulation. On the other hand, this finding indicates the importance of further studies being done in this area and deeper, thus directing an agenda for future research to investigate the ultimate performance of production systems with and without modularization strategy

6. References

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