THE EFFECT OF COMPONENT COMMONALITY ON INVENTORY RELATED COST UNDER INNOVATIVE PRODUCT

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Abstract
Creating new products is not an easy matter. Components and technology has created new product, which is distinct from previous series. However, it is not easy to maintain the entire component needed in innovative products; there is also products that will be obsolete, which means there are components that will not be needed anymore. Hence, commonality is introduced manufacturing processes. Yet, the effect of commonality on supply chain costs under innovative products has not known yet. Therefore, this research will simulate the effect of commonality with different levels on a set of given scenarios to show the effect of commonality. This research contains five experiment factors, commonality index in steps of 0.2 starting from 0 to 0.8 commonality. Conducting 100-week period with silver meal lot sizing policy. Series of process will need to be done in each experiment factors. Building bill of materials, determining product demand (lifecycle), compiling component demand, randomizing and create rolling horizon, and results summary are the basic 5 step to extract the needed data. After all the critical data compiled, the summary then will be compared and analyzed what the effect of commonality on the measured variable. The result is Commonality affects inventory cost, order cost, and SKU. Where the smaller the commonality is the higher the costs is. However, there is one variable that did not affected by commonality: obsolete cost. In all costs variable, order cost rank in number 1 for its biggest contribution to the cost. Inventory is slightly higher than obsolete in term of costs contribution.

Keyword: Component Commonality, MRP, Simulation, Inventory, And Innovative Products

1 Introduction
The current business models are based on a continuous cycle of production/consumption/disposal. Even the product life expectancy is becoming shorter every year. Innovative products are only expected to have a short life cycle in trade than those in early year. In the global competition, to provide new products and new solutions in satisfying a growing needs of global market mean sustainability. Hence, to provide new product will not be a simple task for manufacturers. The essence of product innovation is to create or establish something new (Keizer, Halman, & Song, 2002).

Constructing a new product means new component will be needed in production process. It is generally accepted that a rapid increase in number of products will result in deterioration in the stakeholder’s logistics performance. Higher product variety leads to higher forecast errors, excessive inventory for some products and shortages for others, higher overhead an administrative costs, and higher manufacturing cost due to more specialized processes, materials, changeover, and quality assurance methods (Lee and Billington, 1994). Not to mention the existence of obsolescence, which is inevitable.

As the new product use different components from the existing, whether it is more advanced or not, the old component will not be used again in the future. This occurrence then becomes a problem as they generate not only holding cost but also capital loss as they eventually exterminated by manufacturer. One even says that over 2000 components pass into obsolescence every month. The use of modularity or commonality in the design of a product provides the manufacturer a chance to fulfill the consumer’s broad-diverged needs with less cost due to economies-of-scale in procurement, production, and distribution. Hence the commonality concept in design of product, the new one, is widely used in many industries.

Commonality, the use of the same type of component in different product, is common in manufacturing industries. It is famous for its solution to an innovative product where there will always be new components that we need to stock in order to fulfill the production needs, which depends on how “common” the product is regarding the proportion of the old and new component – degree of commonality index introduced by Collier (1981). The uncertainty of the new product life cycle also needs to be paid attention to, because the dynamic movement of its demand can cause stock out and overstock of
materials. Combining the knowledge of the proportion of the new and old component and the impact of it to the product lifecycle will help in projecting how the effect of innovative product development to the manufacturer’s supply chain system, especially in one’s inventory. Basically, utilizing commonality reduces the inventory level, shortens the lead-time for reaching the market, decreases the set-up time, increase productivity, and improve flexibility.

Eynan and Rosenblatt (1996) study the impact of component commonality escalation for a single-period model. They relate a two-product, two-level configuration with a general component cost, and derived optimal solutions for the commonality and non-commonality models. Their studies show the total savings resulting from the usage of commonality. However, they demonstrated that some forms of commonality might not always a preferred strategy.

Hillier (1999,2000) enhance the single-period model to a multi-period model. He establishes simple multi-period model with service level constraints to compare the effect of commonality in single-period and multi-period cases. The results were shown to be quite different for those two cases. When the common component is more expensive than the components it replaces, commonality is often beneficial in the single-period model, but hardly ever in the multi-period model.

Zhou and Grubbstrom (2004) expand the model to show the effect of commonality in multi-level production-inventory systems with complex product structures. Using the set of assembly systems with fixed order quantities or lot-for-lot ordering principles. The study shows that employing commonality is profitable as long as the price of the common component is below 2.5 times that of the unique items.

Kranenburg & Houtum (2007) provide managerial insights into the effect of commonality on spare parts provisioning costs of capital goods. The result of the study shows that the larger the groups mean the lower costs, and the higher the commonality also means lower costs.

However, the literature on the effect of product commonality under short life cycle product to manufacturer supply chain costs is quite limited, most of the earlier paper did not consider the life cycle or only implicitly look at the products with long life cycle. This research attempts to study the impact of employing product commonality in product design phase, whereas the impact will be measured in total cost. Total cost consists of ordering cost, holding cost, and obsolete material cost. The environment of the simulation is short-life-cycle product where there are a lot of new products appear and vanish as the period moves. A new product will use certain proportion of component from its predecessor. Adopting deterministic product life cycles, Silver Meal lot sizing policies, and basic MRP theory, this research aims to present the effect of commonality with different commonality index on performances under a set of scenarios.

Based on the research background, the main research problem is how different commonality index impact the inventory-related costs under innovative products environment.

The research objectives are to provide simulation system that can ease the simulation process and to provide insight about impact of product commonality in product design to supply chain costs.

The benefits of this research is to establish recommendation of how the commonality perform under sets of scenarios provided and clarify the contributing factor to the total cost.

Several assumption like lead times is 2 weeks, product consists of 5 component, all costs stays the same, demand can be predicted from the lifecycles, and no capacity constrain are used to set boundaries in this research.

This research will be done in five chapter: Introduction, literature review, research methodology, system building, numerical experiment and conclusion-suggestion.

2 Methodology

In this research the methodology can be divided into 2 steps:

- Spreadsheet model developments, in this stage the simulation system will be built in excel utilizing vba and macro. The spreadsheet itself will be divided into 3 big parts: input interface to input the experiment factors, multi-period MRP to simulate rolling horizon, and results summary containing the summary of all iteration.
- Design of experiment, in this stage control variable will be injected in the previously built system. All 5 commonality scenarios are the inputs and the results of the iteration will be the output.
- Data Analysis Stage, in this stage the iteration from design of experiment then summarized and analyzed to conclude the outcome of this research.

3 System Building

In this chapter, the details of the whole system will be built. The system purposes is to illustrate how the usage of product commonality may affect inventory related cost, especially innovative products. Commonality, which is the usage of the same type of component in different products, in this case new products, may affects various things, such
as total cost and the number of stock keeping unit (SKU).

However, the application of commonality has to be designed with careful thought. The higher the product commonality means less unique parts per product, at the maximum 1 which mean no differences between products. The level of commonality can be marked as better if the total costs are lower than the other. The considered -inventory-related costs in this research are holding and order costs. Failure in designing the commonality will results in the surge of the total costs and the number of stock keeping unit, which is not desirable.

The system was designed to simulate the real-life condition, to make the system behavior closer to reality several factors then adjusted. The overall system can be described as following; there are two key entities, buyers and manufacturer, the supplier will manufacture the products based on buyers demand. The demand itself will be changing along with the moving period. The demand of the products then will be converted into materials demand. This materials demand is the input for the MRP (Material Requirement Planning). Furthermore, MRP helps this research by showing in what form and how big the impact of commonality in this system.

Experiment factor is a subject-to-change variable given to the system to see how the system react / change under the effect of different experiment factor. In this research the experiment factor is Commonality Index (CI). Uncertainties in products actual demand and lifecycles also help this system to simulate as close as possible to real life problems. All of the experiment factors will be discussed further in this sub-chapter.

Commonality index affects components that compose the products; Commonality Index (CI) is basically the proportion of unique parts and total parts. The index ranging from 0 t o 1 describe no commonality (every product use unique component) and 1 describes total commonality (every products utilize no unique component). In the steps of 0.2 starting from 0.2 (0.2, 0.4, 0.6, 0.8) will be used in this research. The illustration of each product structure:

![Figure 1 Product Structure (CI = 0.8)](image1.png)

The example of how commonality index affects the product structure can be seen in [Figure 1] where P2 differentiate its component from P1 by 1 component (C1 > C6). This is the form of the lowest commonality in this research.

![Figure 2 Product Structure (CI=0.4)](image2.png)

After the completion of all product component the next task is to generate all predetermined product demand.

Table 1 example of product demand

<table>
<thead>
<tr>
<th>Product</th>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Product demand and product component then makes component demand

Table 2 example of component demand

<table>
<thead>
<tr>
<th>Demand</th>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C2</td>
<td>45</td>
<td>30</td>
<td>15</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C3</td>
<td>95</td>
<td>75</td>
<td>55</td>
<td>40</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>C4</td>
<td>105</td>
<td>90</td>
<td>75</td>
<td>65</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>C5</td>
<td>105</td>
<td>90</td>
<td>85</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>75</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>C6</td>
<td>90</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>90</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>C7</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>110</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>C8</td>
<td>10</td>
<td>15</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

After every demand listed, the demand now become the mean of normalized demand with the original demand as mean and defiance of 20% of mean.

Table 3 example of normalized demand and lot sizing

<table>
<thead>
<tr>
<th>Demand</th>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>14</td>
<td>11</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
After normalizing the demand, the rolling horizon also running the logic of silver meal lotsizing to fulfill the demand and release it prior 2 weeks for the lead time.

Numerical Experiment and Analysis

After the simulation system is ready to go, all of the commonality are simulated one by one. The following table will explain the results.

<table>
<thead>
<tr>
<th>Commonalities</th>
<th>Mean SKU</th>
<th>Inventory cost</th>
<th>Order cost</th>
<th>Obsolete cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>20.3</td>
<td>$6,574.65</td>
<td>$54,480.00</td>
<td>$8,976.00</td>
</tr>
<tr>
<td>0.6</td>
<td>14.2</td>
<td>$5,221.80</td>
<td>$26,680.00</td>
<td>$6,400.00</td>
</tr>
<tr>
<td>0.4</td>
<td>17.6</td>
<td>$6,091.85</td>
<td>$42,150.00</td>
<td>$6,496.00</td>
</tr>
<tr>
<td>0.2</td>
<td>23.1</td>
<td>$7,176.75</td>
<td>$68,710.00</td>
<td>$10,256.75</td>
</tr>
<tr>
<td>0.6</td>
<td>214</td>
<td>$8,976.00</td>
<td>$1650</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>604</td>
<td>$10,256.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 shows the summary of 0.8 with measurement indicator and its value. Containing total 45 component.

Table 5 shows the summary of 0.6 with measurement indicators and its value. S lightly higher than 0.8 commonality and containing total of 85 component.

Table 6 shows the summary of 0.4 with its measurement and indicators. Consist of 125 component.

Table 7 illustrate 0.2 commonalities with its measurement indicators. Consists of 165 component.

Table 8 illustrate 0 commonalities with its measurement indicators. Consists of 205 component.

Table 9 illustrates the increase usage of commonalities results in lower SKU. Lower SKUs is
preferable because its easier to managed.

The lowest cost is 0.8 CI in $3495; the next lowest cost is 0.6 CI in $5222. 0.4 CI return mid rank cost ($6092) while 0.2 CI and 0 CI return the highest and the second highest at $7177 and $6575. Inventory level gives similar result with SKU; the higher the commonality index means the lower the inventory cost is.

The lowest order cost is 0.8 CI ($11,000), almost twice the cost of 0.8 CI is 0.6 CI at $26.680. Mid rank filled by 0.4 CI at $42,150, and 2 highest cost is 0.2 CI at $54,480 and 0 CI at $68,710. Having a huge gap, order cost still consistent that the higher the commonality is, the lower the order cost is.

The highest obsolete cost is 0.8 commonality ($10,256). The second highest is 0.2 at $8,976. 0.4 dan 0.6 have similar costs, the higher cost is 0.4 at $96 margin ($6496) and 0.6 at $6,400. The lowest obsolete cost is 0.8 at $3,024. In this series of information, it can be obtained that the decreasing of obsolete cost is the result of the commonality utilization.

The result is the biggest contributor is order costs.

4 Conclusion and suggestion
1. Excel-based simulating system utilizing macro and VBA function were made to ease the simulating process. In this simulating system, all 5 commonality scenarios will be put in the system to see how the system reacts. The reactions itself become a raw data that can be processed and analyzed to conclude the effect of commonality on inventory-related costs.
2. Stock keeping unit will decrease when higher commonality applied. In this simulation, it gives further decrease when 0.8 commonality applied.
3. The increasing commonality index result in decreasing number of inventory cost. Every 0.2 increase in commonality impact in 8% decrease in cost, except in the 0.8; 0.8 save 50% of inventory costs.
4. Order cost affected by the increase of commonality whereas 0.2 commonality increase will drop the order cost by roughly 18–22%. However, week-to-week cost is hazy and only can be effectively interpreted at peak period.
5. Obsolete material found to be fewer in higher usage of commonality. In this simulation environment, the effect of commonality to obsolete cost can save up to 80% at 0.8 commonality.

5 References


Hillier, M. S. (2002). The costs and benefits of commonality in assemble-to-order systems with a $\delta Q$; rb-policy for component replenishment, 141, 570–586.


