Plastics Injection Molding Process Improvement

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ภูมิ โพธิ์พัฒนชัย : การปรับปรุงกระบวนการการฉีดขึ้นรูปพลาสติก (Plastics Injection Molding Process Improvement) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. จิรพัฒน์ เงาประเสริฐวงศ์, 73 หน้า.

วิทยานิพนธ์นี้มีวัตถุประสงค์เพื่อทำการศึกษาและปรับปรุงความสอดคล้องของการวางกลยุทธ์ต่างๆของโรงงานฉีดขึ้นรูปเครื่องใช้ในชีวิตประจำวันที่ทำจากพลาสติกซึ่งมีขนาดเล็ก เพื่อนำมาวิเคราะห์และปรับปรุงเพื่อเพิ่มประสิทธิภาพในกระบวนการที่โรงงานเลือกใช้ให้ตอบสนองกลยุทธ์อย่างลงตัว

ผลที่ได้รับจากวิทยานิพนธ์นี้คือต้นแบบของกระบวณการการวิเคราะห์ พัฒนา และติดตามทั้งเชิงยุทธศาสตร์ทางธุรกิจของโรงงาน รวมไปถึงการเลือกปรับปรุงกระบวณงานโดยยึดยุทธศาสตร์หลักเป็นที่ตั้ง เพื่อเพิ่มประสิทธิภาพของการทำงานอย่างมีความสอดคล้องกับเป้าหมายระยะยาว โดยมีการนำเครื่องมือที่ช่วยในการวิเคราะห์ข้อมูลเชิงอุตสาหการและธุรกิจเข้ามาประยุกต์ใช้ร่วมกันอาทิ Terry Hill's Framework ในการกำหนดภาพรวมของการศึกษา LEAN Concept: ECRS - SMED ในการลงรายละเอียดของการปรับปรุงกระบวณการการฉีดขึ้นรูปพลาสติก

ประโยชน์สำคัญที่ได้รับจากกระบวณการวิเคราะห์และพัฒนาดังกล่าวคือ การพัฒนาอย่างต่อเนื่อง โดยเน้นการคงไว้ซึ่งตัวตนของบริษัทในเชิงของกลยุทธ์การแข่งขัน การขาย และการผลิตที่สอดคล้องกัน เพื่อสร้างภาพลักษณ์ที่ชัดเจนและเป็นที่น่าจดจำในสายตาของผู้บริโภค สามารถแข่งขันในตลาดด้วยจุดแข็งของโรงงานได้อย่างดี และมีการพัฒนาเพื่อความยั่งยืนอย่างต่อเนื่อง

การนำผลจากการศึกษาดังกล่าวไปพัฒนาต่อยอด และประยุกต์ใช้กับโรงงาน จะสามารถช่วยให้โรงงานมีประสิทธิภาพในการผลิตที่ดีขึ้นโดยการกำจัดงานหรือกิจกรรมที่ไม่เพิ่มมูลค่าออกจากกระบวณงาน การปรับเปลี่ยนประเภทและชนิดของผลิตภัณฑ์ให้สอดคล้องกับความต้องการของตลาดเพื่อเพิ่มกำลังการผลิตสินค้าหลักของโรงงาน รวมถึงการลดการสูญเสียจากการหยุดทำงานของเครื่องฉีดขึ้นรูปพลาสติก อันเนื่องมาจากทั้งการหยุดโดยมีการวางแผนล่วงหน้า และการหยุดโดยไม่มีการวางแผนล่วงหน้านั้น จะคืนเวลาการผลิตให้กับบริษัทได้เป็นจำนวนมาก อีกทั้งยังทำให้การทำงานมีมาตรฐานตามกระบวณการที่โรงงานได้วางไว้ในแต่ละขั้นตอนเพื่อความยั่งยืนในการพัฒนาของโรงงานอีกด้วย

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ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

สาขาวิชา การจัดการทางวิศวกรรม

ปีการศึกษา 2560

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The purpose of this thesis is to investigate, analyze the strategies that a small plastic injection molding factory uses. It emphasizes process improvement which is aligned with and support the factory's main strategies.

The result from this thesis helps factory analyze, improve and monitor changes in business strategy that the company chooses to use as well as the manufacturing strategy. The aim of this framework is to ensure that the long term objectives of the company can be achieved under the trends that the company is evolving into. The principal tools and techniques that have been used in this thesis are Terry Hill's Framework, LEAN ECRS and SMED.

The expected benefits from this this improvement framework is the continuous improvement in ability to compete and win in the market by improving on the company strengths. Create a unique customer perception to the compnay's products in order to have deep impact in company image.

By applying the framework to the factory operation, the efficiency in the platic injection processes will be improved by eliminating the non-value-added activities. Changes in product varieties and variations can help company prioritizes the limited machine time to the right products. Reduction in machine down time is achieved by applying the Single-Minute Exchange of Dies approach. Work procedures that can help company ensure the sustainable improvement in the future is also proposed.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	.....
		Advisor's Signature	.....
Field of Study:	Engineering Management		
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1. Introduction

1.1 Background of the research

Nowadays, Thailand has continuously developed the capacity in Industrial domain such as the automotive industry, electronic industry, food industry, and etc. Thanks to the good foundation of the infrastructure which attracts many global companies to invest in Thailand. This fact contributes to the competitive environment that promotes the rapid and continuous improvement of product quality and service level offered to both local and international end-consumers. As a result, the quality standard of every product has been steadily increasing in order to capture the market share within the intense competition aiming to overgrow the competitors.

Operating as base for various industry sectors, Thailand has growing consumption rate of raw materials and parts such as metal and plastics which are the fundamental material in every industry. According to the Plastics Institute of Thailand, in ASEAN region Thailand is the leading plastics manufacturer in term of amount of company. This also indicates that plastics manufacturer will not be able to stay in the market if they cannot effectively and efficiently operate their factories and businesses.

Looking at the plastics industry, plastics manufacturers have various options regarding their target market because plastics are used in both the industrial segment for parts and components as well as in the commodity segments such as household products. These opportunities normally benefit the plastics manufacturers in terms of the market volume. However, if the companies are not well prepared for the challenges, these opportunities might transform into problems as a result of poor planning and management due to multiple products varieties and variations.

In order to stay healthy and profitable in the fierce competition of plastics manufacturers, it is important that the companies must identify their target market segment and try to deliver the products which are up to customers' requirements. However, in most cases, companies do not try to fulfil only a specific market segment, but they try to capture as much segments as possible. It is, without any doubt, highly attractive in term of profit but it will also pose complexity in term of operation management. Dealing with multiple product varieties and variations is one of the key in gaining competitive edges over competitors.

The importance of achieving the target capacity plan has been studied by many academics, industries and consultants. According to North Carolina State University, capacity planning is the process of identifying the production capacity needed in order to fulfil the dynamic demands for products from customers. It can be carried out at different level of the operation such as the resource requirement planning, rough-cut capacity planning, or capacity requirement planning. According to Wang (Wang et al., 2007), capacity planning can be very importance in relation to the level of commitments with the customers as a result from his study in strategic capacity planning in aerospace industry which is a long term relationship with customers. Teamquest (Teamquest), an IT solution provider company, regards capacity planning as a mean to impose order on an increasing complex and dynamic environment. The fact that nowadays business environment has become highly dynamics makes it even more challenging to carry out an effective capacity planning. The decision on capacity can potentially affect various aspect of the total business such as the ability of the firm to meet the future demand. Capacity decision also directly impacts the operating cost. On one hand, having too much capacity in hand means the company has higher operating cost. The non-value-adding extra cost will reduce the margin per unit making the financial result lower or the extra cost will force the company to increase the price of products which will eventually leads to lower volume sold. On the other hand, having insufficient capacity will lead to customer loss. However, the nature of the products or services is an important factor in this issue. For example, customers might be more willing to wait a couple months for cars they really want to buy but they might not be willing to wait that long just for plastics kitchenware. The higher the value customers regard in the products or services play an important part in the willingness to wait for those products.

Different manufacturers have different method for their capacity planning and process selection. Bigger companies who have been operating their business for a long time possess capacity management system and optimized manufacturing processes due to their large customer base and product variety. It is, however, different for smaller size company or newly start-up businesses. The latter groups in general have lower capacity in hand, lower customer base, and lower product variety as well as less

efficient manufacturing processes. At the beginning, by only managing capacity based on experience of the shop floor worker and factory manager can give harmony to the operation thanks to the uncomplicated environment. Nonetheless, small companies who are growing often confront with the inability to response to the changing demand or increasing demand. The more customers and product varieties there are, the more complicate the operation flows and processes becomes. Lacking the capacity planning process might result in overlook in the difference between existing capacity and required capacity in the medium and long term plan.

Capacity planning in the operation management is one of the key that will help companies to be successful in the competitive business environment as it can help in the following subjects;

1. Prepare the organisation capacity for the future demand
2. Optimised the operating costs
3. Improve the responsiveness of the lead time
4. Give organisation competitive edges over competitors
5. Lower chaotic atmosphere due to short term pressure
6. Provide the actual situation of the business

2. Statement of the problem

This research will focus on the process improvement of a growing plastic injection factory involving in three major factors which are the capacity of the factory, products, and the order volume & customers. Figure 1 and Figure 2 summarize the company's sales and revenue of the year 2015.

INVOICE OUT JANURAY 2015 - DECEMBER 2015

	Category	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
1	OEM	902,200.40	606,041.00	828,436.94	512,619.00	612,455.80	688,029.50	525,532.40	614,749.50	437,447.60	423,629.00	405,570.00	293,987.00	6,850,698.14
2	ANT	-	-	117,666.00	309,963.00	374,115.00	341,548.44	558,096.00	420,979.00	925,332.46	888,361.87	1,120,185.93	997,399.03	6,053,646.73
	Total	902,200.40	606,041.00	946,102.94	822,582.00	986,570.80	1,029,577.94	1,083,628.40	1,035,728.50	1,362,780.06	1,311,990.87	1,525,755.93	1,291,386.03	12,904,344.87

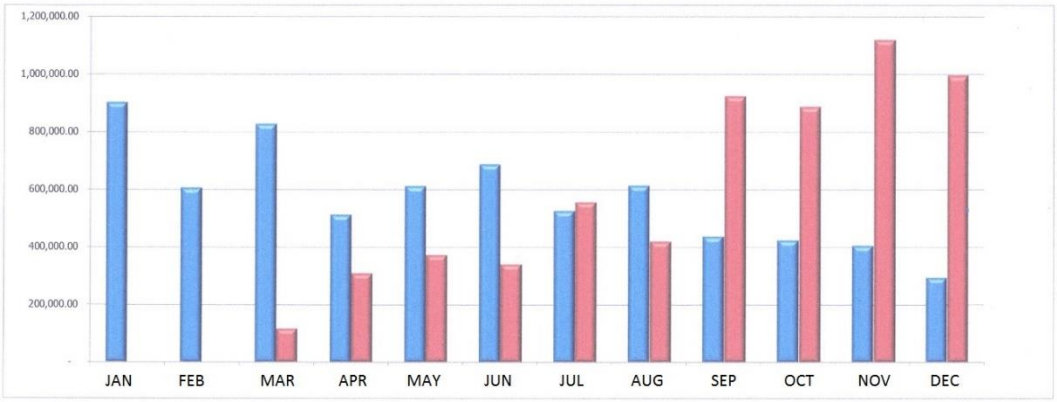

Figure 1: Sales summary 2015

Figure 2: Monthly Revenue 2015

Gathering data and plan for the next 5 years from the marketing team and company director, the business is expected to grow by roughly fifty percent in revenue thanks to the new international market that the company has initiated deals and contracts with. Figure 3 and Figure 4 give information about sales forecast of 2016.

SALE FORECAST 2016

Export

ITEM No.	DESCRIPTION OF GOODS	SALE FORECAST 2016	GCC ORDER/SHIPMENT pcs/color	cols	total	ORDER/YEA	TOTAL ORDER	VIETLAND ORDER/SHIPMENT pcs/color	cols	total	ORDER/YEA	TOTAL ORDER	KILIMANJARO ORDER/SHIPMENT pcs/color	cols	total	ORDER/YEA	TOTAL ORDER	CITIHARDWARE ORDER/SHIPMENT pcs/color	cols	total	ORDER/YEA	TOTAL ORDER	price	total price
A-001/6	TUMBLER 8 OZ. 6 PCS SET	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	13.75	528000
A-101	SALAD BOWL (L) 2,000 ML	25,600	800	4	3,200	4	12,800	800	4	3,200	2	6,400	800	4	3,200	2	6,400	0	4	0	2	0	18	460800
A-102	SOUP CUP 20 OZ.	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	9	345600
A-103	TUMBLER 16 OZ.	115,200	3,600	4	14,400	4	57,600	3,600	4	14,400	2	28,800	3,600	4	14,400	2	28,800	0	4	0	2	0	7.5	864000
A-104	BASIN 6.5L	19,200	600	4	2,400	4	9,600	600	4	2,400	2	4,800	600	4	2,400	2	4,800	0	4	0	2	0	23	441600
A-105	TWINS FOOD CONTAINER 1,200 ML	25,600	800	4	3,200	4	12,800	800	4	3,200	2	6,400	800	4	3,200	2	6,400	0	4	0	2	0	20	512000
A-106	SINGLE FOOD CONTAINER 2,000 ML	25,600	800	4	3,200	4	12,800	800	4	3,200	2	6,400	800	4	3,200	2	6,400	0	4	0	2	0	25	640000
A-201	BATH BOWL	9,600	300	4	1,200	4	4,800	300	4	1,200	2	2,400	300	4	1,200	2	2,400	0	4	0	2	0	12	115200
A-107	SMALL MUG	115,200	3,600	4	14,400	4	57,600	3,600	4	14,400	2	28,800	3,600	4	14,400	2	28,800	0	4	0	2	0	8.75	1008000
A-108	TALL MUG	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	15	576000
A-109	SALAD BOWL (S) XX ML	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	7	268800
A-110	CRYSTAL TUMBLER XX OZ.	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	9	345600
A-111	CRYSTAL BOWL (S) XX ML	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	12	460800
A-112	CRYSTAL SOUP PLATE	25,600	800	4	3,200	4	12,800	800	4	3,200	2	6,400	800	4	3,200	2	6,400	0	4	0	2	0	12	307200
A-113	CRYSTAL BOWL (L) XX ML	25,600	800	4	3,200	4	12,800	800	4	3,200	2	6,400	800	4	3,200	2	6,400	0	4	0	2	0	20	512000
A-114	SALAD BOWL (M) XX ML	38,400	1,200	4	4,800	4	19,200	1,200	4	4,800	2	9,600	1,200	4	4,800	2	9,600	0	4	0	2	0	16.25	624000
A-115	ORANGE SQUEEZER	64,000	2,000	4	8,000	4	32,000	2,000	4	8,000	2	16,000	2,000	4	8,000	2	16,000	0	4	0	2	0	13	832000
A-116	STRIPS TUMBER 14 OZ.	115,200	3,600	4	14,400	4	57,600	3,600	4	14,400	2	28,800	3,600	4	14,400	2	28,800	0	4	0	2	0	5.25	604800
A-301	METAL SHEET SQUARE TRASH CAN 4.5L	7,920	240	3	720	4	2,880	240	3	720	2	1,440	0	3	0	2	0	600	3	1,800	2	3,600	35	277200
A-302	METAL SHEET SQUARE TRASH CAN 9L	7,920	240	3	720	4	2,880	240	3	720	2	1,440	0	3	0	2	0	600	3	1,800	2	3,600	65	514800
A-303	SWING BIN 9L	7,920	240	3	720	4	2,880	240	3	720	2	1,440	0	3	0	2	0	600	3	1,800	2	3,600	100	792000
A-304	SWING BIN 18L	7,920	240	3	720	4	2,880	240	3	720	2	1,440	0	3	0	2	0	600	3	1,800	2	3,600	160	1267200
A-901	CIRCUIT BOX	0	0	0	0	4	0	0	0	0	2	0	0	0	0	2	0	0	0	0	2	0		0
???	BENTO FOOD CONTAINER XX ML	25,600	800	4	3,200	4	12,800	800	4	3,200	2	6,400	800	4	3,200	2	6,400	0	4	0	2	0	20	512000
																								12,809,600.00

Figure 3: Expected international sales 2016

Sale forecast 2016
10/1/2016
Local

Customer list

No.	Item No.	Description	A	AMK	FFF	B	C	D	E	F	G	H	I	J	K	Other	Quantity	Pr/Un	Total (Baht)
1	A-001/6					1440		1440			6000		1440		4800		15120	10	151200
2	A-101	Salad Bowl	32400	3600	4800	3600	21600	2160	3600	12000	6000	1200	3600	1440	24000	12000	132000	13.5	1,782,000.00
3	A-102															10000	10000	6.5	65,000.00
4	A-102/2	Soup Bowl pack 2	3600	3600	4800	3600	21600	2160	3600	1440	14400	1200	3600	1440	48000	48000	161040	13.5	2,174,040.00
5	A-103															12000	12000	5	60,000.00
6	A-103/3	Beer Mug pack 3		3600	3600	3600		2160	2400	7200	12000	1200	3600	1440	48000	48000	136800	13	1,778,400.00
7	A-104	Basin			3600	3600		2160	2400	12000	12000	1200	1440		48000	12000	98400	14	1,377,600.00
8	A-105	Twin Luch Box	3600	5760	4800	3600	8640	3600	3600	12000	12000	1200	2160	1440	48000	12000	122400	13	1,591,200.00
9	A-106	Lunch Box		5760	4800	3600	8640	3600	3600	12000	12000	1200	2160	1440	48000	12000	118800	13.5	1,603,800.00
10	A-107	High Mug																	
11	A-108	Regular Mug																	
12	A-109	Small Salad Bowl																	
13	A-110	Crystal Design Glass																	
14	A-111	Crystal Design Bowl																	
15	A-112	Crystal Design Plate																	
16	A-113	Crystal Design BBowl																	
17	A-114	Medium Salad						2880								16000	18880	12	226,560.00
18	A-115	Juice Squeezer	2400	3600	3600	2400		2160		7200	7200		1440			2000	32000	9	288,000.00
19	A-116	14 oz. Glass		3600	4800	3600	14400	2160	3600	12000	12000		6000		24000	12000	98160	13.25	1,300,620.00
20	A-117	Bento Box			115200												115200	13	1,497,600.00
21	A-201	20 cm. Bath bowl				3600		1728			4320		1152		12000	9600	32400	9	291,600.00
22	A-301	4.5 cm MetalS Bin	3600	3600	4800	3600	8640	2160	3600	4800	4800		2160		4800	10000	56560	13	735,280.00
23	A-302	9 cm MetalS Bin																	
24	A-303	9 litre Bin																	
25	A-303L	9 litre Swing Bin																	
26	A-304	18 L. Bin																	
27	A-304L	18L Swing Bin																	
																			14,771,700.00

Figure 4: Expected domestic sales 2016

Compare to last year total revenue of 12 million baht, the company expects that by the end of 2016, they will reach total revenue of 30 million baht which is 250 percent growth. However, they do not wish to invest a lot into infrastructure and instead, they prefer to optimize the utilization of the existing facilities to the fullest extent. Arriving at the new capacity plan are among the fiercest obstacle that cause delays, backlogs and miss-orders which are needed to be solved and improved. Figure 5 illustrated the underlying problems of the operation that could not deliver the target capacity.

Month	Forecast	Order	Deliver
JAN	171020	92000	92000
FEB	171020	132000	108000
MAR	171020	116000	102000
APR	171020	160000	108000
MAY	171020	76000	76000
JUN	171020	108000	102000

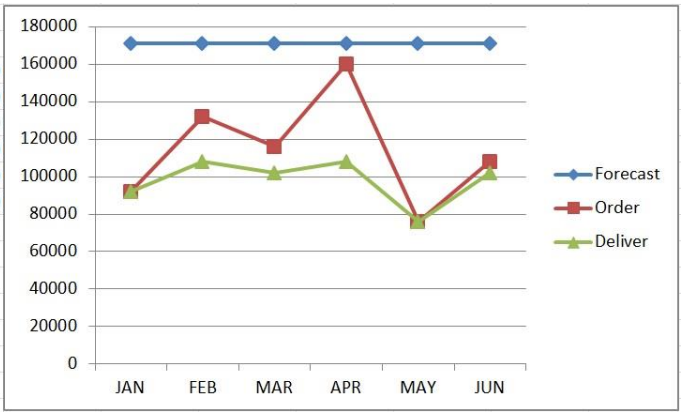

Figure 5: FORCAST ORDER and DELIVER Results

Classic plastic injection processes are applied in the factory consisted of receiving orders, checking the level of required raw material, machine setup, first run trial, product finishing, quality control, packaging, and storage. As illustrated in the following figure;

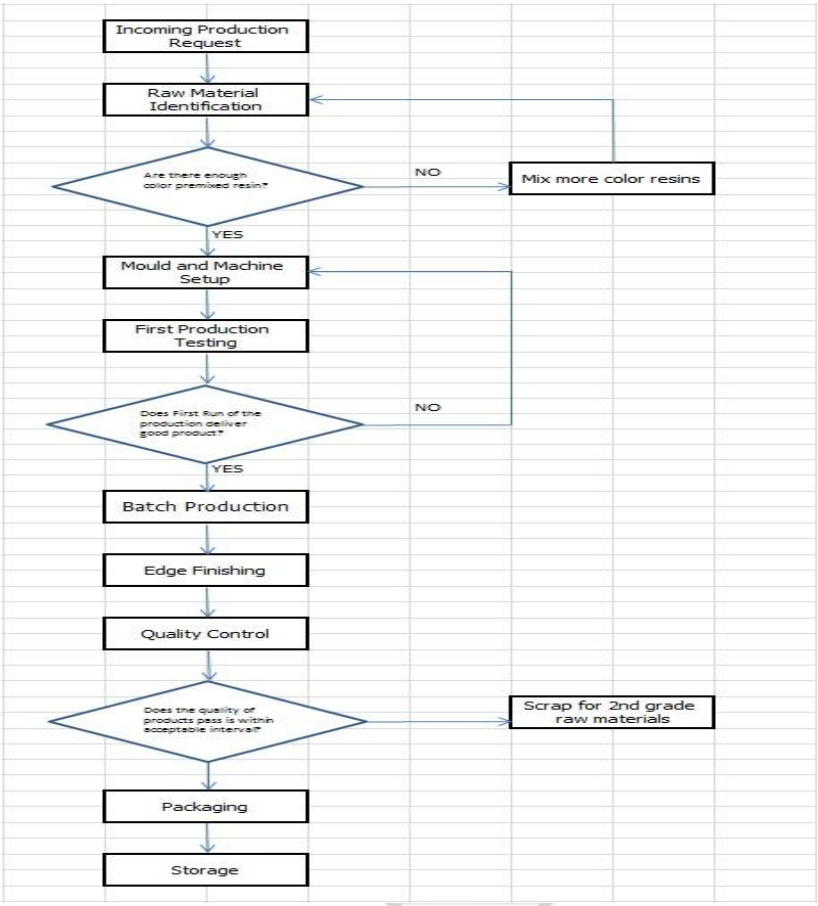

Figure 6: Plastic Injection Moulding Processes

In the research, the first steps on capacity that will be identified are the design capacity which is the level of capacity according to the plant equipment specification and other constraints which will be discussed in the following context. Afterward the actual capacity will be measured in order to verify the level of efficiency of the current situation. Details of current workflow and work efficiency will be measure and analyze in order to determine the area that is needed to be improved.

There are two categories of product in this research which are the consumer products and the OEM products. The OEM products are contracted for long term and they must be fulfilled and delivered to the OEM according to the due date. Penalties will be imposed to the company if it cannot carry out the promise. While the consumer products are the company's own product line up. They are sold to both domestic distributors and international distributors. There are 23 varieties of product with up to

83 variations. This product category gives higher profitability compared to the previous category and is much higher in volume as well.

The order volume & customers' session will discuss about the nature of different customers which are distributors and OEM and the prioritization among these customers.

After the preparation step are completed and all the relevant factors are crystallized, the ultimate objective of this research is to improve the plastic injection molding process using ECRS (Eliminate, Combine, Rearrange, and Control) approach in order to achieve the optimum workflows.

2.1 Idea Description

1. In this research, the environment of the scenario is the following;

Number of available Plastic Injection machine:	6	
OEM customer:	1	
Principal domestic distributor customers:	13	
Principal international distributor customers:	4	
OEM product variety:	2	
Consumer product variety:	21	
Consumer product variation:	81	
Total forecast for domestic volume for all product:	1,159,760	unit
Total forecast for export volume for all product:	892,480	unit

2. Nature of order placement by customers;

- OEM customer requires lead time to be no more than 1 weeks after the notice for goods
- Volume per order can vary depending on the OEM
- Distributors usually place their order when they are low in stock. The ordering interval is inconsistent.
- The order size is normally predictable. Distributors often order for the same volume each time.

2.2 Assumptions in the research / Company Policy

1. Raw materials required for the plastic injection process are always available in the factory.
2. Shop floor employees are equally skilled and can deliver the same amount of work under the same condition.
3. It is possible to outsource the over-capacity volume when both working hour could not fulfil the orders.
4. OEM orders must be fulfilled in-house only. (Company policy)
5. OEM orders have the highest priority and must be deliver on-time. (Company policy)

2.3 Parameters

Control parameters

There are many parameters that are needed to be identified. These data will act as the starting point in process improvement such as:

1. Annual total sales forecast.
2. Annual sales forecast separated by individual customer.
3. Number of total customers.
4. Number of total product variety.
5. Number of total product variation.

Apart from the given information, there are also data that must be determined before the optimization can be implemented such as:

1. Total capacity of the factory and capacity separated by machine
2. Average cycle time of each product
3. Product classification and ranking

2.4 Objective of the research

Deliver new process that are optimised and compatible with the new company objectives and goals

2.5 Thesis Scope

The goal of the research in this context is to analyze existing environment resource data and expected future sales then critically evaluate the circumstances and plan to response to the dynamics demand with the optimized work processes. Forecasting of future sales is not in the scope of this research and as a result, the sales forecast data must be provided by the marketing team at the beginning of each fiscal year in order to plan for the future and cope with changes.

ECRS approach will help improve the plastic injection process by eliminating the unnecessary work and optimizing others in order to achieve the target capacity. This improvement approach is highly suitable for the company thanks to the nature of its efficiency increase and cost optimization rather than other approaches that aim to do cost cutting. Suggestion concerning further investment of the factory will be provided at the end of the research based on the result from simulation.

For the mentioned context, the scope of the thesis will cover the area of plastic injection process improvement.

2.6 Expected Results

- New plastic injection molding processes that can deliver the work stated in capacity plan.

3. Methodology

This research shall carefully examined the company with Terry Hill's Framework and apply LEAN ECRS approach in order to eliminate, combine, rearrange, and simplify the processes aiming to increase the level of efficiency and meet the target capacity set by the factory. Suggestion using Single Minute Exchange of Dies will also be discussed and provided in the conclusion.

4. Literature Review

4.1 Capacity Planning

Capacity Planning Process helps company identify and determine the required resources to cope with incoming demands. Capacity planning are categorized into three categories which are long-term capacity planning, medium-term capacity planning, and short-term capacity planning.

According to Olhager et al, (Olhager et al., 2001), long-term capacity planning is related to the strategic decision of when and how much should the firm's capacity levels change. Long-term capacity is analyzed and planned at an aggregate level rather than going into details of individual resources. The forecast information used to design long-term capacity is the forecast of product families or portfolio. Decision and action on long-term capacity planning are important because it can lead toward competitiveness over competitors in the long run, while misplay the long-term capacity planning can introduce disruptive environment due to inability to cope with the changing demands.

Medium-term capacity planning in the view of Chen et al. (Chen et al., 2009) is normally associated with the setting monthly or quarterly resources requirement for each factory in the interval of typically one-year horizon. At this stage many factors are designed and implemented such as workforce level, raw materials, inventory level, and overtime workhour. It is also possible to plan for outsourcing if the calculated capacity during a certain interval are insufficient. In practice, there are two traditional approaches for medium-term capacity planning which are matching demand and level capacity. Nevertheless, facing the current dynamics market situation, many manufacturers adopt the hybrid approach between matching demand and level capacity.

Short-term capacity planning is the most visible and tangible process of all three capacity planning categories. It sets capacity plan for a planning horizon which is long enough to satisfy customer's orders. The objective of short-term capacity planning is to make certain that the firm has enough available resources and capacity to respond to the production orders.

4.2 Make-to-Stock (Push)

The traditional production system environment that have been widely used in many industry is the Make-to-Stock environment. In this environment capacity planning process try to match the production with the forecast demands. In the past where the change in demand for product were low or were more likely to be predictable, MTS capacity planning can be effective in dealing with production. According to Imaoka (Imaoka), MTS approach can prevent opportunities loss due to stock out while also minimize excessive inventory with the help of accurate forecast. However, the work of Moon and Mentzer (Moon and Mentzer, 1999) regards forecast as the closest to reality to the true customer demands for company's products and service, during a particular time frame, under a group of assumption during that particular time and environment. This perception of forecast argues that the MTS approach which is based heavily on sales forecast might work at the situation that possesses less variance while might not be suitable in the situation that the environment changes rapidly.

4.3 Make-to-Order (Pull)

Imaoka (Imaoka) has described the MTS capacity planning as a train which has predefine schedule and the routing frequency is calculated based on the forecast passenger numbers. The train will continue to operate according to the timetable regardless of the change in passenger numbers until the train traffic control modify the schedule. He, on the other hand, has described the MTO capacity planning as a lift which will operate only when a person pushes the button to go up or down. Make-to-Order production starts only when customer's order is received.

This MTO process is called Pull because it is pulled by the real demand from customers. Pull production can be further classified into several type which are, Assemble-to-Order (ATO), Build-to-Order (BTO), Engineer-to-Order (ETO). Each type of MTO is separated by the nature of business or the starting position of raw material or components. ETO type can be products that are usually one-off. It is made to fit a specific purpose or to solve specific problems. ATO type is related to the products that can be customized such as personal computer or Xerox Printer business model where the company keep inventories of components and assemble them to orders.

Pull capacity planning in manufacturing means the company does not keep inventory of finished good. This give the shop floor operation management higher level of flexibility in consuming raw materials. Achieving and managing the flexibility of the Make-to-Order production capacity planning require attention in process flexibility which is the ability to produce multiple products in multiple production line and operational flexibility which is the ability to dynamically change capacity allocations among different product families overtime according to Tanrisever et al. (Tanrisever et al., 2012). Jordan and Graves (Jordan and Graves, 1995) identified the process flexibility to be the ability of companies to manufacture all products on multiple production lines.

4.4 Hybrid Capacity Planning (Push-Pull)

In the field of product manufacturing, choices in the way that companies make in planning their capacity in operation management are often taken based on the strategic decision in the way they operate their business which are Make-to-Order (MTO) or Make-to-Stock (MTS). According to Soman (Soman et al., 2004), the study in the field of food industry has shown increasing product variety which can potentially affect the way companies prepare themselves for the capacity. Increase in product variety and variation make it less efficient to perform MTS based capacity planning due to the more complex parameters such as number of raw materials. He proposes hierarchical planning framework which is served as a starting point for planning system evaluation in the hybrid MTO-MTS environment. This finding also enforce the statement of Williams (Williams, 1984) that there are lesser and lesser production planning system that are purely Make-to-Stock or Make-to-Order. The work has also addressed various strategic questions such as which products should be stock in the MTO environment, criteria in order acceptance in MTO environment and the optimum batch sized in the MTS environment. The hybrid approach between MTO and MTS in capacity planning can only be made possible, critically analyzed and carried out when strategic characteristics of the business in both MTO and MTS context are known. Dealing with MTO environment is about overcome the uncertainty by being responsive to demand changes. It is proposed by Bemelmans (Bemelmans, 1986) that uncertainty

in demand of a product can be prepared for and cope with the inventory of another product that possess less demand uncertainty or higher volume. This proposition helps increasing the available capacity that can be used to deal with the uncertainty demands of some products at the cost of inventory build-up of other products with less dynamics. This study focuses in the risk management in capacity planning which allow MTO environment to be accomplished.

Federgruen and Katalan (Federgruen and Katalan, 1999), investigate the impact of adding MTO in MTS production system under stochastic economic lot scheduling problem. Rajagopalan (Rajagopalan, 2002) develops a heuristic approach to solve the MTS-MTO hybrid production trade-off. He also identifies various inter-relation between MTS and MTO which can affect the capacity planning decision. Köber and Heinecke (Köber and Heinecke, 2012) implement the hybrid strategy in agriculture machinery manufacturer whose demands are seasonal and volatile.

4.5 Product Classification

Van Donk et al. (Van Donk et al., 2005) develops decision-making model which is based on ABC classification theory in order to deal with choosing between MTO and MTS in food industries. Dhoka and Choudary (Dhoka et al., 2013) work on the time factor that is being employed in ABC classification process aiming to optimize the accuracy of the product classification. Eslaminasab and Dokoohaki (Eslaminasab et al., 2012) attempts the multi-criteria ABC classification using distance based approach method to improve the accuracy of the classification. Ravinder and Misra (Ravinder and Misra, 2014) have also argue the dollar factor criterion which is the sole consideration in the classic ABC classification. They suggest that in the nowadays business context, company must consider other important factors that affect the level of competitiveness of a firm in the competition as well.

4.6 LEAN & Six Sigma

Six sigma is regard as strategy to improve process quality aiming to deliver the operation excellence that can convey the company commitment to its customers. Six sigma is a powerful tool that is being used to improve performance in the world of

business. It is flexible for use in various situation in which things need to be improve. Sagnak and Kazancoglu (Sagnak and Kazancoglu, 2016) apply six sigmas in their work to reduce the gas emission. They identified the limitation of the old lean process and they implement six sigmas in order to overcome those limitations. Six sigma helps many companies to increase their profitability such as GE which has more than 10% increase in revenue in the period of 2 years. It has also been agreed to the importance of six sigmas by stating that six sigmas is the process quality management that leads to excellent quality level by ensuring the continuous improvement of internal processes. Six sigma aims to identify the variation of the data and perform root cause analysis to get to the very source of the problem. Six sigma DMAIC methodology concern about define, measure, analyses, improve, and control. DMAIC helps greatly with the trouble shooting and solution finding in every process. It also ensures the sustainability of the improvement by implementing control system to keep things in check.

Lean concept was defined by Womack, Jones and Roos (Womack et al., 1990) in their study of automotive industry. They determined the crucial factors that differentiate Japanese automotive industry from American competitors. According to Kennedy (Kennedy, 2003) and Gautam and Singh (Gautam and Singh, 2008), lean is not only apply in the manufacturing process but it is also used in the entire product life cycle management. Moreover, lean usage has also extended to other domains such as aerospace according to Crute (Crute et al., 2003). Lean is often known as “doing more with less” which describes its characteristics of efficiency improvement. Lean emphasizes on time between activities, events or cycle reduction or even elimination when possible. ECRS is an approach of lean concept focusing on the elimination, combination, rearrangement, and simplification of processes or steps. ECRS aims to minimize the time a product spends in the manufacturing process thus increase the level of productivity.

Lean and six sigmas are often implement together in the world of manufacturing industries aiming to optimize both the effectiveness and the efficiency of the operation processes. Depending on individual situation lean and six sigmas can support each other to overcome obstacle and achieve the objectives

4.7 Toyota Production System House

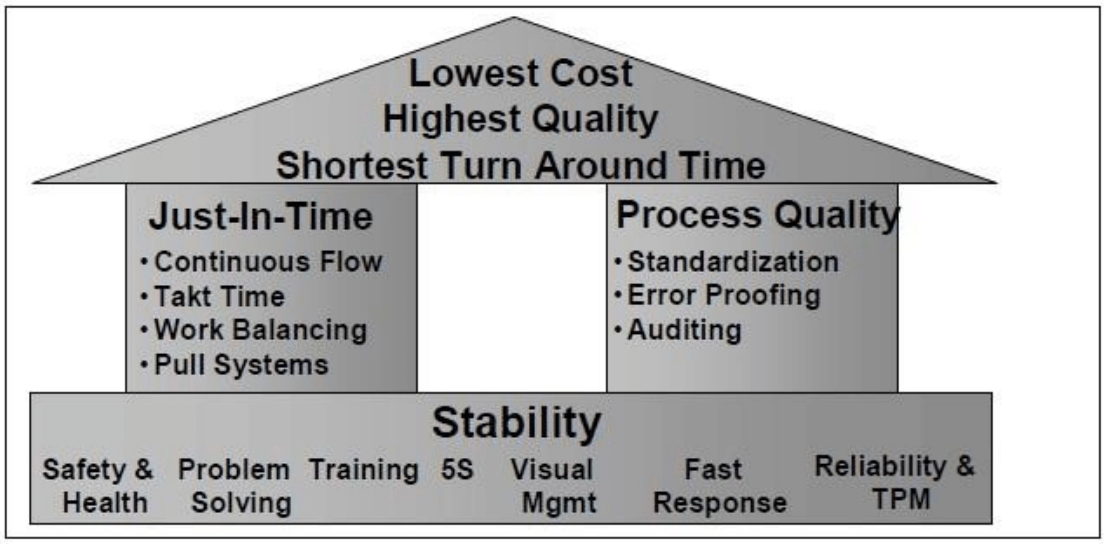

Figure 7: Toyota Production System House

A solid "basement" is the premise for "Just in Time" (JIT). Having strong internal and external suppliers, the bottom part of the base, makes possible to achieve the 5R's (Right part, Right quantity, Right time, Right amount, Right location). The second step or the base is motivated employees and teams. All employees must be integrated in the TPS work until the whole organization is penetrated. If the employees are frequently informed and are involved in the TPS work, it is more likely that they will be motivated. The third step, continuous improvement or kaizen, is another key factor for success. The improvements should be made with small steps with a short planning period, little or no investment and with intensive cooperation with operators. Also innovative improvements in large steps are necessary, which have longer planning periods, higher investments and lower operator involvement. The fourth step of the base is standardization, which sustains lasting improvements. The standards can be applied in different manners, such as manuals, handbooks, rules, quality requirements, etc. The innovations, continuous improvements and standardization should work in conjunction.

4.7.1 TPS Workshops

A TPS workshop, sometimes called kaizen workshop, is an activity where team members from various departments collaborate to improve a specific area in the company. The area may be a machine, a production line, a product development process or even an office. As mentioned before, the target of a workshop is elimination of waste.

Waste, or Muda in Japanese, is any operation or action that does not add value to the product. An example of a non-value adding action is transporting the product, while a value adding operation can be the actual machining of the product or the assembly, such as things that the customers are willing to pay in order to obtain the goods or services. In the TPS philosophy 7 wastes are defined. The goal is to identify and eliminate those in order to reach the targets of increased customer satisfaction, profits and employee satisfaction.

- Over production
- Stock
- Transport
- Waiting
- Space
- Defects
- Distances

4.7.2 TPS Workshops: Single Minute Exchange of Dies

SMED (Single Minute Exchange of Dies), also called changeover time reduction or rapid changeover, is a lean production technique which are widely used by

practitioners to analyze and reduce resources needed for equipment setup, including exchange of tools and dies or improve the efficiency in performing those changeovers. This is one of the most effective tools to increase output while at the same time decrease quality dropped due to changeovers. Single-Minute Exchange of Dies objective is to reduce all changeover time to be a single digit number of minutes. The method was pioneered and developed by Shigeo Shingo (Shingo and Dillon, 1989), a Japanese industrial engineer and one of the world's leading experts on the Toyota Production System.

Definitions and theory, the changeover time of a machine starts after producing the last part of product A and ends with the first good part of product B. The changeover time can be divided into two parts; mechanical change and configuration change. The mechanical changeover time concerns the physical aspects of the changeover where real materials are moved such as the change of dies in the machine, or the change of materials. The configuration changeover time is the time from when all parts and dies are in place and machine setting has to be altered in order to achieve the acceptable results i.e. until the first good piece of B has been produced. The start-up time is not considered in the changeover by many literatures due to the inability to differentiate between start-up failures and normal failures. Still, start-up failures should be carefully monitored, studied, and eliminated as well by appropriate actions.

If the processes are decoupled, the parts will most likely be produced and transferred in batches and the storage areas will be dimensioned for these batches. However, if the processes are connected, each part would be transferred immediately to the next process, creating a one-piece flow. Subsequently the storage area is reduced to the space of the transferred part. Even though the target of SMED is ten minutes, the long-term goal is always zero changeover time so that changeovers are instantaneous and do not interfere in any way with one-piece flow. (Burton and Boeder, 2003) A reduction of changeover time by 50% means the batch size can be reduced by half. By reducing the changeover time several times, the frequency can be increased step by step to "one-piece flow", which the LPS theory mean should be strived to achieve, see Figure 45 below. Furthermore, since one-piece flow reduces the inventory, it leads to an increase of the ROCE (Return on Capital Employed).

The changing in nature of market characteristics towards a more customize demand has force manufacturer to do multiple setup resulting in reduction of times for production for each lot. Consequently, changeover has become an important aspect of managing the business. The less setup time means the flexibility of responding to demand is not affected according to McIntosh et al. (McIntosh et al., 2000). Shingo (Shingo and Dillon, 1989) claims that SMED is a tool that can help company achieves a setup time better than 10 seconds by reducing waste in processes and improve flexibility. Ana Sofia Alves et al. (Alves and Tenera, 2009) suggests that by combining SMED with classic tools and frameworks, SMED can reduce the non-productive time by streamlining and standardizing certain operations or activities. Cakmakci (Cakmakci, 2009) showed the relation between both the setup time reduction (SMED) and product design efficiency through quality control technique, and process capability analysis, he also showed that SMED is still a suitable method not only for manufacturing improvement but also for equipment/die design development. Michels (Michels, 2007) stated that application of SMED methodologies is an effective way to analyze, improve and reduce existing processes used to change over manufacturing equipment. This field study has shown that it is possible to reduce the amount of time required to perform a changeover as well as reduce the amount of direct labor needed to perform some changeovers through improvement of processes.

Single Minute Exchange of Dies or SMED has established itself and become one of the most preferred improvement approaches that has been widely used in the real world situation. SMED is well-known for its aims to reduce the changeover time for the processes that contain machine setup and changeover during its operational times.

Processes of SMED can vary from one practitioner to another, however the essences of SMED still being kept strong, and are the fundamentals to the implementation.

- **Observation of current methodology:** It is recommended to record in video format all the changeover processes from the last good part before the changeover taken places, until the first good part after the changeover has been completed.

- **Separate the Internal and External Activities:** We call an activity internal if that said activity requires the processes to be completely stop before an action can be taken toward the goal of that activity. It internally depends on the elements of the processes or it is a direct element to the processes. On the other hand, external activity is something that can be prepared beforehand or prepare in parallel with the running processes. In a sense, it is something that can be done when the last batch is being produced or once the next batch has started. Potential candidate elements can be Retrieval, Inspection, Cleaning and/or Quality related activities.
- **Convert internal elements to external:** If there are any possibilities to convert internal elements to external, then consideration should be focus on trying to make it possible. By successfully convert internal element to external one, not only does it allow preparation to be done without intervention to the process, but it will also reduce the level of complexity in the processes which will contribute to the next step of SMED.
- **Streamline the process of changeover:** In this step, the remaining elements are investigated with the objectives of streamlining and simplifying so they can be consistently completed in less time. First priority should be given to internal elements to support the primary goal of reducing the changeover duration. Examples of techniques that can be used to streamline elements are

ITEM	Description
Release	Elimination of bolts by opting quick release mechanisms
Adjustment	Standardized numerical setting, Fixed setting
Motion	Eliminate motion by reorganizing workplace
Waiting	Eliminate waiting
Standardizing	Standardize of hardware
Operations	Paralleling processes

Table 1: Potential Streamline Elements

4.7.3 TPS Workshop: OEE

An OEE workshop supports the Takt principle. OEE is the abbreviation of Overall Equipment Effectiveness. This approach helps factory to measure the availability, performance efficiency and quality rate of equipment. The best practices and most practical method is to monitor and improve the effectiveness of manufacturing processes in machines, manufacturing cells, and assembly lines. It takes into consideration the most common term and culprit and root causes of manufacturing productivity loss, places them into three main families and refines them into metrics that provide a gauge for measuring where you are – and how you can improve.

OEE is frequently used as a key metric in TPM (Total Productive Maintenance) and Lean Manufacturing programs and gives a consistent way to measure the effectiveness of TPM and other initiatives by providing an overall framework to measuring production efficiency (Borris, 2006).

To calculate the OEE of a process, three categories of data with respective losses are needed.

$$\text{Availability} = \frac{\text{Planned production time} - (\text{Equipment breakdown} + \text{Setup} + \text{Wait for material})}{\text{Planned production time}}$$

$$\text{Output} = \frac{\text{Actual production time} - (\text{Brief malfunctions} + \text{Reduced cycle time})}{\text{Actual production time}}$$

$$\text{Quality} = \frac{\text{Net working time} - (\text{Ramp up problems} + \text{Rejects, rework})}{\text{Net working time}}$$

$$\text{OEE} = \text{Availability} * \text{Output} * \text{Quality} \quad (\%)$$

Figure 8: OEE Calculation

5. Data and Information Analysis

5.1 Company Strategic Standpoint

5.1.1 Formulation of Operation Strategy

Similar businesses or similar factories can opt to use entirely manufacturing processes or courses of action to achieve the targets. It is vital to suitably choose the most appropriate processes that matches the company characteristics and goals. There can be various relevant factor that indicate the nature of the business such as the approach of the company in regards to the business, the current size of the company, the rigidity of the company's structure, the positioning of the company in the market and the long term goal of the company. The director of the company must engrave the clear directions and goals that the company will work and improve toward. By having the evident goal, the company then will be able to change, adapt and improve its current processes or courses of action to effectively answer the ultimate goals of the company.

Studies and real world cases have shown that many organizations failed to survive or barely alive because of the poor leadership skills used by management. Newly founded or small size company are more likely to rely on a single director or manager to provide the direction of the business. People have different perspectives and views of point and what cannot be seen by one individual may be seen by others. The limitations that some managers have in the important aspect of work-relation is to listening to perspectives and opinions of others which can be severe to the organization. Moreover, traditional leaders in small company usually have short-term focus. The plans, schedules and strategies are always designed are short-term. This is considered to be a serious drawback because today decisions cannot be decided correctly without analyzing the short and long-term sequences of the actions that will be taken today. The long-term analyses are important to make an appropriate decision for the organization's future. Another drawback is related to the controlling strategy used by traditional leader. The control is considered to be a limit for the creative and quick solutions. Organizational environment is full of issues that require creativity and speed in solving. If employees are limited by the control of their leaders, issues will not be solved in an effective manner which will negatively affect the organization.

Voss (Voss, 1995) classifies three families or theoretical frameworks that will facilitate the problems in dealing with decisions and contents in operations strategy. By taking into account the reference to the Skinner's seminal work (Skinner, 1969), the first paradigm according to Voss concerns with how to opt operations as an instrument to compete with competitors in the current marketplace, the next point is revolving around consistency of both internal and external operation. The third one emphasizes on the helpful effect of best practices on firm's operations behavior. The easiest one is the first paradigm because it only looks at the manufacturing as a competitive function. In other words, any firm may have or control different operations capabilities that can be used as strategic assets that must be defined in coherence with success key market factors, global and marketing strategies as well as market demand (Skinner, 1969) (Wheel Wright, 1984) (Slack and Lewis, 2002). Nevertheless, several papers dealing with manufacturing activities have considered that operations decisions should actively influence global strategy and not only react to it (Hayes and Wheelwright, 1984) (Buffa, 1984). In the same stream of thought, Platts & Gregory (Platts and Gregory, 1990) define the company's objectives as the relevance of operations strategy. They considered that firm capabilities are the base for developing innovative operations strategies. In addition, other models define and propose measures for operations capabilities. In this sense, Noble (Noble, 1995) suggests that processes competences must be established successively in a path-dependent sense, in order to be jointly covered. The findings show that more competitive plants are those that compete on the basis of their non-imitable and non-substitutable processes competences. The identification of some inside success key factors related to operations management has been another research area that has received great attention the in literature. A notable contribution is Hill's proposal which is widely used in today application called Terry Hill's Framework. He raised a point concerning markets where company's action have to be carefully studied, reflected and analyzed in the way that the criteria could explain the origin of the current competitive advantage position, price, delivery, quality, product design, and product variety (Miller and Roth, 1994) (Platts and Gregory, 1990).

The Voss (Voss, 1995) second paradigm is the one related to manufacturing decisions considering content operations strategy from an integral consistency –

internal: among all manufacturing decisions, capabilities and competitive priorities; and external: among all manufacturing decisions, and competitive strategy– point of view. Skinner (Skinner, 1969) identified that key content operations decision areas were those related to layout and equipment design, production planning and control systems, work force, product design and organization. Hayes & Wheelwright (Hayes and Wheelwright, 1984) came up with new member, but Hill (Hill, 2017) insisted only on two operations aspects of the management which are processes and operations infrastructures, which can also be considered as the structural and infrastructural operations decisions, as Heineke (Heineke, 1995) stated. These arguments and decisions were carefully investigated and criticized from a contingent approach, as they are affected by the context of the development of the firms in their manufacturing works as well as the competitive strategy (Acur et al., 2003). The last framework refers to implementation of best practice as operations, thanks to the ability from the continuous development which enables firms to gain competitive advantages over the competitors. Best practices refer to several techniques, as material planning requirement (MRP), Flexible Manufacturing Systems (FMS), Just in Time production (JIT), lean production, Total Quality Management (TQM), concurrent engineering, and the like. From implementing these operations best practices emerges a sort of production systems, named ´World Class Manufacturing (Hayes and Wheelwright, 1984) (Schonberger, 2008). This concept was introduced by Hayes y Wheelwright to describe those capabilities developed by Japanese and Germany firms to compete in foreign markets. For the mentioned reasons and analysis, Voss three families are heavily related to the contents of operations strategy. But none of them can explain or attempt to give clear view on the topic of how to form an effective operations strategy.

It is crucial for a young company to grow its root very deep in order to sustain the dynamic of the fast pace of the changing markets.

5.1.2 Modified Terry Hill's framework

Corporate Objectives	Marketing Strategy	Order Qualifiers and Order Winners (Competitive Priorities)	Operations Strategy	
			Operations Design Choices	Infrastructure
• Growth • Survival • Profit • Return on investment • Other market and financial measures • Social welfare	• Goods and services markets and segments • Range • Mix • Volumes • Standardization versus customization • Level of innovation • Leader versus follower alternatives	• Safety • Price (cost) • Range • Flexibility • Demand • Goods and service design • Quality • Service • Goods • Environment • Brand image • Delivery • Speed • Variability • Technical support • Pre- and postservice support	• Type of processes and alternative designs • Supply chain integration and outsourcing • Technology • Capacity and facilities (size, timing, location) • Inventory • Trade-off analysis	• Work force • Operating plans and control system(s) • Quality control • Organizational structure • Compensation system • Learning and innovation systems • Support services

Figure 9: Terry Hill's Framework

According to Davis (Davis et al., 2005), every organization, firm, or business employ similar approach in business management where the objectives, goals and their operation domain are clearly defined and written. The organization's characteristics is also defined by its very own policy which foreseen by the board of directors or owner. This policy is very important because it also serves as a measurement for the organization performance in achieving its goals.

The strategy can mean a plan or a course of action to achieve the organization's policy, objectives and goals. It redefines how the organization should be structured to support the business. Davis (Davis et al., 2005) explained about the relation between strategies and the level of management within an organization. Higher and lower will share some strategies and can have entirely different set of plan that is appropriate to the operating level. However, all strategy across the entire organization should be designed and aimed to support each other in order to achieve the final objectives and goals of the single biggest entity, the organization. Corporate strategy can involve the organization ability to achieve its goal while business unit strategies can be marketing strategy, production strategies, etc.

To integrate different department within an organization in hoping for the most harmonize integration, business units need strategies that can be differ from one department to others. However, collaboration and linkages must be formed internally to achieve common goal. These requirements can be formed and set up by clear and precise corporate strategy. To give an example, in a manufacturing company, the production and the marketing people should have the same mindsets and objectives when speaking about the outcome of the works. They should aim to serve the same target market and same customer segmentation. Products will not be able to attract the customers if the production team comes up with a product mixes that do not design for the target market that the marketing team try to reach. In order to bridge and form those linkages, Hill (Hill, 2017) presented a 5-step framework that can help practitioners understand the situation clearer.

The Terry Hill's framework is a tool that can help company visualize its current level of alignment between its corporate objectives and its marketing and manufacturing strategy as well as setting up the alignment of a new founded company during its setup period.

Hill proposed five important checkmarks that management team can use to identify, modify and improve their organization which are:

- Define Corporate Objectives
- Determine marketing strategy to meet the objectives
- Identify the winning criteria in the target market
- Setup the appropriate delivery methods
- Establish necessary infrastructure to support operations

For small companies, there many cases where the corporate objectives were not clearly defined or were to be simply "making profits" or "stay competitive in the game" which are acceptable. However, the problems that occur for small companies are the contradiction between their ultimate objectives and the methods they choose to use to achieve the objectives or adrift in companies' generic strategy.

Porter's (Porter, 1980) generic strategy provided three main types of strategy which are differentiation, overall low cost and focused cost/differentiation. This information can be easily identified at the beginning of the company lifeline as it is the way or strategy that the company intends to use in order to stay alive, be competitive or even gain more market share in its business. Company usually start out with a strong mindset regarding the way they operate the business. However, as they start to operate fairly well over the initial lifespan of the companies, they look to strengthen their businesses and this is the point where many encounters strategic adrift. A company usually stays alive in the market because they have customers. And by having customers buying their products, it means the company provides competitive edges either in its products or services or the way they deliver the mentioned products or services that satisfy the consumers. By further strengthen the competitive advantages that the company possesses, it will allow company to stabilize its business as well as create a strong company image in its offering. Management of the company is able to identify the company's strengths and weaknesses. However instead of solidify the strong traits, it is often clearer on how to improve the blind spot of the company. By attempting to improve the area which is prone to weaknesses, the company often incurred unnecessary costs into its overall processes to improve the area that customers do not care about or have very little concerns about and as a result, increase the price of the products or services. This situation can cause upsets to consumers and can potentially cause market share losses.

There are attempts to explore the middle ground between those main strategies which is called the best cost strategy. This is a hybrid strategy where company aim to provide similar product differentiation at a better bargain by optimizing the costs of its products. A good example of a brand or a company that employs this strategy with a success is Lexus, the luxury Japanese car manufacturing company. Lexus cars are considered a luxury classy vehicle that rivals the European car maker such as Mercedez-Benz and BMW. By offering similar product characteristics at a better price or offering slightly better product characteristics at the same price range, it is possible for a company to gain the competitive advantages over the competitors. There are many small companies or newly founded ones who attempted

to beat the competition using this hybrid strategy but they failed to achieve their dreams. These companies were stuck in the middle because they can neither provide enough differentiation nor can efficiently optimize their costs. One of the most important factor that enable Lexus to be successful while prevent many others is the leverage capability. Lexus possesses all the relevant knowledge, know-how and infrastructure from the Toyota businesses. They have been building their capacity in LEAN manufacturing processes allowing Lexus to have highly competitive edges over the competitors. Lexus can also use Toyota well-established supply chain to get the necessary materials without creating too much risks. These situations are what allow the hybrid strategy to be firmly implement and be rewarding. The level of readiness in implementing this hybrid cost optimized strategy can be the key to success or failure of companies.

By regularly reviewing the Terry Hill framework of the company or by reviewing the framework before making adjustment to the company internal statements and processes, the management will be able to recall the important factors of the company and direct the company to the most appropriate way.

5.1.3 SWOT Analysis

One of the most commonly used tool to exam the organization's internal strengths and weaknesses as well as opportunities and threats to the organization in its operating business.

Strength: For the company, it has several strengths that can be considered as competitive edges over its competitors. For examples, the company is a spin off/diversification from the main company which is specialized in automation. For this cause, the financial pressure is low because it can sustain with support from the main company. Moreover, the main infrastructure such as crane system for lifting the mold and mount it on the machine is also delivered to the factory by the main company.

Weakness: Weakness of the company is that it has low experience in this field of expertise with just one single capable manager who is responsible for almost everything in the factory. This high level of dependency makes the well-being of the company relies on the happiness of the manager. Additionally, the company still lacks

the effective process management and planning, this will cause a serious management issue when the company is getting bigger and everything cannot be covered by a single person management approach.

Opportunity: Because the plastic consumer product market is one of the largest market. Everyone no matter what his/her financial status is, is the consumer of plastic products. This fact shows the huge customer base which means in details, there can be numbers of market segments in this industries and that is one of the opportunity in entering into the market segment that is still underserved or overserved.

Threat: The concerns in this market is that the complexity of technology in this industry is not high and others can also compete with the company by using a better leverage.

5.1.4 Generic Strategy Formulation

5.2 Product Complication Level

5.2.1 Puttick Grid

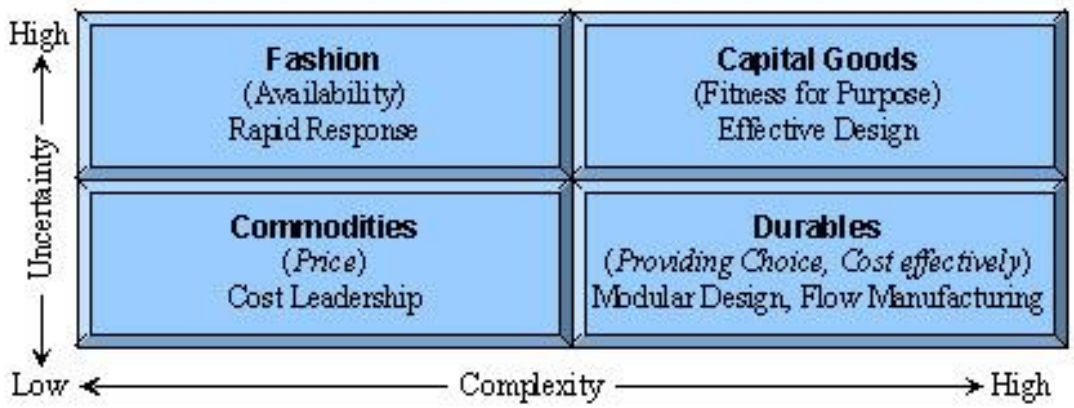

Figure 10: Puttick Grid

John Puttick developed a methodology which allows the companies to evaluate how the markets perceives their products or services. This information serves as an indicator on how much the customers think of the products and how much they are willing to spend to obtain the mentioned products or services. Moreover, each panel can give ideas about the nature of the company's offerings such as the product life which can influence the manufacturing process choices.

Considering plastic consumer products, it is clear that the segment of this product is mostly commodities which has cost leadership characteristics. Even when looking within the product segment only, the characteristics of products that the company is producing is simple consumer products targeting lower markets.

To compete in this market segment, cost or price of the product is the key to win orders. However, the company can also employ a hybrid strategy where better quality is delivered to the customer through goods or services while keeping the price competitive.

5.2.2 Order Winner / Order Qualifier

Order winners and order qualifiers are the key characteristics that allow products or services to penetrate, gain and maintain market shares on target market. According to Hill's definition, order qualifiers is "those criteria that a company must meet for a customer to even consider it as a possible supplier". Providing the qualifying criteria in products or services will open up a possibility leading to customer consideration in buying the products. However, order qualifiers do not win market share off of markets. Order winners, on the other hand, are the winning criteria that allow products or services to win in the market. Normally, order qualifiers will have acceptable ranges for each customer that the suppliers need to make sure they meet and satisfy those ranges. Order winner can win market by being the best in category. The example of characteristics that might be the qualifiers or winners are purchase price, delivery reliability, delivery speed, development costs, product information, quality conformance, performance, uniqueness, flexibility. One characteristic of a product can be either order qualifier or order winners in different market segment depending on the perception of the customers to the products. For example, cars for customers who regard them as a durable consumer product might have the performance aspect as an order qualifier and the purchase price as an order winner. While customers who regard cars as super value product may prioritize performance aspect as an order winner as long as the price of the cars stay in a reasonable range.

It is important to understand different view of the products or services in the point of customers' perception. Misinterpret customers' perception of the order

winner – qualifiers criteria can lead to heavy market losses as the offering products or services fall short of customers' expectation.

5.2.3 Five Performance Objectives - Polar Diagram

Slack et al. (Slack et al., 2010) came up with five operation performance objectives which help measuring the performance of the organizations' products or services. These performance objectives are quality, speed, dependability, flexibility and cost. Each of these objectives play different roles in different product types and target markets.

- Quality objective is the used to be just an order qualifier in many businesses in the past. However, with the advancement that human has been doing in all fields of study, quality objective has continually become more and more important and has taken both role of order qualifier and order winner in today business world. Quality can be perceived as an act of doing the right thing at the right time in the most appropriate manner which can satisfy the needs of customers. In this performance objectives discussion, quality according to Heizer and Render (Heizer and Render) is often viewed in term of conformance to the requirement, specification or promises.

- Speed is another common parameter that can measure the performance of the company and compare it to the requirement in the market. Doing things fast is the minimization of time between the point where orders have been placed and the point where those orders have been made available to the customers. Or it can be a service that help customers achieve their objectives faster. Heizer and Render (Heizer and Render) described that Externally speed is important because it helps to respond quickly to customers. Again, this is usually viewed positively by customers who will be more likely to return with more business. The internal effects of speed have much to do with cost reduction of the organization manufacturing processes.

- Third performance objective is dependability that means doing things in time for customers to receive their goods or services when they are promised. In short, dependability means: 'being on time' for every promises that have been made to the customers. In other words, customers receive their products or services on time. Again, it has external and internal affects. Externally dependability is generally regarded by

customers as a good thing. Internally dependability has an effect on cost. Three ways in which costs are affected can be – by saving time (and therefore money), by saving money directly, and by giving an organization the stability which allows it to improve its efficiencies according to Heizer & Render (Heizer and Render).

- With the fast changing environment in current world, it is crucial that organization must allow certain degree of flexibility in order to cope with those sudden and unexpected situations. Krajewski and Ritzman (Krajewski and Ritzman, 2001) raised the argument that organization must learn to love change and develop flexible and responsive organizations to cope with the dynamic business environment. Chase et. al. (Chase et al., 1998) provided the definition of flexibility in the context of performance objective as the important point to remember is that flexibility always means 'being able to change the operation in some way'. Some of the different types of flexibility are product/service flexibility, mix flexibility, volume flexibility, and delivery flexibility

- The last objective is the cost. Cost is often the order winner criteria in the business. This implies the significant of cost in the business world. Low price is a universal attractive objective to customers, which can be achieved by producing goods at lower costs. There are two main key points here. The first is that the cost structure of different organizations can vary greatly. Second, and most importantly, the other four performance objectives (mentioned above) all contribute, internally, to reducing cost. Davis et al. (Davis et al., 2005) has pointed out that cost is the major revelations within operations management over the last twenty years.

5.2.4 Hayes and Wheelwright Elements

According to Hayes and Wheelwright's element, there are 2 side of the coin that need to be considered before formulating a manufacturing strategy. Because the infrastructural and the structural side of the Manufacturing strategy are related to each other, when organization wants to apply improvement work to one of the element it needs to be aware of the unintentional effect resulted from the change. As a result, Hayes and Wheelwright element can help organization foresees the smooth improvement in its manufacturing processes and can deliver a more reliable and

sustainable development to the works. These elements of Hayes and Wheelwright are considered the major element of operation strategy by many practitioners.

According to the study in the effect of these operation strategy element on firm competitiveness by Diaz Garrido et. al. (Díaz Garrido, 2003), Operations strategy can be conceptualized as a set of decisions or practices with regard to structure and infrastructure variables. On the one hand, these strategic decisions influence firm's abilities to successfully reach some competitive priorities such as, cost, quality, delivery, and flexibility, and, on the other hand, to obtain the expected performance. This research analyses which are the main structural and infrastructural practices that constitute operations strategies in manufacturing companies, and test the effect of these decisions on some firm competitiveness indicators.

Firms' competitiveness and different areas of decision can delimit the content of operations strategy. Both concepts are strongly interrelated as operations decisions and competitive priorities must be congruent. The fit between these variables and the necessary investments in operations structure and infrastructure, may justify the role of operations area as a source of sustainable competitive advantage, as it is showed in (Buffa, 1984) (Hayes and Wheelwright, 1984) (Miller and Roth, 1994) (Skinner, 1969) (Voss, 1995) (Acur et al., 2003). There is no consensus among scholars about how to establish the areas of decisions that must be included in the operations function. Following Schroeder (Schroeder, 1985), these areas influence the way competitive priorities will be reached. Some authors directly identify operations decisions with firm strategy or with operations objectives. If we integrate the arguments presented up to here, we can define them as the bundle of practices that constitutes the entire operations strategy and contributes to get operations competitive priorities and general firm's objectives. Therefore, firms are only well positioned when competitive priorities are strongly supported by operations decisions. There are several studies trying to unlimit and found which areas of operations strategy decisions should be included. The conceptual framework can be organized around two main categories: structural decisions and infrastructural ones.

6. Practical Improvement using ECRS framework

6.1 Company Situation and Problems

This section of the study will be talking about the current situation of the business by evaluating the company using tools and technics that have been covered in the previous section. The objectives of this activity is to define the characteristics of the company products in the market in order to understand the perception of the company to its own products. As well as discover the perception of customers who buy the products from the company. Then it will be crosscheck back to the company's business strategy and its current facilities and operation strategy used. From this comparison, the study aims to point out the misunderstanding between company and customers about the products that are offering in the market by looking at the criteria of order winner – order qualifiers.

Company's ultimate goal for short, medium and long terms will be analyzed and the manufacturing strategy and product mixes will be taken into account to identified the internal contradiction between macro scaled business strategy and smaller scaled operation manufacturing strategy and processes.

With the analytical results from the previous activities, the study will propose adjustments to operation strategy, processes and product characteristics to match the company's long term ultimate objective while trying not to damage the short and medium term targets too much.

Being a small factory, the company ultimate objectives are to stay alive in the market while continuously build up its internal capacity both in human resources and facilities in order to gain more market share in the consumer plastic product businesses. The structure for the company is very simple. It consists of two divisions; the shop floor production team and the sales and marketing teams.

The shop floor manager is responsible for the oversight of all production taken places inside the factory, maintenance of equipment inside the factory as well as storage and inventories of finished goods. The production team is also responsible for new product design and development.

The sales and marketing team main responsibilities are to find new customers, present new products to customers and encourage customers to buy products from the company. Additionally, expected sales forecast will need to be performed too. The instruction that sales person received from the directors is to sell everything as much as you can sell. While the production team will have to keep up with the customers' orders that sales representatives received. This is very common work culture in small or newly founded company, to get the highest profit in the short term and to get even more higher profit in medium term. Long term goals are less often stated in the situation that these companies are in. This also reflect the intense competition in the plastic consumer product market.

The interaction between the two department are usually about the information such as potential orders from customers given by sales person to the production manager, the status of the inventory and finish good stocks from the production team to the sales and marketing department. However, the duration before the sales persons decided to inform the production team can be highly varied. This is because the sales team wanted to be certain that they can firmly secure the orders from customers before telling the production team about the deals. One of the reason that they decided to do things in this way is because they do not want the production team to produce products that cannot be sold because of the failure in order securing of sales division. To put it in another word, they wanted to protect themselves from being blamed for the over-produced products. However, in another perspective, the production team who is responsible for delivering the products that are being sold to the customers might have to confront difficulties in delivering products within the short notice from sales person. If the sales person secured the deal that required the products to be delivered within a short notice, the production team will have to do urgent task to assure the in-time delivery of those orders. If the production lines are not too crowded, this kind of situation could be handled with no major concern. However, if the production capacity is full or highly crowded, the production might be put under pressure due to the urgent request of goods.

The company produced two categories of product; a consumer plastic products and OEM plastic products. The OEM plastics products is a small portion of the overall products amounts produced by the company. For this job, the company acts as a facility and worker provider. The customer provides their own molds and raw materials due to their strict specification and the factory will produce those products in exchange of production fees. These kind of orders are guaranteed with yearly minimum orders and lead time is stable for each order request.

The second category is the consumer products. This line pf production is owned and managed by the company. There are various type of products ranging from a small tea cup to a big bucket of water. Molds and all equipment belong to the company. The company is responsible for the sales generation and as a result the demand for products are much harder to forecast than previous category.

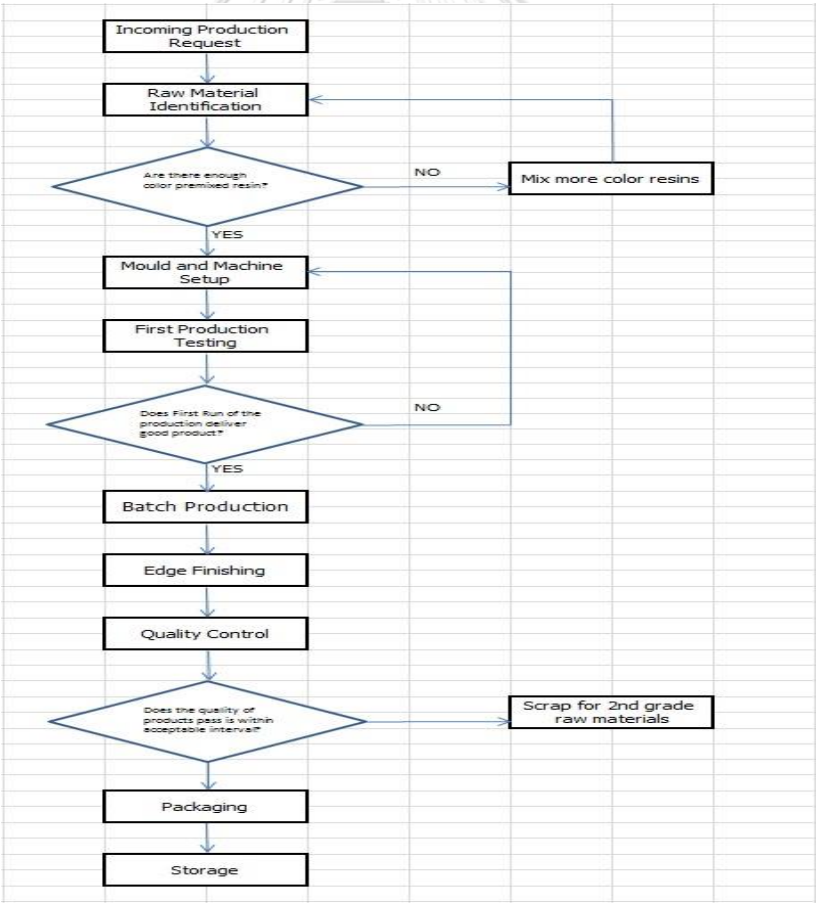

Figure 11: Current Workflow

In case there are enough products in the storage, the company can directly deliver the orders to the customers using premade goods. However, if the stocks are insufficient the factory will need to produce more in order to fulfill the orders.

To trigger the production of goods, there must be either an order requests placed by the sales and marketing team or a stock building requests by the production manager. Incoming production requests will trigger the production team to check for the availability of pre-mixed color plastic resins. They will have to make more color resin in case the current raw material stocks is not enough for production.

Figure 12: Color Mixing Steps

Figure 13: Color Mixing Machine

When raw materials are ready to use. The workers will identify the molds required to make products according to the orders and check for its general condition, machine selection will also be decided by taking into account the limitation of mold compatibility with several machine models.

Figure 14: Mold Area

Mold will be mount to the machine with the help of factory crane lifting system and raw materials are put into the machine bowl.

Figure 15: Mounting Mold with Crane System

The first test run will be performed in order to check for the preliminary product quality. Changes for the machine setting such as temperature and pressure can be modified at this stage in order to ensure that the production will be within the acceptable standard of the factory and customers.

Once the preliminary production is finished. The machine will perform batch productions for the entire orders. At the dejection of each plastic injection step, a worker stationed at each machine will retrieve the products and perform edge trimming to cut off extra material on products and put those products in a box.

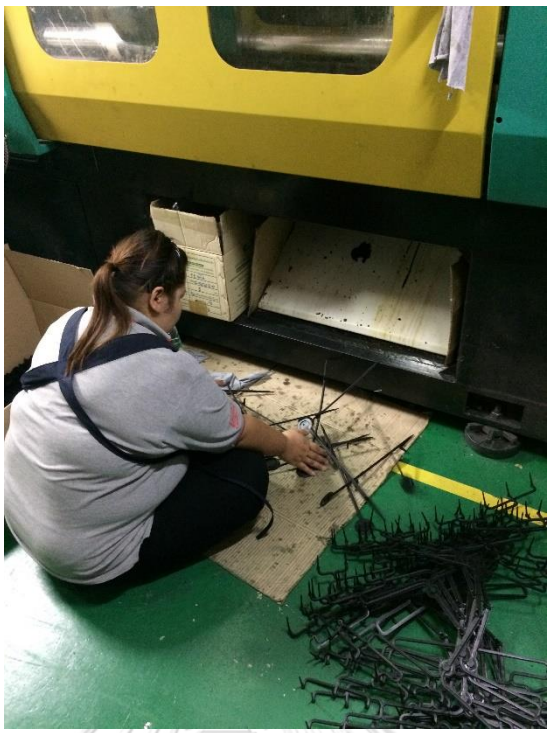

Figure 16: Operator stationed at the dejection from machine

At the stop of the batch production, the box will be moved to an open space. The products will be counted and checked for quality then arranged into primary packages which are sorted by color. Those unacceptable products will be moved to recycling area to be scrapped and used as second grade raw materials. The primary packages will be moved away from production floor to a rented warehouse.

At the warehouse, the company have two processes to performed. The first one is to put them in-coming products on the shelves and update inventories. The second process is the packaging of finished good for customers' deliveries. The pre-packed products will be retrieved and re-packed by a team of workers for an order. The finished packages will be put in a delivery area in front of the warehouse.

Figure 17: Finish Goods Storage Area

Figure 18: Finish Good Storage Area

6.2 Product Variety / Variation Optimization

Consumers Product	OEM Products
Generate half of the company Revenue	Generate half of the company Revenue
High growth potential from sales team	Volume depend on the customer request
Company owns all related equipment to generate products	Company rents out the production capacity in exchange of money
Low technical specification	High technical specification conformity

Table 2: Consumer Products Versus OEM

Consumer products and OEM products possess different kind of contexts. For consumer products, the company is the owner of all relevant tools and equipment using in the production. While for OEM products, the customer has their own raw materials and molds delivered to the company. In the term of growth potential, Consumer products has high growth potential which is not the case for OEM lines that have stable demands. The profit generating from the consumer products is also better. The OEM production is good to fill the spare capacity because the company only gets the labor and facility fees from customers. Because OEM products will be used in the assembly line back in customers' bases, the quality control for these kinds of product is very high and subjects to rejection where the controls were proven to be below acceptance level. This can pose challenges to the technical staffs because the consumer products are far less strict in term of quality control.

6.2.1 Order Winner – Order Qualifier Application

Winner Criteria for OEM products	Qualifier Criteria for OEM products
Cheap Capacity costs	Low Lead time
Flexible Production Capacity	Technical Specification Conformance
	Dependability

Table 3: OEM Winner/Qualifier Analysis

Consideration or perception of customers/consumers toward company's products are also different. For OEM, the customers will only be willing to consider the company if the lead time, dependability and quality conformance can be guaranteed. The winning of orders will be decided by the production costs and scaling of capacity on demands.

Winner Criteria for Consumer Products	Qualifier Criteria for Consumer Products
Product Price	Lead Time
Product Quality	~~Product Quality~~
Color options	
Safety Features (i.e. Microwave compatible)	
Design	

Table 4: Consumer Product Winner/Qualifier Analysis

In the case of consumer products, the company's hybrid strategy is targeting the underserved/overserved market segment where the customers are unwilling to pay premium price for everyday consumer products but they still love to use something with good quality for the money paid. This derives the value perception from the customers/consumers to be focus on price and quality as both winning criteria.

There are a few things that the company needs to seriously consider. Because hybrid strategy is used to compete in the market, company performance depends on the good balance between cost and quality/differentiation. Because to improvement often leads to changes in the cost structure of the product lines, the manager needs to be fully and firmly aware of those impacts and understand of the impacts will affect the company overall performance. Improvement in quality or increment of differentiation can lead to higher costs. Focusing on cost reduction can also affected the quality or reduced the differentiation. Balancing the two side of this arrow is the key to stay healthy as a hybrid practitioner.

6.2.2 Pareto Principle Analysis

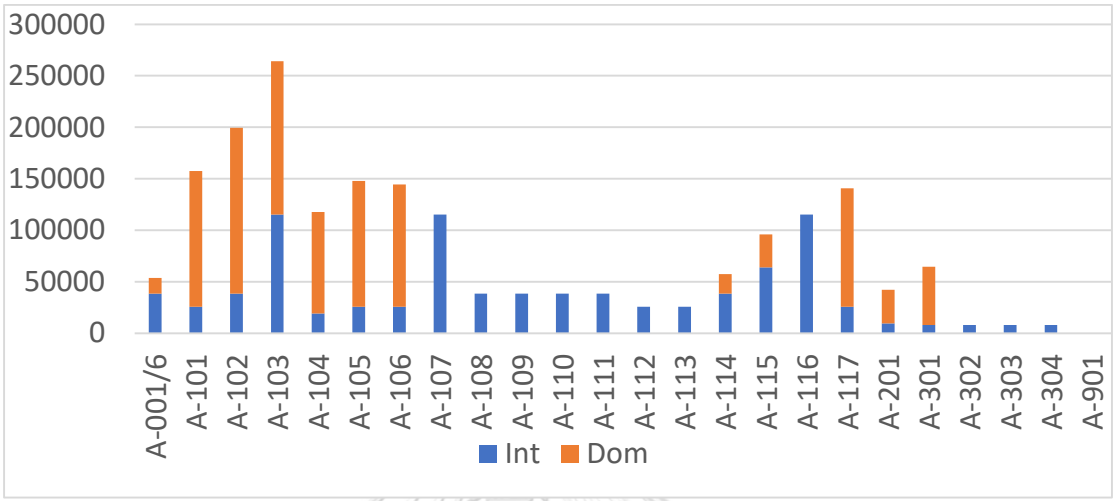

Figure 19: Sales Volume by products

Study on upcoming orders/demands from customer has shown that 80 percent of the product volume that the company needs to make are from just 12 out of 24 product lines. While the other half of the product lines are not as popular as the formers, if they are manufactured to fill the available capacity and can be sold, then the company might reasonably decide to keep running the product lines.

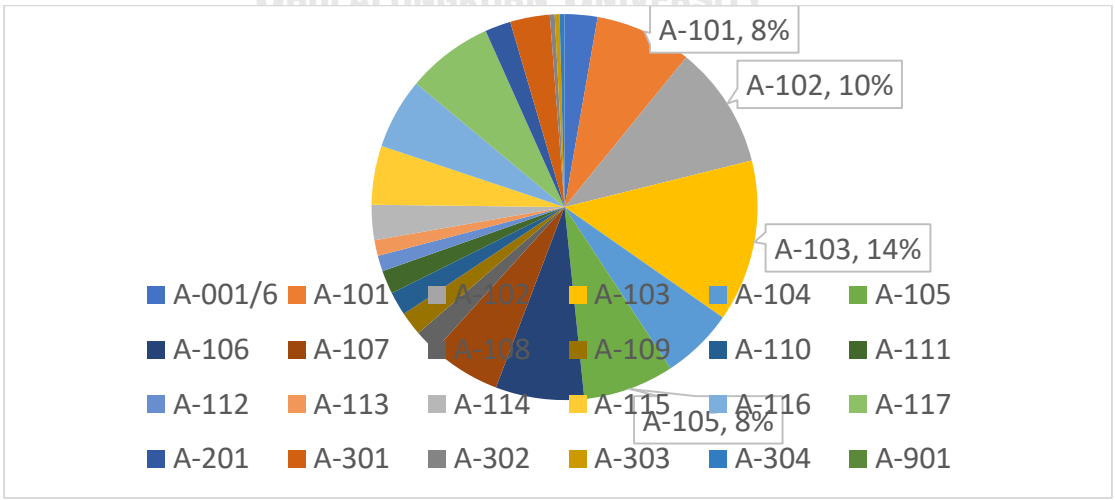

Figure 20: Circular chart with 4 best-selling products

Product A-101, A-102, A-103 and A-105 are the best-selling product lines of the company accumulating to 40 percent of the total volume. They currently have the highest sales potential.

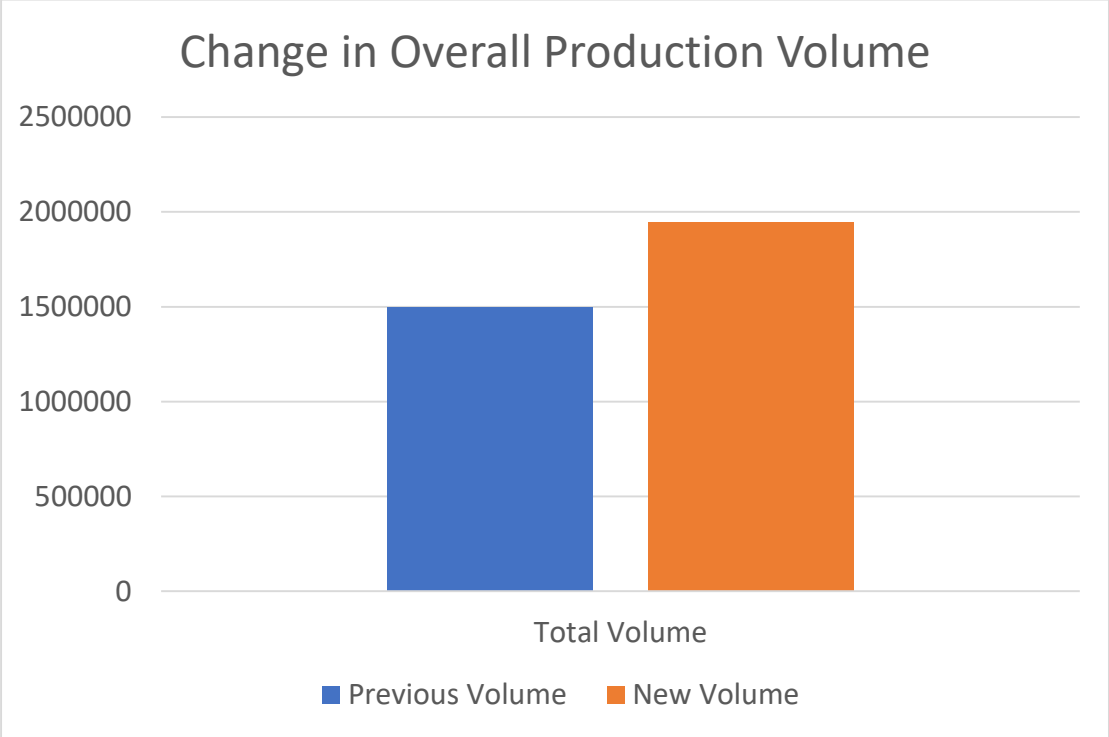

Figure 21: Change in demanded production volume

The above figure illustrates the increasing in demand from previous season recorded at 1,495,490 to the new capacity at 1,944,080 which is about 30 percent increase or 448,630 pieces.

6.2.3 Theoretical Suggestion

Considering that there is no new purchase of machine to increase the manufacturing capacity, the surge in volume by 30 percent is a challenging goal for the company. According to the Pareto Analysis, it is an attractive option to simplify, if not eliminate, some of the product lines that the company currently offers. The unhealthy half of the product lines that contribute to a lowly 20 percent volume should be

reduced in order to regenerate more capacity available to other production. There can be two types of modification in this situation which is the total elimination of the bottom four product lines which has very low volume and simplification of some color variations to reduce machine stoppage.

For the A-302, A-303 and A-304 which will be eliminate from the production plan, it normally takes 60 second to produce one product. To produce 7,920 pieces of each product it will takes 1,425,600 seconds or as long as 396 hours for the machine to continuously producing the goods. There are also additional 7.75 hours of resin color change to cover 4 colors. In total, 403.75 of machine time will be get back from the stop of those lines which in turn can be used to produced additional product that have high demands. The average production time of the 4 best-selling products of the company is measured at 40.5 seconds. The company can use the time regain from the unwanted lines to create additional 35,888 pieces of the top products. Further reducing more product lines will regain more capacity to the company. With total discontinuation of product lines from 24 to 14, the company will be able to use additional 2536.5 hours to work with the selling products which generate cash for the company. Color variation simplification can also reduce the setup time for the production line but it gives back just a small amount of machine time comparing to previous elimination.

6.2.4 Improvement Suggestion

Eliminating product lines or simplifying color variation can potentially give back machine time to the operation. However, in order to realize and seize those return, the company must be able to respond in term of operation excellency to those opportunities. Single-Minute Exchange of Dies or SMED can be used in this context where changeover can happen from various reasons.

6.2.5 Consequences from the Elimination and Simplification

It is important to take into account the opportunity cost as well as adverse effects that might occur from elimination or simplification of product verities and variations. There are times when customers decide which suppliers they will buy products from by the varieties and variation of products on offers.

Four questions are needed to be answered before discontinuing products are;

- Does the segment have a positive contribution margin?

In case the product inconsideration has positive contribution margin, it means that the product itself paid for its variable cost and it is contributing toward fixed cost of the company. It means by discontinue the product, the company removes the variable cost from the bills. However, the fix cost, which remains the same no matter what the decision for the discontinuation is will be higher because the contribution from that products has since disappeared.

- Can any of the fixed cost be avoided if the product line was discontinued?

Again, the company will need to seriously look at the cost structure of the product as well as the company as a whole. Direct fixed costs are fixed costs that can be directly traced to the segment. Just because a fixed cost is direct does not mean that it is avoidable. There may be depreciation, contractual obligations, and other costs that the company will not be able to cut even if the segment is discontinued. If the fixed costs cannot be avoided, losses will increase if the segment is discontinued because the segment will no longer be contributing to the total contribution margin. Moreover, Common fixed costs are organization sustaining fixed costs that are allocated to the segment. These fixed costs will continue even if the segment has been eliminated; they will just be allocated to the remaining segments.

- Can the freed up capacity be used for another purpose?

Unused freed up capacity is one kind of waste that the company must avoid at all cost. Because the aim of discontinuation is to improve the overall profitability of the work, unless the company is selling products at a price lower than the total product

costs, it is unacceptable to have idle machine sitting in the factory while company pays the fixed costs of that idleness.

- Will discontinuing a product have negative effects on the sale of others?

Before eliminating any product lines, the company have to make sure that it will not affect the sale of other products. Or if it affects sale of others, what is the scale of such impacts and is it a healthy decision considering all the tradeoffs. Sometimes it is acceptable for a product to be unprofitable if it can generate other sales which contribute to the positive margin.

For the company, the products that are planned to be discontinued slightly contribute to the positive margin. However, it is more favorable to the company to discontinue these low contribution products and transfer the machine time to other product families whose contributions are more significant. Nevertheless, the issue regarding the effects of discontinued products to other products must be further investigated. If there is any indication that the sales can be secured because the abundant product varieties including the product that is being studied, then the company should not stop producing this product just because it is less profitable for this product has become the winning criteria that customers use to decide which suppliers they will deal with.

Thanks to the nature of the work that even if the company decides to discontinue some product varieties, those products can still be brought back to production with some efforts since the molds used to produce these products still belong to the company and can be easily kept in the storage. In general, the factory still possesses spare capacity on Sunday where the employees use this time of the week to rest up and enjoy their private life after a long week of work. If there exists such a situation where the company need to fulfill bundle orders from customers, they can run the production of these products during the off-shift time with additional expenses of OT paid to the employees. However, having employees regularly work overtime on the weekend where they usually use to rest and spend time with their family can also possess adverse effect that can be a long term negative impact to the company. The company should also consider the human resource management

aspect of the operation because unhappiness can significantly reduce the productivity as well as raise accidents and unfavorable attitude of employees toward the company stance.

The make-to-stock approach that the company uses must also be changed to something a bit of Mixed. Because these lines possess low volume and are not interesting to the company unless they are bundle orders, the company should only start producing these products only right after they have confirmed the orders with customers in order to avoid stocks of unsellable finish goods. This approach will introduce lead time in these product lines. However, giving the nature of plastic consumer products, lead time is a qualifier criterion. The company should be able to deliver products within a respectable time.

6.3 Mold and Machine Management

For the mold and machine management, the study has found that there are limitations about the how one mold can be mounted on some specific machine and not every machine. Additionally, not all machine can inject the resin to the mounted mold.

From investigation and discussion with the shop floor manager, the first issue which was the mold compatibility, was studied and the team has founded that some molds cannot be mounted on some machines because of the size of the molds are too large for the supports. Some molds are designed to be able to create multiple products with just a single round of resin injection. These kinds of mold are usually for the small objects or items.

The second problem concerned technical characteristics of the injection machines themselves. It turned out that some molds, despite being mountable to the machine, cannot be used with certain machines due to the insufficient injection pressure generated by the machines themselves.

These problems imposed unnecessary limitation to the capacity planning, decrease the level of flexibility in the operation making the level of efficiency drops. In time of busy shop floor, the problems might create a situation where some

machine are left idle even though there are backlogs of order waiting to be produced because molds and machines are not compatible.

6.3.1 Theoretical Suggestion

Mold and Machine management is a part of the core activity which is one of the strategic processes of the factory which should never be eliminated. Combine and Rearrange approaches do not directly address these two issues because they are neither the issues of scheduling nor the issues of grouping. The principle of ECRS that the study deems suitable for this process is the Simplify approach to help loosen the rigidity imposed by the compatibility limitation.

The principle of Single-Minute Exchange of Dies can also be applied in order to improve the changeover time in the injection processes. This will be further discussed in the following section.

Color changeover is another important topic that often encounters in plastic injection molding factory. Because changing from one color to another and changing it back can take totally different duration required, it is important that the company understand the logic behind color sequencing. Changing color from white to black or from vanilla color to chocolate color can be very simple and quick. Very little cleaning process is needed before the new material can be put in and start producing new color product. On the contrary, if the change is from black to white or chocolate to vanilla, intensive cleaning must be thoroughly performed to ensure that there will be no drop of black or chocolate colors mixing in the whit or vanilla colors.

It is due to the color intensity that contribute to the degree of difficulty in color changes. Changing from intense/darker color to a subtler/brighter color is difficult because the company will have to make sure that the container is perfectly cleaned because if a slight amount of darker color is left behind, it will be easily visible to naked eyes. On the other hand, changing from subtler colors to darker color is very easy compared to the previous cases.

The company should sequence their production in the most appropriate way which is from subtler/less intense to the more intense/darker to ensure that this processes are fully streamlined according to SMED framework.

6.3.2 Improvement Suggestion

Brainstorming session with the production team consisted of the manager and the technicians was conducted in order to find a solution that can resolve these problems. Suggestions have been made in the meeting which will be discussed in the following section of the report. The use of "5 W 1 H" or five why one how has been employed as a part of root cause analysis.

1 Why	Why can't the machine work with a mounted mold?	Because the resin cannot thoroughly form in the mold.
2 Why	Why the resin does not run through the whole mold cavity?	Because the pressure not high enough to drive the resin all the way?
3 Why	Why can't the pressure be increased?	Because the guiding pipe of the machine can only tolerate this level of pressure.
Suggestion: Change the equipment part to obtain higher pressure / Buy a new machine with more powerful pressure generation.		

Table 5: 5 W's Analysis

To address the problem of machine cannot work with the mold. One of the quickest suggestion raised by the technicians are to purchase a new machine. Suggestion to modified the current machines has also been raised during the meeting and the other suggestion is to modified the mold.

The idea of buying a new machine is not unusual solution to a growing company. Getting the production team, a new machine not only lessen the compatibility issues in time of busy work floor, it also permanently increases the

factory capacity which will be needed in the long run as the company grows and received more and more orders from customers. However, at the current situation that the company are trying to stay competitive and survive in the current market, heavily investing in machine without the justified and confirmed increase in new orders, buying a new machine will incur additional cost to the company which can result in the increasing price of the end products. This downside of the implementation is not in line with the strategy of the company to optimized cost and can cause negative effect such as losing customers due to higher product pricing or company might be struggling because it cannot fully absorb the additional expenses from buying new machine.

Modification of machine injection pressure can definitely resolve the machine to mold compatibility issue without introducing unnecessary extra payment by the company. However, this solution is highly technical and expertize in the machine characteristics is required in order to execute this operation. Unsuccessful in modifying the machine can result in the machine going out of order which will temporarily lessen the factory capacity to produce products.

Application of SMED: to improve the mold and machine management in plastic injection processes is another promising improvement because the operation consisted of several planned changeovers throughout the day.

Before SMED	Changeover			
Separate	Changeover			External
Convert	Changeover		Removed	External
Streamline	Changeover	Streamline	Removed	External

Table 6: Evolution of Changeover

What the company could apply SMED is to reduce, simplify and standardize the changeover so that it can be completed in a shorter time and the production line can resume the nominal production schedule as soon as possible after the changeover finished. The stop of the machine can come from different reasons such as “stop to

change resin color", "stop to change mold", "stop to perform machine maintenance or fix".

The most common stops that happened in the factory are the stop to change resin color and the stop to change the mold, all of which are planned or expected stop.

These kinds of stop generally possess, to an extent, external elements and/or internal elements that can be convert to external elements.

Firstly, the company must remove External elements from the changeover and perform those activities before, after, or even in parallel with the operation. In this scenario, the potential external elements to the changeover can be the retrieval and refill of raw materials, the retrieval and checkup of molds or quality check for the productions. To improve the efficiency of the factory and to be able to respond to the regain machine time from product line elimination and simplification, it is necessary that the company is able to reduce unnecessary activity that will halt the production line. Raw materials that will be used to fill the machine should be just right at the machine before the last run of the current operation finish, so that the shop floor workers can promptly stop the machine to refill the material with least time. By doing things in this manner, the company has eliminated the unnecessary stop time caused by the act of raw material transportation from one place to another.

In case where mold will be changed to another one, there are a few external factors that can be moved away from the changeover. Unmounting the current mold from the machine and bringing it all the way back to storage before retrieving the next mold back to be mounted on the machine can take a long time. Due to the size and weight of molds that can be very heavy, the company can only move it slowly with the help of crane retrieval system, making machine stop for a long time during the replacement of molds. Additionally, checks have to be carried out before mounting the new mold on the machine which further extend the machine stop time. The company should consider setting up an open space centered at all machine as a mold-waiting-area where they conduct a few activities before, after and in parallel to the changeovers. The next mold to be mounted should be retrieved and placed at the waiting area for inspection activity to be carried out right before the planned stop. The

crane system after transporting the new mold to the waiting area then go to the target machine to remove the mounted mold from the machine and bring that mold back to waiting area. The mold that just arrived from the machine, instead of moving it back directly to the storage area, the technician should perform inspection and maintenance if necessary right away at this point where the mold will not be used in the near future. This will further prevent mold problems at the production test run, because every mold will go through an additional health check to ensure the good functional status.

Work instruction should be drafted and reviewed together by both management and operation levels. Afterward, the instruction should be officially deployed to the shop floor in order to standardize and control the common activities and processes that different operators have to performed. This will also build up the experience of the employees and open up rooms for further improvement. For example, there should be a clear sequence of how a production color will change in every production line.

It should at the very least consist of important milestone in the changeover activity as well as time consumed in each activity which can be used to analyze the performance of the shop floor after the improvement project has been implemented. Example for the mold changeover milestones can be the following;

- *2-hours-alarm triggered before the end of the current production batch*
    - *Check color sequence for the next production*
    - *Check availability of raw materials that will be used for the next production*
    - *Prepare additional raw materials if needed*
    - *Move the raw materials to the waiting-station beside the machine*
- *1-hour-alarm triggered before the end of the current production batch*
    - *Retrieve the mold from the storage to the waiting-area*
    - *Perform mold condition inspection with fixes if necessary*
- *Alarm trigger at the end of the current production batch*

- *Perform color changeover*
- *Retrieve the current mold from the machine to the waiting-area*
- *Move the new mold from the waiting-area to the machine and mount it*
- *Adjust relevant parameters of the machine*
- *Small batch production for production QC, modify until QC has passed*
- *Start of the new production batch*

6.4 Packaging

6.4.1 Theoretical Suggestion

Packaging is by no mean the core competency of the company. However, the marketing promotion where the customers can freely choose the combination of color of products they want do generate high sales volume and revenue to the company. As a result, one of the non-strategic process becomes the competitive advantages that the company can use to compete in the competition.

Table 7: Finish Goods waiting to be repacked

The marketing strategy that lets customers pick their favored color sometimes cause the inventory to be filled with a certain product with certain colors because no one wanted to buy it.

Since the company do not possesses specialize in packaging, it is currently performed the bare minimum requirement of plastic wrapping and logo stamps on the package. Nonetheless, this level of packaging does not cause any problems to the company sales because the target customers of the company give so little importance to the packaging. In fact, this packaging is well aligned with the company strategy to perform cost optimization.

Table 8: Finished good packed by color

By mixing color tailored to customers' preferences, the company cannot avoid unpacking the products from the primary packaging and repacking them in accordance to the customers' requests. These works cause the stocks of finished goods to be moved from and to the shelves many time during the packaging processes.

The "Rearrange" and "Simplify" concepts of the ECRS will be used in this context to improve the packaging efficiency.

6.4.2 Practical Implementation Suggestion

Even though outsourcing the non-core activities of the company is the right thing to do in theory, it does not mean in the real life company has to push through that change right away.

Outsourcing the packaging works to the packaging company required the clear and definite packaging details, the information that the current company has little control over due to the use of marketing strategy in color combination customization to customers. It can be costly to obtain a premium service for a dedicated operation that the company required. As a result, in-house packaging is still favorite for the company.

In order to improve the packaging time, a study on division of labor has been reviewed and it is promising method to help the company improve its work efficiency. Because the packaging processes are not complicate and can be entirely carried out by human labor, the division of labor which categorized the actions and appropriately group and distribute them to a certain team to perform is applied.

Table 9: Packing with division of labor approach

Division of labor can be implement without introducing any cost to the processes and it can significantly boost the efficiency because it creates expertise in the assigned team who will improve his respective responsibilities over time by exercising the same routine every day. Instead of having a team to work on an order, the whole packaging team will work on the same orders but different packaging steps ranging from stock retrieval / inventory updates, unpacking and counting, plastic wrapping the bundles, decoration of the packaging to boxing and moving to delivery area.

Table 10: Finish Goods waiting to be delivered

Table 11:Finished Goods waiting to be delivered

6.4.3 Conclusion

From the investigation, analysis and intensive discussion regarding the problems, their causes and effects as well as the solutions or workaround to overcome those problems, the team are able to greatly prioritize and manage the production of varieties and variations of the current products. Not only can the company improve its operation efficiency and effectiveness, the company has also established countered measured in preparation for the foreseeable adverse effects resulted from the product variety and variation changes. Single-Minute Exchange of Dies or SMED has been applied to the changeover taken places throughout the production time. The company will be able to considerably reduce the changeover time as well as create work instruction to further standardize the work processes such as color changeover sequence and the resin color and mold changeover processes.

Product varieties and variations study helps the company to prioritize the production of products according to the demands of customers. By freeing the time usages of unprofitable products, the company can move those available machine time to other products that are more promising in sale volumes. In order to efficiently seize the opportunities from the elimination and simplification of variety and variation, the

company. For 1-month worth of production time, the factory allocates weekdays for full production and 2 extra shifts on Saturday which accumulates to 544 hours. In order to respond to the high demands of certain product lines, the company should discontinue some of the low volume products for the extra machine time. Nonetheless, company can still further increase the machine time by allow the production on off-day which accumulates to an extra 128 hours at the expense of overtime payment to the employees.

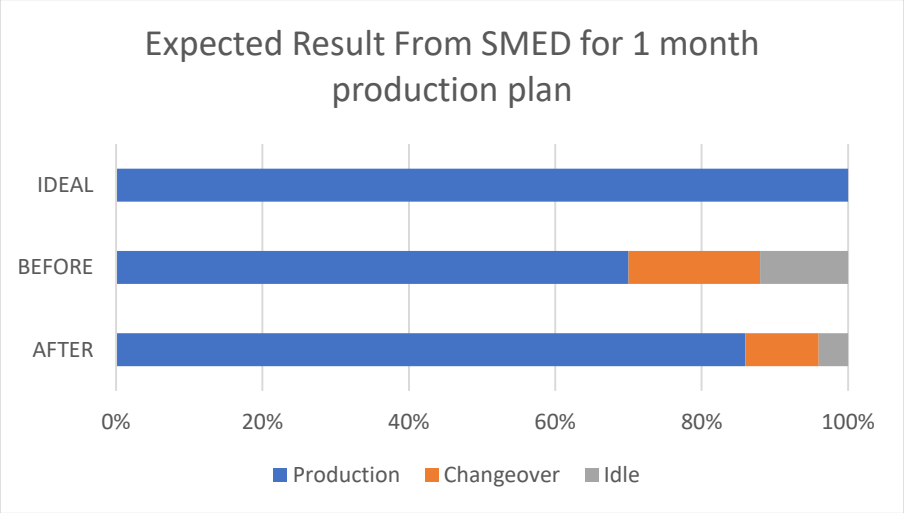

Figure 22: : SMED Improvement Expectation

The Study expect that SMED can improve the overall efficiency by reducing the duration required in both planned and unplanned changeovers which are the causes of the idle time of the machine. SMED can help the company in mold and color changeover management by removing external factors such as raw material and mold transportation and mold inspection and maintenance from the changeover process which contribute to the better and more efficient changeover processes in the factory. Because some internal elements of the changeover cannot be converted to external elements or has substantial cost attached to it, color sequencing is one of the way that company can use to streamline the internal elements of the changeover in order to improve the internal element time of the changeover.

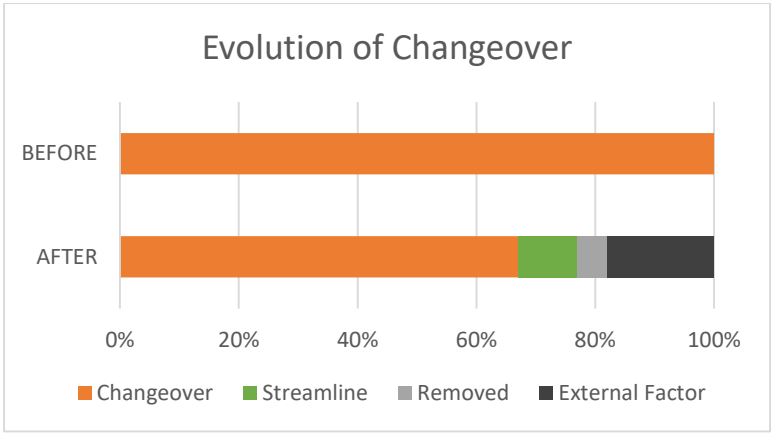

Figure 23: Improvement in Changeover process

7. Recommended Further Studies

The current situation of the company is a small plastic injection molding that starting the business with simple plastic consumer product and plastic injection works from OEM. The corporate goals and objectives are to expand the businesses and grow profits by selling quality products at reasonable price to the middle market where both cost and quality are the important factors to the customers.

The writer of this thesis has discussed about vision of the company with its owner and the expectation from the owner is to compete in both domestic and international market. The way the factory is managing and producing all relevant items can be described as what Micheal Porter described as the so called “Struck-in-the-Middle” situation, while there are others practitioner who disagree and define the same situation as the “Hybrid strategy”.

In the view of writer of this thesis, hybrid strategy where both cost and differentiation are treated as the winning criteria required substantial support in finance and knowledge in the business. For a small company, without the good leverage, hybrid strategy posts more threats than benefits in running and competing the businesses in the market because small or newly founded company lack the sale volume that needs to be rocket-high in order to enable the low cost, high differentiation strategy.

The recommended study that the company should consider and attentively plan for is the path that the company will take. In the opinion of the writer, there is a strong current of mass customization in every market because the demands from the current world population required almost everything to be more personalized. This leads the way toward an even more challenging manufacturing strategy and management because mass customization required high degree of flexibility in manufacturing processes which is the direct averse to the cost structure of the products. It is important that the company should prepare itself in term of workforce quality, manufacturing excellency, and innovative products to prepare itself for the fierce market requirement and tough competition in the future.

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APPENDIX

VITA

Poom Popattanachai was born on April 2nd, 1988 in Bangkok, Thailand. He obtained his bachelor degree in Conception et Fabrication en Aéronautique from Université Toulouse III in Toulouse, France.

After his graduation, he joined Geo-Informatics and Space Technology Development Agency (Public Organization) as an Image Ground System Engineer, in the department of Production and Data Archiving Division, Satellite Operation Center. Later on, he decided to continue his higher education in Master of Engineering, Faculty of Engineering, CUSE, Chulalongkorn University.