IMPROVING DELIVERY LEAD TIME IN MEDICAL DEVICE SUPPLIES TO PUBLIC HOSPITALS IN MALAYSIA

by

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Abstract

This project paper focuses on issues affecting Thera Medic on its delivery lead time for supplies of medical devices (surgical products) to public hospitals in Malaysia. This paper also aims to provide recommendation to improve the overall lead time to meet the lead time expected by the customers. This project paper gives an overview of the case issue concerning the current medical devices industry scenario as far as supply chain is concerned and challenges being faced by manufacturers. In the case analysis part, analytical tools were used to identify root cause and gaps in the supply chain process flow. The tools that were applied are, cause and effect diagram, supply chain value stream mapping and interview questions.

The root cause reveals several significant root-causes primarily stemming from people, process, and material and machines related factors that impact towards delivery delays. Focus of this paper addresses primarily the internal factors which are controllable and manageable. In contrast, the external factors which primarily stems from customers or suppliers are analyzed from risk management approach to minimize the risks associated with delivery lead time issues caused by external factors.

To overcome the delivery delays and improve this further, recommendations and possible solutions are provided with critical analysis to indicate any disadvantages of these risk management plans.

Executive Summary

Thera-Medic is a local SME manufacturer of medical devices which produces wide range of surgical products in wound care segment. One of the challenges faced by Thera Medic is the delivery date requirements from its customers, primarily the public hospitals. The fact is that the medical devices has non-predictive nature of demand, where the demand fluctuates according to healthcare requirements, such as number and timing of surgeries, high mix of product range especially the single use devices, lack of planning awareness in hospitals and tender or budget dependant purchases. The delivery issues occur because of the short lead time required by the hospitals which is around 4 weeks. However, the current scenario is that the lead time ranges anywhere between 8 to 21 weeks which is a huge gap compared to the required delivery date by the hospital. The delay in delivering goods has several business implications including cancellation of order, credibility of delivery, competitor’s entry, and overall customer dissatisfaction.

The delivery delays are caused by internal and external factors. The external factors include customers, suppliers of raw materials and competitors. The internal factors concerns the issues stemming from machine, manpower, material, process and management. The external factors although are important issues, but these are largely beyond control of Thera Medic. The internal factors, however, can be managed and controlled to a certain extent. This project paper focuses on issues that are considered to be internal factors. In order to derive the improvement plans, first the root cause of these delays is analysed using specific tools. The Fishbone diagram

or Ishikawa diagram is used as basis of determining the root cause of these delivery delays. The analysis found that several significant factors contribute to the delivery delays from manpower, machine, process and equipment. This includes, factors stemming from machine downtime, manual process that creates the backlog situation, low operator performance, absenteeism among production operators, and stock out of raw materials.

The root cause are also verified and supported by conducting interview with the key personnel in the supply chain department. Inputs from these personnel are gathered to gain understanding of the supply chain practises which will help to formulate the improvement plans. Next tool used to derive the improvement plans are the value stream mapping. The objective is to determine gap in the process and determine the efficiency in the order processing flow. Analysis shows that the order processing involves both manually processed information and information processed via a system called AIMS (Accounting and Inventory Management System). The manually dine process take relatively longer processing time as these are carried out offline using excel spreadsheets, therefore making the ERP system as non-integrated.

The strategy to improve the lead time falls into two categories, whereby the improvement action plans (IAP) are based on internal root-cause are addressed. Each category of the root cause from machine, manpower, process and material are addressed individually. The external factors are not neglected completely but rather taken into consideration by managing the risks associated with external factors. These are called risk management plans (RMP) that concerns the issues involving primarily the raw material suppliers and customers.

The implementation of the IAP and RMP would require a new target lead time to be set by management of Thera Medic. As these implementation consumes resources and money, a periodic review crucial to ensure its effectiveness and that the plans meets its object

1.0 Introduction

The supply chain management of medical devices to hospitals are a complex, critical and challenging task for all manufacturers and suppliers.

One of the challenges is able to deliver products within shortest possible time. However, the reality is, medical devices supplies are faced with several supply chain related issues. Firstly it concerns on its predictive nature of demand of medical products. For example, no one can anticipate emergency surgery cases or accidents cases that require immediate medical attention and treatment. This causes planning for stocks a challenge for both for the hospitals and also for the manufacturers. In addition to this, tenders and budget dependant purchases poses another challenge in planning for stocks or forecasting for demand. Tenders usually involves higher volumes of purchases and hence the inventory management plays an important role to ensure tender supplies are done as per the stipulated delivery deadlines. Another challenge especially when it involves high mix products such as the medical disposables, the inventory planning is more tedious and risk of having high number of slow moving inventory due to the high mix product range if inventory planning is not done properly. The other aspects of supply chain of medical devices is that the lack of planning awareness among hospital procurement personnel. Hospital personnel are more focused on the core responsibilities, which is to save lives and ensuring good healthcare services to patients. Therefore, inventory planning is often neglected (Raeeda, et al, 2013). This project will focus on analysing the underlying factors that contributing to long lead time to supply of surgical products by Thera-Medic to public hospitals in Malaysia and possible solutions that can be practically implemented to improve the lead time.

2.0 Current scenario

Lead time of supply of medical devices (total lead time) currently ranges anywhere from 8-21 weeks from the date of order from hospitals. However, most of the order from hospital required to be supplied ideally within 4 weeks. This based on the required delivery date mentioned in local purchase orders from hospitals (LPO). This situation poses several business related risks. One of the major risks is the cancellation of order. When orders are cancelled, chances of getting repeat orders from customers are compromised and at the same time, the ordered raw materials or work in-progress becomes excess liability for the company if not sold to others. In addition to this, certain supplies all for penalty if not delivered as per stipulated delivery deadline and the company running into risk being blacklisted in the particular hospital. The delivery delays ultimately will cause customer dissatisfaction and eventually will diminish the company's credibility and image. When the reliability of the supplies becomes an issue, this opens door for competitors to enter the hospital and get the orders. This poses a re-entry barrier for Thera-Medic.

2.1 Industry background

Healthcare expenditure in Malaysia in 2014 is estimated at RM 42.3 billion and continues to grow each year. The healthcare expenditure is on increasing trend due to various factors including growing population in which the growth rate is approximately 1.3% annually. In 2013, statistics from Ministry of Health shows that the crude birth rate per 1,000 population is 17.2% while the crude death rate is at 4.7% per 1,000 population (Ministry of Health, Health facts). The medical device industry is a highly diversified industry that comprises of wide range of products and equipment which includes medical gloves, implantable devices, surgical devices and active devices such as in-vitro diagnostic devices (IVD).

The industry players include many small to medium-sized enterprises (SME's) with certain multinational companies from US and Europe. The industry is regarded as capital and technology-intensive. Medical device industry has generated employment for more than 20,400 people, from various levels including in the managerial levels, professional, supervisory and technical staff levels. Based on information obtained from Malaysian Investment Development Authority (MIDA), there are more than 180 medical devices manufacturers in Malaysia. By end of 2015, it is forecasted that the medical devices marketing Malaysia is expected to reach USD 1.69 billion.

Table 1: Medical Device sales indicators in Malaysia, 2009-2015 (Source: www.mida.gov.my)

Malaysia's Medical Devices Sales Indicators, 2007-2015 (USD billions)

	2009	2010	2011*f*	2012*f*	2013*f*	2014*f*	2015*f*
Medical devices sales	0.936	1.091	1.253	1.371	1.464	1.580	1.692
Medical devices sales % of GDP	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Medical devices sales % of total healthcare sales	9.70	9.79	9.83	9.93	9.96	10.13	10.27

In 2013, a total allocation of RM 22.16 billion budget were allocated for Ministry of Health which comprises of 141 public hospitals and medical institutes and over 2,800 health and community clinics. This allocation accounts for 8.4% of the total budget national budget in 2013. (MOH Health Facts, 2014)

In line with the increase in healthcare expenditure, the usage of these wound closure surgical products in hospitals are increasing every year. The wound closure products are generally used whenever any closure of wound is required, either from natural causes, for example child birth, or due to external factors such as surgical interventions, disease or accidents. In addition to this, more and more competition are entering into medical field and the hospitals have more options in selection. Based on information obtain from market intelligence of Thera-Medic, there are 3 active and main supplier of these surgical products that commands more than 50% of the market. There are also estimated another 3 to 5 smaller suppliers of these products but their market share information are not available as there are relatively new to the market and no direct representative offices in Malaysia.

The healthcare supply chain is often described as highly fragmented and inefficient (Schneller and Smeltzer, 2006). Hospitals expect fast delivery of medical products and they can't afford to have "out–of–stock" situation for critical supplies of these surgical items in operating theatre. This is more crucial for fast moving codes which are used on almost daily basis. The usage of these medical products in hospitals is on surgical procedures primarily in general surgery, orthopaedic, obstetrics & gynaecology, urology and cardiovascular surgery.

Given these facts, supplier who is able to deliver the goods within the fastest possible time is one of the key success factors, besides than product quality and pricing which are also crucial in decision making for purchases.

3.0 Company background

Thera-Medic Sdn. Bhd. is a small medium enterprise (SME) medical device manufacturer based in Penang. Established in year 2002, Thera-Medic is involved in manufacturing and distribution of medical devices, namely surgical products for wound closure, to both government and private hospitals. The company also exports to overseas and it has to date more than 12 active export markets. Thera-Medic is ISO 13485 certified which is a quality management system for medical devices. In addition to this, the products are CE marked and has recently obtained FDA approval for one of its range of wound care product. Large portion of its domestic sales are concentrated on public (government) hospitals. Thera-Medic also has a local sales office in Selangor that handles all the marketing and distribution of the products to hospitals throughout Malaysia.

Being a SME, Thera-Medic has relatively lean organization structure with total manpower of 75 people. The organization structure of Thera –Medic is as per Figure 1 below.

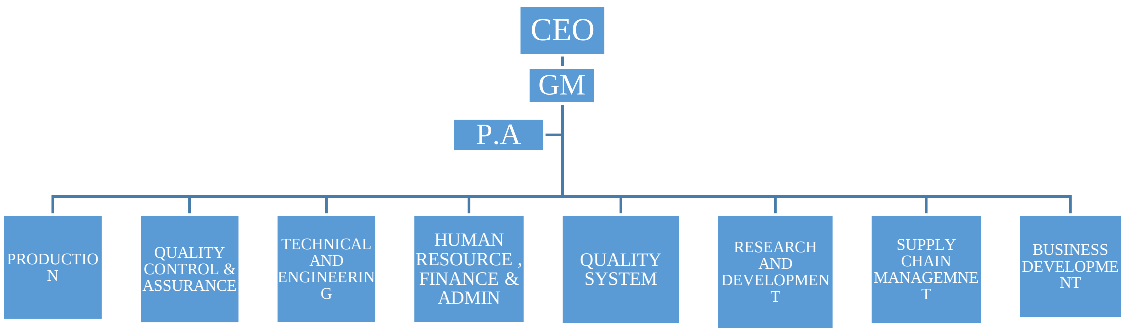

Figure 1: Organization chart of Thera-Medic

The vision of the company is based on principles of being the leader in the manufacture and supply of world class medical and surgical devices and with quality services. This vision is aimed at developing medical devices which are considered to be innovative and at the international quality level. The mission of Thera-Medic is to consistently and continually manage quality expectations, innovation and trends, human capital development and last but not least, customer satisfaction.

Main products manufactured by Thera-Medic are categorised into single use surgical devices (SUD) that are high mix in nature. The specification of the product varies from country to country and even according to hospitals. In single use devices, inventory management and delivery lead time plays a crucial role to ensure continuous supply without disruption. Therefore, the supply chain that handles the delivery and order planning will be the source of primary information for analysis in this project. The supply chain department structure in Thera-Medic consists of following sub-department and their roles and responsibilities are summarized in the job matrix below:

Table 2: Job matrix of Supply Chain Department

Section	Function	Staff details
Order processing and planning	To receive and process purchase orders, maintain contact with customers and distributors, prepare shipping documents and follow up on order status and delivery	Supply Chain Assistant, Officer and Executive (headcount : 2)
Material Management	Receiving and issuance of raw material Manage inventory and stock accuracy	Material store Officer, Store clerk (headcount : 2)
Logistics	To arrange for inbound and outbound transportation to customer and for sterilization.	Supply Chain Officer (headcount :1)
Purchasing	To plan for raw material procurement and issue purchase order to suppliers	Purchasing Executive, Purchasing Asst. (headcount:2)

4.0 Case Issue

The consistency of supply and stock availability of the surgical products are crucial in ensuring that the hospital able to carry out the surgical procedures on timely manner. The case issue for this paper will be based on delivery information of the medical devices to 3 major hospitals in the northern region namely (Hospital Seberang Jaya, Hospital Pulau Pinang and Hospital Sultan Abdul Halim, Kedah). These 3 hospitals are chosen as they represent approximately 45% of products sold within the northern region. Based on information gathered from these 3 major hospitals, the supply of disposable medical products is expected within 4 weeks of order date for LPO. Exception for this is the tender supplies which are usually required on staggered delivery or based on fixed schedule usually over a period of 1 to 2 years. The required delivery date (RDD) is a challenge as the raw material delivery lead time is almost double of that, which ranges around 8-12 weeks. Thera-Medic manufactures all their products based on orders due to the high variety of the devices (exceeding 1,000 article numbers) and considering the shelf life of these devices (between 3-5 years). When the product has high variety, it makes stock keeping almost quite impossible. Furthermore, the hospital prefers freshly produced stocks with shelf life at least 3 years and if Thera-Medic were to keep stock and if the stocks did not move for several years, ultimately the remaining shelf life becomes less and stocks has to be eventually written off, if its nears its expiry date.

The main component raw materials for the manufacturing of these surgical products are based on steel material and polymer based material. Theses raw materials are fully imported as these are medical grade materials which are not available from local suppliers. The tables below gives the simulation of the delivery lead time based on 3 give scenarios; finished goods in stock, second scenario if raw materials are in stocks and the 3rd scenario if raw materials are not in stock. The basis of this simulation is as follows:

1. Shipping time to local hospitals are around 1 to 2 days via lorry, hence it does not gives a major impact on lead time issues which are calculated by weeks.
2. Quantity of order is taken on average for 1 carton of finished goods which is 132 boxes of surgical devices.
3. No backlog, quality issue or machine downtime in production.
4. Production are based on first in first out (FIFO) to consider 4 weeks lead time.
5. Production capacity is available

Scenario #1: Finished goods in stock

Required Delivery date (RDD)	Raw Material lead time (average)	Production Time (average)	Total Lead time (TLT) (average)	Difference between RDD and TLT
4 weeks from order date	Not applicable	Not applicable	**1 – 2 days**	**0 weeks**

Scenario #2: If raw materials are IN stock

Required Delivery date (RDD)	Raw Material lead time (average)	Production Time (average)	Total Lead time (TLT) (average)	Difference between RDD and TLT

4 weeks from order date	Not applicable	4 weeks	**4 weeks**	**0 weeks**

Scenario #3: If raw materials are NOT in stock.

Required Delivery date (RDD)	Raw Material lead time (average)	Production Time (average)	Total Lead time (TLT) (average)	Difference between RDD and TLT
4 weeks from order date	10 weeks	4 weeks	**14 weeks**	**10 weeks**

Based on the simulation of the lead time above, it is clear that the lead time for delivery to hospital can range anywhere between 1 day to 14 weeks which is a huge gap. Therefore, in priority, Thera-Medic need to address scenario 3 as scenario 2 is still manageable within the given required delivery date by the hospital which is 4 weeks. Scenario 3 gives a delivery delay of 10 weeks. The second level priority will be to address scenario 2 in managing risk in case raw materials in stock has quality issues or unanticipated shortages (discrepancies in stock count, misallocation to other customers).

To verify this situation further, an analysis is carried out on top 10 commonly sold surgical products to hospitals. The top 10 common codes contribute to 40% of overall sales of the surgical products. Table 3 indicates the summary of the Total Lead Time (TLT) for the top 10 codes and the comparison against the required delivery date based on data collected from January 2014 to December 2014.

Table 3: Total lead time analysis for top 10 common codes

Article Number	Total Lead Time (TLT) (weeks)	Required delivery date (RDD) (weeks)	Delay (weeks)
F2	20.7	4	16.7
B3	18.2	4	14.2
E1	12.0	4	8.0
B4	10.1	4	6.1
S2	9.7	4	5.7
B2	11.4	4	7.4
C2	10.7	4	6.7
B5	7.6	4	3.6
E8	9.4	4	5.4
P4	14.5	4	10.5
MIN	**7.6**	**4.0**	**3.6**
MAX	**20.7**	**4.0**	**16.7**
AVERAGE	**12.4**	**4.0**	**8.4**

The average lead time of the supply is around 12.4 weeks. On average, the delay is approximately 8.4 weeks of delay if considering 4 weeks required delivery date (RDD) from customer and the difference are significant which could affect the business of Thera-Medic.

4.1 Business implications on delivery delay

There are several business implications as a result of the delivery delays :

a. Cancellation of order

When goods are not delivered on the required delivery date of customer (RDD), there are high risk chances that the order might be cancelled by the hospitals. Hospitals can’t afford to run out of stocks of surgical products and in such cases, they will turn to other suppliers who can supply the similar specifications of the surgical products. At the same time, the goods which are probably half way through in production or raw materials which are on transit, but have to be kept as stocks or allocate to other customers, if at all there is an order for similar item. In any case, this may also cause excess stock at Thera-Medic.

b. Image and credibility of the company affected

When order gets cancelled, the credibility of future supplies from Thera-Medic will be affected. This makes a major impact on future order decisions from the hospitals, more so if the delays are frequent. Hence, it’s imperative that the issue of delivery lead time must be addressed in order to ensure continues orders from the hospital.

c. Customer dissatisfaction

Delivery delays do affect customer satisfaction significantly. Customer considers delivery commitment from suppliers are measure of a service quality. When service quality is not met according to what the customer require, customer will be dissatisfied and affects the sustainability of the business in a particular hospital.

d. Opportunity for competitors

As explained earlier, customers nowadays have options due to emergence of new competitors in the field of medical device supplies. Hence, any customer who are dissatisfied will turn to new suppliers and this is paving way for new players to establish account with the hospital. This directly creates another re-entry barrier for suppliers who have been already supplying before.

5.0 Tools for case analysis

The focus of the analysis in the project paper will based on **internal issues** that contributing to the delivery lead time issues. This includes factors such as production and manpower efficiency, inventory management and other internal system factors. The external factors on customers and suppliers are excluded in this analysis as the extents of control of these external factors are minimal. Nevertheless, certain recommendations are given in the recommendations sections as to suggestions to address customers and suppliers issues to minimise or manage external factors risks.

To analyse the case issue further from the internal point of view, several method of analysis will be used in this project. The background and objective for applying these tools are as described as per following:

5.1 Fishbone analysis

Fish bone analysis or popularly known as Ishikawa diagram or "cause and effect diagram" is a tool for analysing cause and effect of a specific issue. Although this tool is originated from quality defect prevention, the supply chain issues can also be can be also analysed using this tool. This tool is chosen in particular to analyse contributing or potential factors that leads to overall effect of delivery lead time issues as it is able to view the issues from various aspects from material to even environment. The segment of factors that will be considered in this analysis are based on people based factors, machine factors, method, material, management and environment [5].

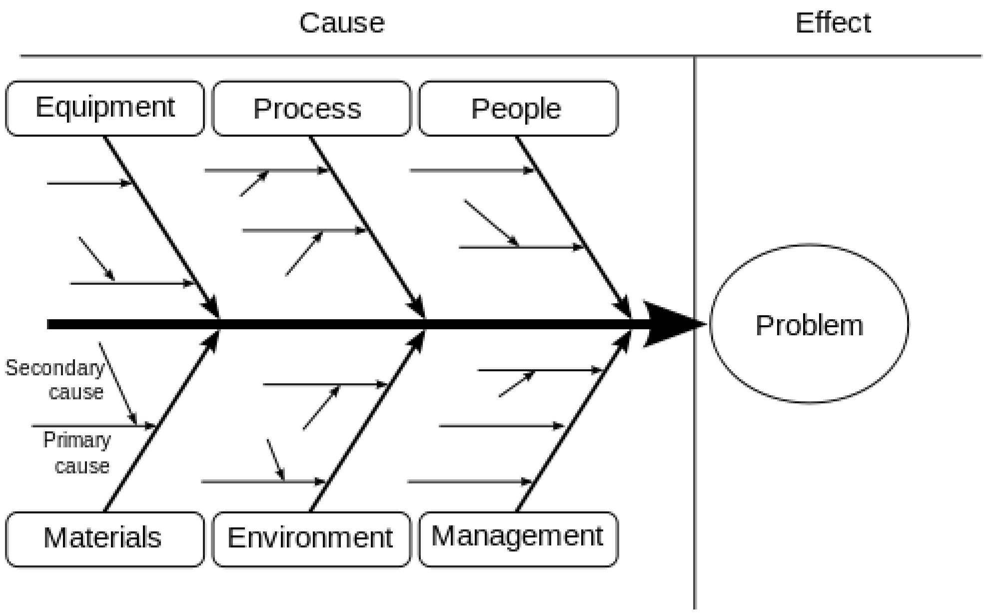

Figure 2: Cause and effect diagram template

The source of data that will be collected and analysed will be in the form of:

i. Order trend data from key hospitals for the top 10 common codes
ii. Historical data on delivery lead time
iii. Production lead time information
iv. Frequency of on-time delivery versus delay in deliveries
v. Raw material lead time of the common codes
vi. Order processing time and production loading performance

5.2 Value Stream Mapping on Supply Chain

This is useful analytical tool for lean management and identifies any non-value added activity or unproductive activity along the various stages in supply chain. This is generally a process activity mapping that will help Thera-Medic to study the flow of process that enables segregation of each critical steps, identify any waste or non-value-added activity along the process and finally can be used as a tool to re-arrange the sequence in a more effective manner to be leaner. The Value Stream mapping in this project is applied throughout the order processing steps that starts from the receipt of order from customer, until delivery is made. Each step involved in the step is analysed in terms of the duration taken and determination whether the process is done via system or manually.

6.0 Interview and questionnaire

In order to obtain feedback from various internal people that has direct influences in the delivery lead time, an interview session were conducted. The set of questions that are posed to the interviewees are unique, and has combination of questions that is able to lead to the contributing factor for the lead time issues. The target group for the questions are

a. Supply chain executives and officers

b. Purchasing executive and materials management personnel

c. Production Executive

The interview plan are summarised as per Table 4.

Table 4: Interview plan

Person to be interviewed	Objective
Supply Chain Officer Supply Chain Executive	To identify the KPI's, challenges faced in supply chain concerning delivery and how it's being managed
Purchasing executive Material management	To identify existing inventory management process and production planning
Production Executive	To understand about the overall production performance from process, machine and manpower that affecting production lead time.

Following are the list of questions that will be included in the interview session

1. Supply Chain Officer/Executive :

    - How many PO do you receive in a month (on average)
    - How long it takes (on average) to produce goods from date of order?
    - Does all your customer provides forecast or rolling forecast?
    - How often are you able to meet customer's required date?
    - Have you experienced order cancellation due to delivery delays?
    - Have you experienced order cancellation due to delivery delays?
    - Do you perform customer satisfaction surveys?
    - Do you calculate and analyse delivery lead time for each orders?
    - What is your delivery performance targets (KPI's?)
    - Did you meet those targets?
    - What are the patterns of customer orders?
    - What are the reason you are not able to meet delivery lead time?
    - How do you manage urgent/ unexpected orders?

2. Purchasing and Materials Management

    - How long it takes to do material planning for new orders
    - What system do you use for material planning?
    - What is average number of loading (shop floor) per month?
    - What issue you face for material planning?
    - What issue you face for material planning?
    - Do you maintain safety stock level?
    - Do you maintain reorder level?
    - How do you manage late deliveries from vendor?
    - How do you manage stock discrepancy issues?

- What is your loading performance targets (KPI's?)
- Did you meet those targets?
- How often do you experience stock out situation for critical items?
- How do you manage urgent/ unexpected orders?

3. Production Executive

- What is your current capacity utilization?
- How often you face capacity issue(s) in a month?
- What is your KPI for operator performance?
- What is your average production lead time?
- What contributes to delay in production?
- What is your major manpower issue?
- How do you manage urgent orders?
- What is the average machine downtime per day?
- Which area has more machine downtime?
- How often do you face material quality issue in a month?
- Do you face downtime due to material shortages?

The feedback from these questions will be analysed as inputs into Case and Effect diagram, and Supply Chain Value Stream Mapping analysis.

7.0 Case Analysis

In all these 3 category of people that are involved in the supply chain, the customer and suppliers are categorised as external factors that are not within a direct control of Thera-Medic. This is due to the fact that the delivery delays of raw materials from vendors is beyond the control of Thera-Medic. Likewise, customers that are not able to provide advance orders or forecasts are beyond the control of Thera-Medic. On the other hand, the factors arising from manufacturer itself can be controlled and managed. Hence, the internal factors will be more discussed in detail as the internal factors can be controlled and managed by Thera-Medic. The external factor, however, will be taken into consideration using the risk management approach which is addressed in section 8.2.

7.1 Cause and Effect analysis

In order to determine the cause or factors that contribute to delivery lead time, a fishbone analysis or well known as Ishikawa or cause and effect diagram is used to identify the various contributing factors. In this analysis, 6 main areas are analysed in particular, equipment, process, people, materials, environment and management. These factors are analysed from the internal activities within Thera-Medic.

a. Equipment or Machine downtime

The equipment that is used in the manufacturing comprises of mechanical or pneumatic-PLC based assembly machine, packaging machine and sterilization machines. The front end manufacturing process are either manual or semiautomated, while the back end process can be considered to be automated process. Given this scenario, the manual operations may potentially contribute to increase in production lead time as the process is human dependant. The standard production lead time, considering a quantity of 132 boxes is about 4 weeks. Assuming that there is no machinery breakdown, no production backlog or any capacity constraint issue, the production lead time can be described per Figure 3 below:

Figure 3: Lead time of back end and front end of production process

As described in Figure 3, the back end process are automated which are machine dependent. The packaging machine and sterilization process could be potentially contributing completion of production of orders to extend beyond 2 weeks if there is machine downtime. Following are the more in-depth analysis of the downtime occurred in the back end process from January to December 2014. These are downtime data which has been recorded on daily basis and then compiled on monthly basis for analysis. The impact of the machine downtime on the delivery delays are calculated based on following formula:

Production lead time delay (in days) = total machine downtime (hours) per month / 8 hours

The 8 hours represents the normal production hours per day (Thera-Medic currently does not operates on shift basis)

Table 5: Machine downtime impact on delivery delays

Month	Downtime (hours)	Delay impact on production lead time (days)
JAN	13.40	1.68
FEB	4.55	0.57
MAR	34.50	4.31
APR	54.40	6.80
MAY	39.25	4.91
JUN	17.30	2.16
JUL	69.55	8.69
AUG	8.35	1.04
SEP	33.15	4.14
OCT	40.15	5.02
NOV	103.55	12.94
DEC	21.00	2.63
MIN	**4.55**	**0.57**
MAX	**103.55**	**12.94**
AVERAGE	**36.60**	**4.57**

As per above analysis, the average number of days the production lead time delay is approximately 4.6 days, while the highest recorded delay was approximately 13 days. The downtime recorded in July (8.69 days) and November (13 days) were almost twice and three times higher than the average due to the back end machine breakdown in which the production was dependent on single machine. This shows that the machine downtime plays a crucial role in influencing the total delivery lead time.

b. Process

i. Production process

Production process plays an important role in determining the overall lead time, especially the type of production process involved, whether the process is manual (human dependent) or automated (machine dependent). The process factor is further analyzed from process point of view than can lead to delivery issues are the backlog occurring due to bottleneck situation. The bottleneck situation occurs primarily due to capacity related issue whereby a succeeding step has lower output per hour than the preceding step. This is to say, for example process B has lower output than process A. Hence, potential bottleneck situation can occur at step B. Hence, the sequence of steps throughout the production process is analyzed to check if any significant bottle neck situation that could potentially contribute to delivery delays.

The front end process is a manpower dependent process whereby many manually carried out process taking place especially in the assembly section. In order to investigate this issue further, the key parameter used is the output per day analysis in order to determine if there are any potential backlogs that can be created. Table 6 shows the average output per day on various steps of front end production versus the back end process. The front end process has 3 assembly stages while the back end process has 3 processing stages which are described in Table 6.

Table 6: Production capacity on various stages of process

Process ID	Capacity per day (pcs)	Stage
LC	15,000	Front end
NA	11,000	
WD	12,000	
PP	15,000	Back end
SP	17,000	
FS	16,000	

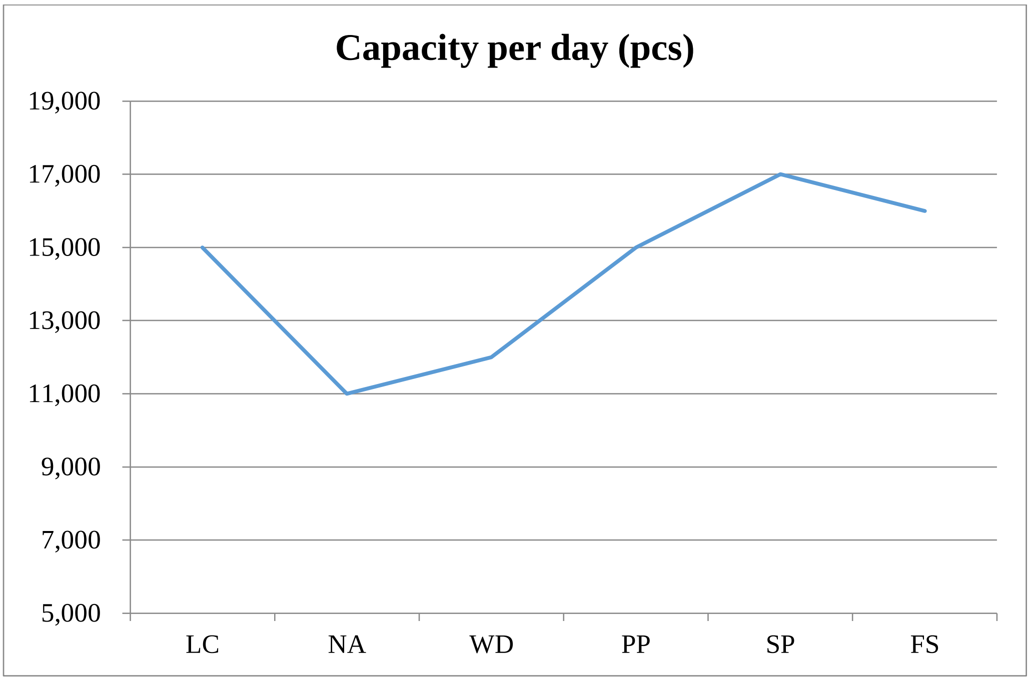

Figure 4: Capacity analysis of various production stages