A Framework for Reverse Engineering Process for an Electronic Manufacturing Company: A Case Study

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Abstract

Since reverse engineering (RE) leads to a tremendous impact on product quality, customer satisfaction, and the level of customer loyalty and retention, increased attention is given to the supply chain process. In this paper, a framework for RE is built for an electronics manufacturing company using PERT (Project Evaluation and Review Technique) while considering financial and political limitations. Prior to this effort, RE efforts at the organization were being conducted on a case-by-case basis. By implementing this framework, the organization can better plan, optimize, and document RE activities. The status and features of this new RE framework will be presented and future improvement recommendations will be given.

Keywords
Reverse logistics, reverse engineering, return merchandise authorization, PERT and supply chain management.

1. Introduction
During the last decades, more awareness has been shown in terms of sustainability in supply chain management and operations, national and international regulations, and social communities all around the world are arguing to push businesses to consider the environmental impact and sustain resources while designing their products and operations (Metta and Badurdeen. 2013).

Sustainability has three main discourses; environmental, social, and business. Environmental sustainability can be defined as the capacity to preserve natural resources and uphold ecological balance in our planet's natural environment for the benefit of present and future generations. While social sustainability is defined as determining and managing the good and bad effects of business on people. And finally, business sustainability refers to the ability of a company to endure through time, in terms of profitability, productivity, and financial performance as well as in terms of managing the environmental and social assets that make up its capital, in another term how business can stay in business (Giovannoni and Fabietti. 2013).
A review report by (Springett. 2003) which aimed to identify the development of business sustainability shows that one of the topics that needs to be addressed and investigated using real case implantation is the return marterial authorization (RMA).

The expectations of customers, businesses, and buyers do not always go as planned, despite the greatest efforts and quality control measures. And in such situations, the item will be sent back through the supply chain. Companies often do this to maximize asset recovery, optimize supply chain efficiency, reduce costs and improve customer experience and maintain the good name of their business so they will be sustained in the market (Chai et al. 2010).
When a product is returned, reverse logistics, also known as the return process, must be followed. Typically, the initial step is to get RMA. However, the RMA may consider several post-sale services. These could involve warranty

management, service contracts, return analysis, end-of-life equipment management, and other factors. RMA can decrease a company's economic, social, and environmental effects. Additionally, it may improve a business's profitability and asset usage (Chai et al. 2010).

Different methods and techniques can be followed to manage the process of RMA in different sectors. Our case study will be carried out in a semiconductor manufacturing company to show a real industrial application of applying RMA processes to one of their main product lines. An evaluation of the current process flow including measuring maximum, minimum, and average process time will be used to find the optimal path that optimizes the RMA process using PERT.

1.1 Objectives

The main objectives of the study are:

- Defining the RMA process for one of the products in a semiconductor manufacturing company.
- Optimizing the time for the RMA process defined earlier in this project by incorporating PERT.
- Making the production process at the company sustainable by linking both (forward and backward) processes together.

2. Literature Review

Different articles related to this topic have been reviewed including the methodologies used to conduct our research. A study by (Metta and Badurdeen. 2013) focuses on the value of incorporating sustainability into product and supply chain design as well as the difficulties involved. The authors conducted a review of the literature, an examination of a case study, and data analysis to pinpoint the main modeling problems and difficulties associated with including sustainable product and supply chain design. They created a conceptual framework that offers a methodical means of tackling these problems and difficulties. The article's conclusion is that companies must give sustainability a high priority during the design process, collaborate with stakeholders to address sustainability issues and create products and supply chains that incorporate sustainability. The authors suggest that future studies concentrate on developing more accurate and detailed models to improve decision-making in sustainable design.

The impact of reverse logistics product disposition on business performance in Malaysia's electrical and electronic (EE) industry is investigated by a Khor and Udin (2011) study using a quantitative research technique. Two-hundred EE enterprises in Malaysia were given a survey questionnaire, and the results were examined using descriptive and inferential statistics. Reverse logistics product disposition considerably enhances operational, financial, and environmental performance, according to the study. The study also found three factors—customer pressure, regulatory pressure, and organizational readiness—that affect how reverse logistics products are disposed of. The study has significant repercussions for managing reverse logistics and sustainability in Malaysia's EE sector, including prioritizing efficient reverse logistics strategies, building organizational capabilities and systems, and working with stakeholders to advance sustainability and enhance business performance.

A simulation study integrated with activity-based costing for an electronic device re-manufacturing was performed that shows there are two main models for re-manufacturing processes (Calvi et al. 2020). The dedicated model is used by organizations to re-manufacture products usually under an agreement with the original equipment manufacturer (OEM). The other model is called the shared model which is used where manufacturing and re-manufacturing occur simultaneously in the same facility and the two processes share resources. The activity-based costing (ABC) system is a map of the expenses of a process and its profitability, which is constructed based on its activities. This system is used to answer two questions; what activities are using or consuming resources? And how much activity is required to process a product? There are three drivers required in order to allocate costs following the ABC system. Those drivers are activity duration, activity occurrence, and cost of all resources used when an activity occurs. The facility processes four product models; in some cases, a station is shared among all models, and in others, a station is dedicated to processing one model. The products are identified as Model N, Model M, Model F, and Model T. The total number of stations in the model is 31. The direct material costs, direct labor costs, and total direct costs are all calculated using specific formulas. The study suggested guidelines to design an efficient re-manufacturing line as follows: The initial phase of designing a re-manufacturing production line starts with determining the type of products to be returned, causes of return, and required processing activities. Allocating costs based on specific production activities allows for reaching the level of accuracy desired to make efficient decisions (direct material and labor). The integrated approach can help planners to determine bottlenecks in the system and devise a list of scenarios to streamline the processes.

Verification and validation are necessary steps for simulation. The results must be correctly interpreted to make correct and appropriate informed decisions.
Using a case-based reasoning method to design a return merchandise authorization system for supply chain management in the Internet of Things, Chen (2017) used data warehousing, data mining, and online analytical processing methodologies to analyze global RMA data for an IT company. The case-based reasoning (CBR) method was also used to deduce RMA behavior. The findings revealed that there were 6,053 cases of failed motherboards (MBs) and an analysis of 2,839 cases (14.03%) was presented. The CBR method was found to be reliable, as 56 cases out of 79 RMA data of the 340S2 motherboard were found to have failure symptoms due to W21. The study also analyzed the RMA repair performance by calculating the turn-around time (TAT). The proposed system was found to be effective, as it provided an RMA progress tracking mechanism, controlled RMA workloads, established a repair diagnostic system, improved RMA turn-around time efficiency by 26%, reduced inventory amount by 12%, and reduced the product failure rate by 85%.

3. Methods

The methodology for this study starts from the idea that the company that this study was conducted on has no standardized procedure related to the RMA process. Besides that, the main focus of the company was taken from the forward production. The RMA practices were done with so much randomness. The first step started with applying the engineering method of thinking. Figure 1 represents the process flow that was adopted in this study. The process flow starts with defining the whole process and this comes after working with the operators. Then, multiple meetings were conducted with different involved teams like warehouse, production, and upper management team in order to come up with a flow chart process explaining the RMA process. Later, the process was applied and the flow chart was adjusted and prepared to fit with PERT to be applied on it. After the planned RMA process was applied and put into reality, data started be collected. The main data needed was the minimum, most likely, and maximum time for each stage in the process flow chart.

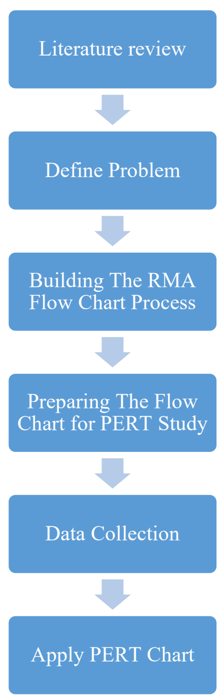

Figure 1. Methodology Flow Chart

After multiple meetings and discussions, a flow chart process was drawn for the RMA process. This process is shown clearly in Figure 2. The process flow chart includes 5 different colors. Each color represents the department or side include or needed for that specific step. The white color refers to the steps and stages that needs the customer or it has something to deal with customers. The yellow color refers to warehouse team. The green color refers to repair team. While quality team is referred to by pink color, and the production teams is referred to by purple.

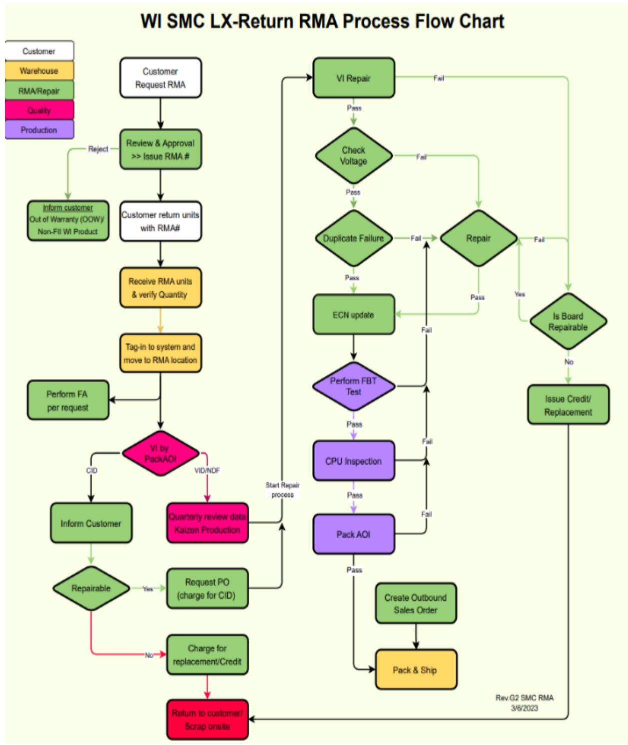

Figure 2 RMA Flow Chart Process

The shape of the process flow chart drawn in Figure 2 cannot be used for PERT. For that reason, some kind of adjustment to the shape is needed order to make it compatible with PERT. Also, each step in the adjusted process flow chart was assigned by an alphabet to make it easier to deal with the process. The adjusted process and the assigned alphabet are shown in Figure 3.

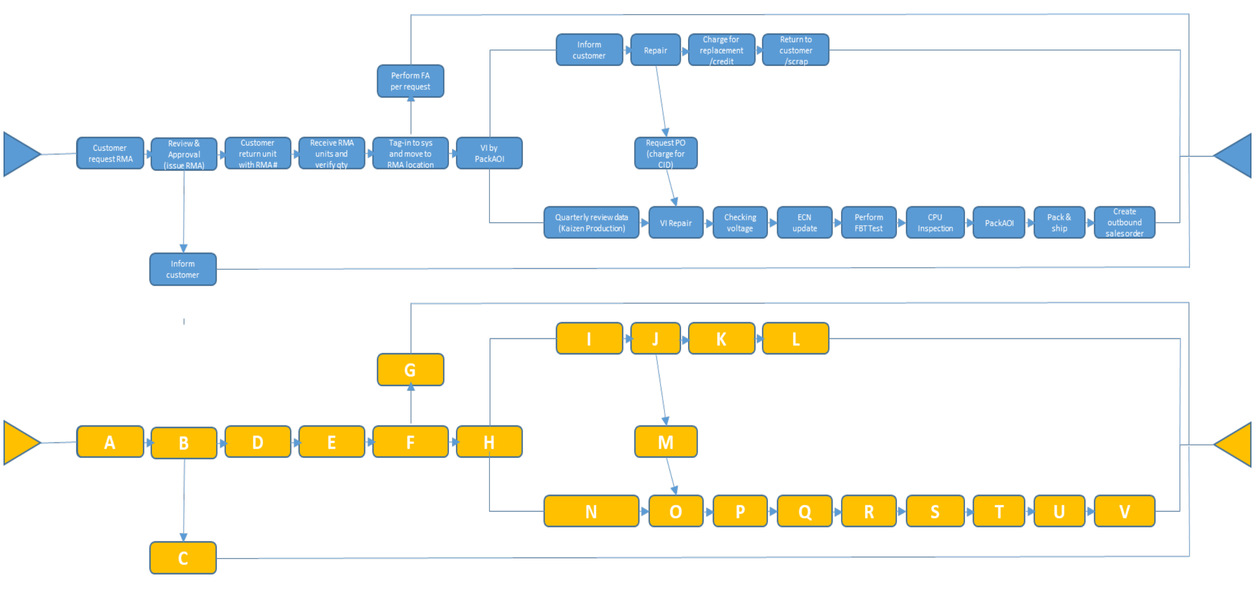

Figure 3. Adjusted RMA Process Flow Chart for PERT

Afterwards, the process was implemented in the real-life process. Our team started observing the process and calculating the measurements needed for PERT. The most likely number represents the mathematical average for those five numbers. Later, for PERT, only one number, the meantime, is needed which is the time estimation of that step. This mean time can be calculated using Equation (1).

$$T_e = \frac{a+4m+b}{6} \qquad (1)$$

Where,

T_e: Time estimation,
a: Minimum time,
b: Maximum time, and
m: Most likely time.

All the minimum, most likely, maximum, and the calculated time estimations are shown in Table 1.

Table 1 Time Estimation Calculation

Activity Number	Activity Code	Immediate Predecessor	a	m	b	Te
1	A	-	0.00	0.00	0.00	0.00
2	B	A	0.50	1.10	2.00	1.15
3	C	B	0.10	0.40	0.80	0.42
4	D	B	15.00	23.00	49.00	26.00
5	E	D	0.50	0.80	1.20	0.82
6	F	E	0.20	0.40	0.70	0.42
7	G	F	1.10	2.30	2.60	2.15
8	H	F	0.20	0.23	0.40	0.25
9	I	H	0.10	0.60	0.80	0.55
10	J	I	1.80	3.30	5.00	3.33
11	K	J	0.10	0.65	0.80	0.58
12	L	K	8.00	23.00	48.00	24.67
13	M	J	2.00	13.00	24.00	13.00
14	N	H	0.10	0.18	0.30	0.19
15	O	M,N	0.30	0.59	0.80	0.58
16	P	O	0.10	0.21	0.30	0.21
17	Q	P	0.10	0.17	0.20	0.16
18	R	Q	0.70	1.30	1.70	1.27
19	S	R	0.50	0.62	0.80	0.63
20	T	S	0.10	0.11	0.20	0.12
21	U	T	9	23	48	24.83
22	V	U	0.1	0.22	0.3	0.21

Figure 3 was used to find all the possible traces that can lead from the start to the end. It was found that there are 5 different possible traces. The critical path will definitely be one of those five options. The critical path by its name means that more attention must be given to its activities because a delay in any critical activity causes a delay to the whole process. The possible traces are defined by the assigned alphabets as:

Trace 1: A – B – D – E – F – G
Trace 2: A – B – C
Trace 3: A – B – D – E – F – H – I – J – K – L
Trace 4: A – B – D – E – F – H – N – O – P – Q – R – S – T – U – V
Trace 5: A – B – D – E – F – H – I – J – M – O – P – Q – R – S – T – U – V

Later, PERT starts by calculating the earliest start time and earliest finish time for each activity by moving forward from the start node to the end. Then, the latest start and latest finish time for each activity were calculated by moving backwards from the end node the start node. For each activity the number shown on the left top side of the activity represents the earliest start. The number on the right top side represents the latest start. While, the earliest finish is shown on the left bottom side of the activity and the earliest finish is shown on the right bottom side of activity. Figure 4 shows all the activity calculated numbers on each activity box.

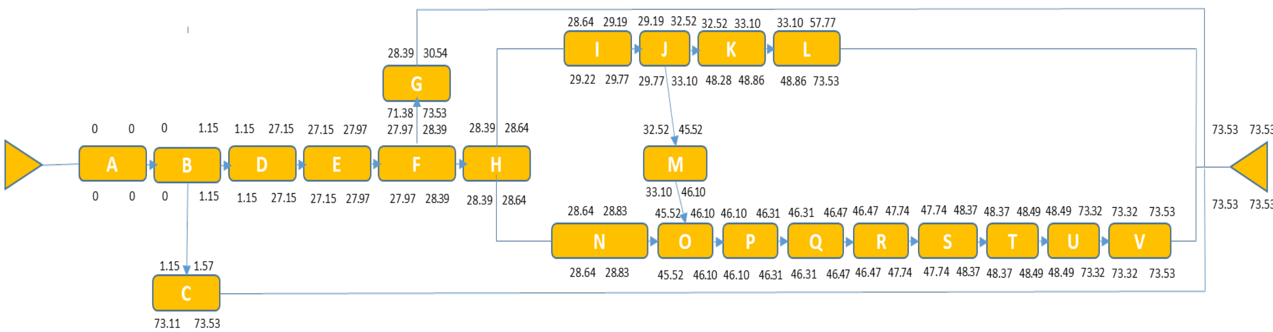

Figure 4 PERT on Adjusted RMA Process Flow Chart

4. Results and Discussion

Slack time for each activity was calculated. Slack number is the difference between its latest start and earliest start time, or alternatively, as the difference between its latest and earliest finishing time. Table 2 represents the earliest times, latest times, and the calculated slack for each activity. Since any delay in the critical activity causes a delay to the whole process. This means the slack time for the critical activity must be zero.

By using the slack time, the critical path was easily detected to include activities A, B, D, E, F, H, N, O, P, Q, R, S, T, U, and V.

Table 2 Critical Activities

Table 2 Critical ActivitiesActivity Number	Activity Code	ES	EF	LS	LF	Slack	Critical Activity
1	A	0.00	0.00	0.00	0.00	0.00	Yes
2	B	0.00	1.15	0.00	1.15	0.00	Yes
3	C	1.15	1.57	73.11	73.53	71.96	No
4	D	1.15	27.15	1.15	27.15	0.00	Yes
5	E	27.15	27.97	27.15	27.97	0.00	Yes
6	F	27.97	28.39	27.97	28.39	0.00	Yes
7	G	28.39	30.54	71.38	73.53	42.99	No
8	H	28.39	28.64	28.39	28.64	0.00	Yes
9	I	28.64	29.19	29.22	29.77	0.58	No
10	J	29.19	32.52	29.77	33.10	0.58	No
11	K	32.52	33.10	48.28	48.86	15.76	No
12	L	33.10	57.77	48.86	73.53	15.76	No
13	M	32.52	45.52	33.10	46.10	0.58	No
14	N	28.64	28.83	28.64	28.83	0.00	Yes
15	O	45.52	46.10	45.52	46.10	0.00	Yes
16	P	46.10	46.31	46.10	46.31	0.00	Yes
17	Q	46.31	46.47	46.31	46.47	0.00	Yes
18	R	46.47	47.74	46.47	47.74	0.00	Yes
19	S	47.74	48.37	47.74	48.37	0.00	Yes
20	T	48.37	48.49	48.37	48.49	0.00	Yes
21	U	48.49	73.32	48.49	73.32	0.00	Yes
22	V	73.32	73.53	73.32	73.53	0.00	Yes

5. Conclusion and Future Work

The study was conducted on a real case in a semiconductor manufacturer in the United States of America. Historically, return merchandised process was not implemented consistently and there was no standardized documentation for it. The research team worked on documenting the process and building a consolidated flow chart for it. This comes as a result of multiple meetings with various teams. The customer service, warehouse, production, and upper management were all included in the meetings. PERT was applied over the build process flow chart and the expected time for RMA is 73.53 hours. The critical activities were found to be A, B, D, E, F, N, O, P, Q, R, S, T, U, and V. Although the average activity durations used in PERT calculations provide for an overall mean time for project completion (in this case a mean completion time of 73.53 for this RMA process), it would also be useful as an ongoing effort to determine, for example, a 95% confidence interval on that path by incorporating the different activities' variations.

The critical path for the RMA process was clarified. Later, studies can be done on the critical activities to find the possible crash time for each step and its cost. So, if a crash output overweighs its cost, that activity will be crashed. By this, the expected RMA time can be decreased.

After being implementing the proposed RMA successfully for five observations, the company, which the research was conducted in, shown huge interest in our research and ask for our corporation to implement it for a long term.

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Biographies

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