Quantification of Losses for a single product flow in End-to-End Supply chain

To pilot ways to identify the losses in the end to end flow and to be able to have a view on which improvement activities to prioritize

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MASTER'S THESIS 2018

Quantification of Losses for a single product flow in End-to-End Supply chain

A case study at Volvo Group, Lundby, Sweden

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ABSTRACT

Plenty of manufacturing cost models have been developed in the past to help companies increase their efficiency and reduce costs and one of these models is manufacturing cost deployment (MCD), developed by Yamashina & Kubo, which focuses on reducing waste and losses.

Manufacturing Cost Deployment is a method aimed to develop a cost reduction program which today is recognized as one of the important pillars in World class Manufacturing.

Manufacturing Cost Deployment has been utilized by Volvo group for quite some time; however, it was constrained to specific plants or specific departments.

It is observed that there is maturity in quantifying the losses inside the powertrain plants, some truck plants, and a few pilots have been performed to understand the losses in the inbound supply chain.

Also, losses that are generated in the entire end to end flow have until now not been visual, quantified and stratified to be able to prioritize cross-functional improvements.

This Thesis investigates on how Manufacturing Cost Deployment MCD can be used to identify and map the losses for a single product flow from an end to end perspective and to be able to have an aligned view on improvement activities that must be prioritized. With valuable inputs from across the organization the authors have identified the top losses and initiated a skeleton for further studies at Volvo Group.

Keywords: Cost deployment, World Class Manufacturing, End-to-End supply chain

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Finally, we would acknowledge all our stakeholders (*Appendix B*) for their support and contribution during this thesis.

CONTENTS

LIST OF ACRONYMS

GTO	Group Tuck Operation
VPS	Volvo Production System
MCD	Manufacturing Cost Deployment
E2E	End-to-End
WCM	World Class Manufacturing
PTP	Power Train Production

1 INTRODUCTION

This chapter begins by explaining the background of the topics pertaining to this thesis study, followed by the problem description, objective of the thesis and finally the delimitations that played a role in defining the scope of the thesis.

1.1 BACKGROUND

One of the major issues faced in automotive industries are the losses that are generated in sectors like production, maintenance, logistics etc. which directly relate to the organizations productivity and economic condition. The losses contribute to significant reduction in efficiency and productivity. When these losses are viewed from an End-to-End perspective, that is from tier 1 supplier all the way till the end customer, the losses generated are many.

Until now at Volvo Group AB the losses generated in the entire end-to-end flow have not been visual, quantified and stratified. There is maturity in quantifying the losses inside the powertrain plants, some truck plants, and a few pilots have been performed to understand the losses in the inbound supply chain.

This thesis aims to develop a model which covers all the missing elements mentioned above and to be able to prioritize cross-functional improvements.

1.2 PROBLEM DESCRIPTION

Volvo Group Trucks Operations (GTO) has followed Manufacturing Cost Deployment (MCD) model in the past, MCD is a general model and its utilization varies from one plant to another.

Cost Deployment carried out till date are for individual plants and the method for doing the same is different in each plant, due to which the data available is not mature enough when viewed from an End to End perspective and the lack of standardization is clearly evident. Therefore, the number of stake holders involved in this study is high.

1.3 OBJECTIVE

The purpose of this project is to pilot ways to identify the losses for a single product flow in the end to end supply chain to have an aligned view on which improvement activities to prioritize.

This is connected to strategic objectives at Volvo Group AB i.e., “Optimization through end-to-end visibility” and “cross-functional continuous improvements”. The strategic objectives mentioned focus on having an aligned view on improvement activities across the organization for the top three losses prioritized in the entire flow.

1.4 DELIMITATIONS

- The data pertaining to the suppliers is not included in the study due to lack of existing data
- Cost Deployment data related to Dealership/Sales is not addressed due to time constraints and data maturity.
- The thesis is based on the existing available data. No new data acquiring methods were used during the study.

2 THEORY

This section provides a theoretical framework for the subject areas, procedures and techniques used to carry out the Thesis study.

2.1 PRODUCTION ENGINEERING & SUPPLY CHAIN MANAGEMENT

There have been significant changes in industries in the past few decades, due to which global competitiveness in manufacturing sector has increased which in turn has led to the integration of different divisions which includes associations with suppliers, manufacturers and customers [1]. The involvement of Production Engineering in supply chain integration has been overlooked [1]. However, they are closely related.

There have been studies that indicate Production engineering and supply chain management go hand in hand, and due to the short product life cycles and increased global competition supply chain management has more prominence in today's scenario [1].

Supply chain management can be defined as a process of controlling the flow of raw materials and the information related to it directly from the source [2] and it involves various bodies like suppliers, distributors, etc. all these entities can be grouped together which in other terms can be called as End- to- End supply chain (E2E).

In other words when different sectors like suppliers, manufacturers, distributors and retailers work together from acquiring the materials to delivering a final product to the customer can be termed as E2E [1]. Below is a pictorial representation of the same.

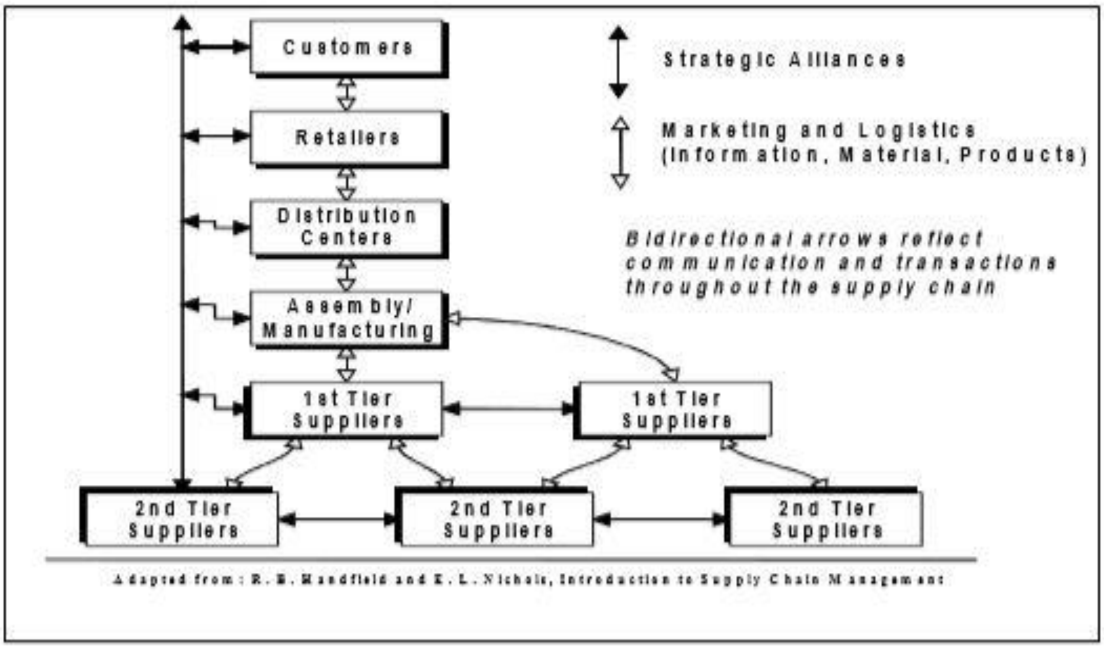

Figure: 1 Pictorial Representation of End-to-End supply chain

2.2 LEAN MANUFACTURING

Lean manufacturing or the philosophy behind it was established by Toyota. The principles involved in Lean which was termed in the 90's was derived from the Toyota production systems TPS where they had focused on eliminating the wastes to elevate the company's overall productivity and customer value [3]. The successful implementation of this methodology gained attention from across the globe and gained popularity among the automotive industries.

The definition of Lean as mentioned by Liker, "a philosophy that when implemented reduces the time from customer order to delivery by eliminating sources of waste in the production flow" [4].

The foundation of Lean manufacturing in industries is to engage in continuous improvement projects where the primary focus is to identify and terminate the wastes and the non value adding activities within the firm [5].

The study carried out by the authors revolve around the concepts of Lean manufacturing as mentioned above where the primary focus is to identify the wastes in the entire supply chain and to suggest methods to eliminate them. This has been achieved by using a tool called Manufacturing Cost Deployment which will be discussed in detail below.

2.3 WORLD CLASS MANUFACTURING

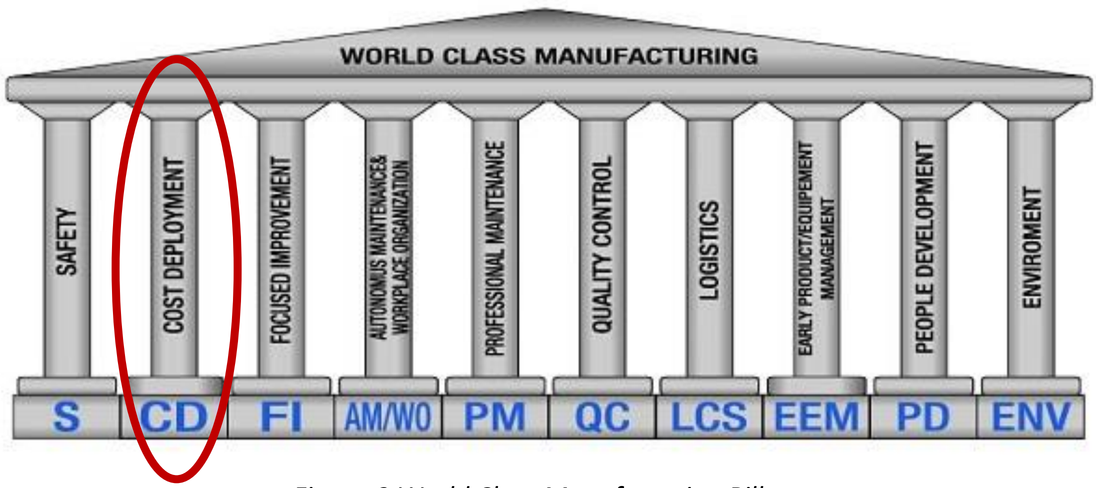

Figure:2 World Class Manufacturing Pillars

The concept of World Class Manufacturing WCM originated in Italy adopted by the Fiat group Automobiles [6]. WCM which is basically a mindset based on a continuous improvement approach or Kaizen [7].

WCM has its foundations in the Total Productive Maintenance (TPM), which is a maintenance process implemented to elevate the organizations productivity by incorporating different processes that are dependent and usefull (minimal waste).

WCM's main purpose is to add value to business and customers by eliminating all the losses in an Organisation and this can only be achieved by,

- continuous development of people by having regular training and self learning
- process by using standard tools and methods
- organization through promting people within the firm [7].

WCM is about involving all the resources available. The 11 pillars represent different themes and losses and focus area as marked in red is cost deployment [8].
Volvo has been utilizing these concepts for quite some time and it has been incorporated in their strategic objectives. The authors have centralized the study based on the focus area marked in red as seen in the picture above which is Cost Deployment.

2.4 COST ENGINEERING

Cost Engineering is defined as 'the area of engineering practice where engineering judgment and experience are used in the application of scientific principles and techniques to problems of cost estimating, cost control, business planning and management science, project management and planning and scheduling' [9]. Recent study related to cost engineering is based on Design Cost, Manufacturing Cost, Life Cycle Cost (LCC), etc. [10]. The concept involved with Cost engineering is vast and there are knowledge gaps in every field mentioned above, however the authors are focusing on manufacturing costs.

There are previous studies that have been established related to Manufacturing cost where a general cost estimate of manufacturing operations is determined [10]. Manufacturing cost deployment has a similar approach where the wastes and losses involved in the manufacturing operations are identified and costs are assigned respectively. Detailed explanation of Manufacturing cost deployment can be seen in the next section.

2.5 COST DEPLOYMENT

Cost Deployment CD is a methodology that was establishes by Yamashina and Kubo which is a cost-reduction program carried out both scientifically and systematically to minimize the costs [11]. It is a methodology created to identify different cost factors and various kinds of waste and losses related to it.
One of the major issues in manufacturing industries is cost reduction which is a barrier for the company in reaching its business objectives [12]. Therefore, the model introduced by Yamashina makes it easier for companies to reach their objectives faster and in an efficient way.
CD is then used to categorize the losses or wastes according to company's strategy and the crucial ones are identified by rating them according to the severity. Finally, improvement activities are assigned to eliminate the wastes and costs for improvements and expected cost savings are recorded.

According to Yamashina, CD solves the following issues:
Identifying production losses/wastes, result and causes. Establishing a relation between loss reduction and their possible cost reduction. Interpreting if the root cause of each loss is available, if not it needs to be acquired. Estimating the cost of reduction.
According to Volvo, waste is termed as throwing a bucket of water away for nothing, whereas loss is defined as a leaking tap [13]. Both are non-value adding.
Losses can be categorized into causal losses these are the loss generated by a problem of a process, equipment or people that can be directly identified, and resultant loss are losses related to material, manpower or energy, which are resultant from causal losses. The general waste or loss categories are usually within any of the following areas: equipment, material, labor, quality, environment or logistics. The procedure of CD can be divided into seven steps [12]:

1. Identifying the losses and waste categories in all processes.
2. Quantifying the wastes and losses
3. Establish cause and effect relationships
4. Assigning costs to the generated losses
5. identifying the improvement projects
6. Estimate cost for improvement and cost reduction
7. Establish improvement plan and implement

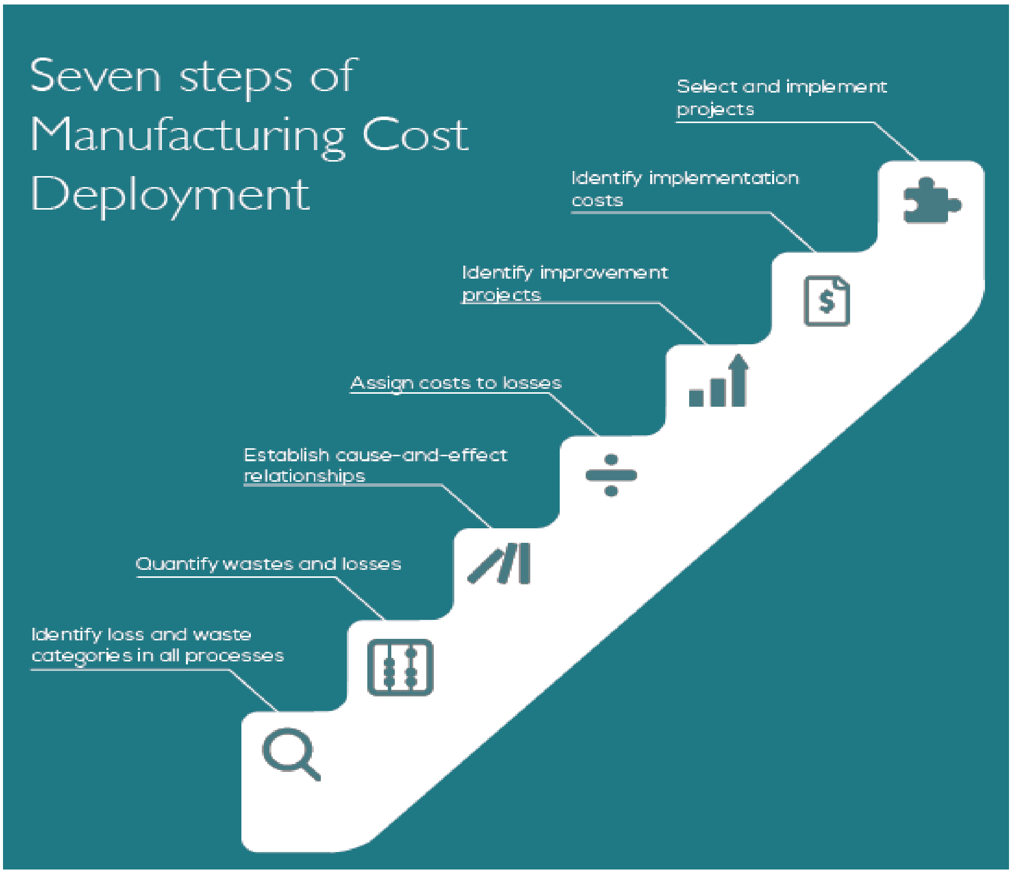

Figure:3 Seven Steps of Cost Deployment

2.6 NEED FOR NORMALIZATION

The data gathered in the End-to-End flow in this study considers all the losses related to the cylinder heads produced i.e., 9 and 11 litre cylinder heads in Plant A, 9 and 11 litre Engines in Plant B and the different variants of trucks produced in Plant C.

Since this study is focussed on the losses related a single 11 litre cylinder head, it is necessary to scale all the data gathered to bring it within the scope.

To do this, data pertaining to the ratio of the Cylinder heads (9&11 litre) produced in plant A, ratio of Engines (9&11 litre) produced in plant B and the ratio of 11 litre trucks and other variants produced in plant C was collected.
Using this data, the losses related to a single 11 litre cylinder head in plant A, losses related to a single 11 litre engine in plant B and losses related to a single 11 litre truck in plant C is found. To further narrow down the scope to the losses related to a single 11 litre cylinder head across the entire End to End flow, the ratio of volume of 11 litre Cylinder heads to a fully assembled 11 litre engine and the ratio of volume of 11 litre cylinder head to a fully assembled 11 litre truck is taken into consideration.

This provides the basis for normalization, wherein the data can be compared which otherwise is incomparable because of different scales. Here the scales refer to the fact that data captured in Plant A is only for cylinder heads, in plant B for engines and in plant C for trucks.

2.7 NORMALIZATION

There are various ways of rescaling the data to ensure the data captured in different scales is made comparable. Normalization of data by using Min-Max rescaling is used for this study to align the data gathered from different plants and to make it comparable across the entire End-to-End Flow.

Normalization has many definitions, but the simplest definition is adjusting the measured values on varying scales to a base or a common scale. This varies as the complexity of the data handled increases [14]. The following formula must be employed to calculate the normalized value "z" [15]

$$z = \frac{x - \min(x)}{\max(x) - \min(x)}$$

Figure: 4 Formula for Calculating Normalized Value

Where min and max are the minimum and maximum values in 'x' in a specific range.

Since the factory in Plant A works exclusively with 11litre cylinder head, it is obvious that the losses in this factory when compared to other factories in the flow is high. However, to normalize this scaling effect and find losses in the entire factory, equivalent to one Cylinder head, the authors use the normalization formula i.e., Min-Max Normalization to compare the losses amongst different factories on equal grounds. This provides the authors the required scalability to derive relevant results and conclusions.

3 RESEARCH QUESTION

- *Which and where are the main losses in the current supply chain flow?*

  For research question one, the literature study shows the methods involved to obtain the desired results. This study is carried out to identify and analyze the top loss inducing factors and to be able to prioritize them by assigning specific improvement activities. Also, the results obtained can be beneficial to provide the necessary recommendations in handling these losses.

- *Can Cost Deployment be used to track the Top loss inducing factors for a single product/component in End-to-End Supply Chain?*

  The second research question suggests methods to analyze the top loss inducing factors for a single product by having a common denominator with the aid of Cost deployment. The study carried out shows that it is possible to track the losses for a single component with the help of Cost deployment, but it is necessary to have the right common denominator. The Study carried out suggests methods on how to find the common denominator with the help of which the results can be achieved.

4 CASE STUDY

This chapter introduces to the case at Volvo Group Truck Operations. The presented information is specific to the Power Train Production PTP and can be subjected to confidentiality.

4.1 CASE DESCRIPTION

One of the major issues in automotive industries are the losses that are generated in areas like production, maintenance, logistics etc. which are directly related to the organizations productivity and economic condition. When these losses are viewed from an End-to-End perspective that is from tier 1 supplier all the way till the end customer, the losses generated are many.

At Volvo the losses generated in the entire end to end flow have not been visual, quantified and stratified until now. There is maturity in quantifying the losses inside the powertrain plants, some truck plants, and a few pilots have been performed to understand the losses in the inbound supply chain.

This thesis aims to develop a model which covers all the missing elements mentioned above and to be able to prioritize cross-functional improvements.

4.1.1 VOLVO

This chapter gives a brief introduction about The Volvo group and Volvo GTO

4.1.2 VOLVO GROUP HISTORY

Volvo started its journey back in 1927 where the first series manufactured Volvo cars rolled off in Hisingen, Göteborg. Volvo's business operations eventually underwent a rapid expansion and they acquired various companies like Svenska Flygmotor, Mekaniska Verkstad, AB Bolinder-Munktell and so on [16].

Later, more plants were opened not only in Sweden but also in Belgium to increase capacity; Volvo Group now had become a European company with Swedish base.
In 1999, Volvo divided into Volvo cars sold to Ford Motor Company and Volvo Group. The Volvo Group is a leading manufacturer of trucks, buses, construction equipment and industrial and marine engines, which later was branched as Volvo Trucks, Renault Trucks, Mack, Volvo Buses, Volvo Penta, Volvo Aero and Volvo Construction Equipment [16]
The Volvo Group has 95000 employees worldwide, production plants in 18 countries and is active in 190 markets [16]. Today Volvo Group is pioneers and leading manufacturers of commercial vehicles across the globe.

4.1.3 VOLVO GROUP TRUCK OPERATIONS

Volvo Group Trucks Operations is the truck industrial entity within the Volvo Group responsible for truck manufacturing, including Cab & Vehicle Assembly, Powertrain Production, Service Market Logistics, Production Logistics and Remanufacturing. Volvo Group Trucks Operations is a global team with approximately 31.000 employees in 32 different countries. Volvo Group Trucks Operations has approximately 82% men and 18% woman in its workforce. Being the truck industrial entity within the Volvo Group, the majority within Volvo Group Trucks Operations are industrial workers. Approximately 79% of the total workforce are industrial workers and 21% office workers.

4.1.4 VOLVO PRODUCTION SYSTEM

The Volvo Production System (VPS) is a dynamic system that consists of several key elements necessary to drive an organization, pursuing a never-ending improvement journey towards excellence. The relationship among key elements are not aggregations of the individual static elements, but are complementary. The right interpretation and translation of key elements and their elements into actions, implemented with rigor, will surely generate expected results. This is accomplished by securing quality, delivery times, safe and environmentally-sound workplaces, reducing waste and using best practice. The five principles for VPS's vision are: [Internal]

- Performance
- People development
- Improvement structures
- Lean practices
- End to End alignment

The VPS model consists of Customer satisfaction and Management commitment apart from the five principles.

Figure: 5 Volvo Production System (VPS) Model

5 METHODOLOGY

This chapter aims to explain the research methods and to justify each choice of methodology used in this thesis. The figure below is a schematic representation of the approach to the thesis work as it progressed through different stages.

The primary step was to secure the authors knowledge base through detailed literature study in the World Class Manufacturing and Cost Deployment areas. With an improved knowledge base, the stakeholders involved were prioritized based on the impact of the thesis work in their respective organization and their proximity towards Cost Deployment.

The next step was to gather the relevant data and existing information from the different organizations within Volvo Group, where previous pilot projects in Cost Deployment were carried out.

The next step involves gathering current data from the plants and organizations involved in this study by interviews, field visits and knowledge sharing workshops. The data gathered triggered the next phase which is data analysis. In this phase the data is compiled and is represented in a single format so that all the plants and the organizations involved are visual in one single document.

The next step involves improvising and normalizing the current data to draw meaningful and relevant conclusions. After this step, the results are drawn in accordance with the research questions stated above which would enable the authors to give recommendations for tackling the top three losses. Final step involves, stating the key improvements areas for Volvo Group to focus on and suggesting alternative ways in which the study could be carried out in future.

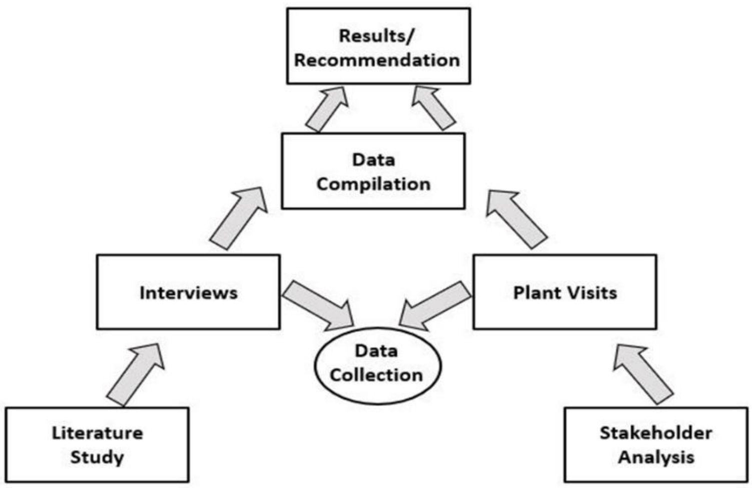

Figure: 6 Pictorial Representation of Methodology used for the Study

First, the scientific view and research method is presented, after which the validity, reliability and credibility of the work is discussed

5.1 SCENTIFIC VIEW

To carry out a Knowledge based study different methods can be used to obtain different results but as mentioned by Arbnor & Bjerke [17] there are different views defined on how to approach the data/information and how these views differ in terms of perspective. There are three types of approaches and each of them are briefly explained below.

5.1.1 ANALYTICAL VIEW

The analytical view assumes that the reality is full of facts which is identical and regardless of the person viewing it. The reality be summative and all the parts in it make the whole. This means that by understanding the parts, conclusions about the whole system can be drawn. It is important for the author to influence the researched topic as little as possible when applying the analytical view. Also, quantitative data is commonly used for analysis in this type of view.

5.1.2 SYSTEMS VIEW

In this type of view the reality contains subjective opinions of structures, except from fact-filled structures that are objective, and those are also treated as facts in the systems view. Hence, Arbnor & Bjerke argues that the reality is not cumulative. While the analytical view treated the parts of the systems as independent of each other, the systems view takes into considerations the negative effects, that can occur when parts interact. Therefore, it is important for the researcher to try to understand the interactions between the different parts in the system. In this type of view both quantitative and qualitative data are used for the analysis.

5.1.3 ACTORS VIEW

To understand the whole system, it is important to study the individuals and to understand their behaviors according to Arbnor & Bjerke. Actors view is commonly based on qualitative data available. The result gained when using this method is thereby dependent on the researcher and their social context.

5.1.4 ANALYTICAL VIEW OF THE THESIS

Since the data acquired was factual and qualitative, we have chosen the Analytical view here since by understanding the whole process, relevant conclusions can be drawn without making any vague assumptions.

5.2 RESEARCH METHOD

When conducting a research study, the research method used usually relies on the nature of the study which further delegates on how the results are obtained and analyzed.

5.3 SECURING KNOWLEDGE BASE

The prerequisite knowledge base for carrying out this thesis is secured by in depth understanding the expectations of this thesis and recap of the knowledge attained by Lean Management Course at Chalmers University of Technology.

To further strengthen this base, independent research is carried out to better understand World Class Manufacturing, End-to-End Supply Chain and Cost Deployment through the currently existing literature. Another important step here is the discussion with Cost Deployment experts at Volvo Group who provided relevant e-course learning documents and access to IT systems to better understand the Cost Deployment Methodology at Volvo Group.

The emphasis of sharing knowledge by using IT structure is shown in the figure [7]. Seamless knowledge sharing is based on Trust, open communication, top management support, organizational structure and culture [18].

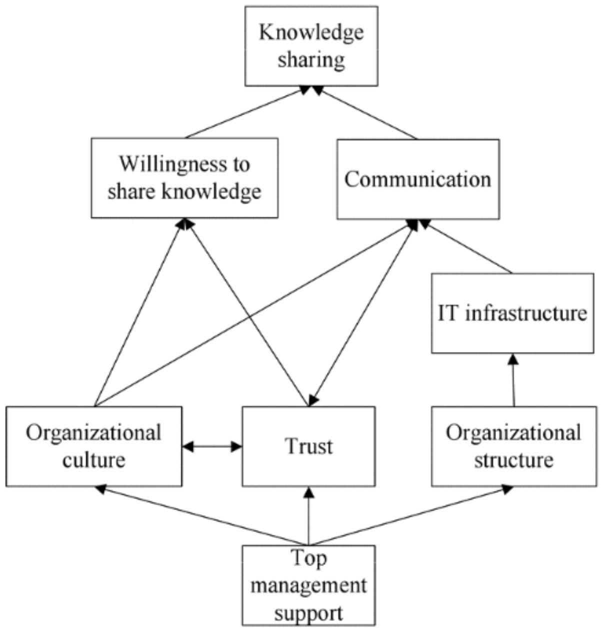

Figure: 7 Knowledge Sharing by Utilizing IT structures

The factors mentioned here were clearly adhered at Volvo Group during this study, as the authors received constant support from the top management and experts without any hindrance. This provides a firm understanding of the existing usage of Cost Deployment at Volvo Group. Since this is a pilot project, the knowledge securing phase is a continued process which lasted throughout the course of the thesis.

5.4 DATA COLLECTION

Data collection method plays a vital role to support the findings and justifying the methodology used, inaccurate data may affect the end result which in turn leads to invalid results [19]. The qualitative approach of data finding is through discussions with stakeholders and procurement of relevant information pertaining to CD from them by conducting interviews, factory visits and exchange of knowledge through workshops.

The quality of data obtained is high and supports the findings accurately. Though this is time consuming it is necessary to ascertain the quality of the results. The quantitative method is only feasible when the results are motivated through justified assumptions.

The data collection for this work makes extensive use of Qualitative method through interviews with CD experts and stakeholders, factory visits and accessing the intranet system to procure accurate data pertaining to the flow under discussion. Data acquisition from Cost Deployment experts from each plant through discussions and knowledge sharing sessions are carried out.

The data procured is validated and processed to provide a common ground to compare the data from different factories in one document.

5.4.1 INTERVIEWS

Interviews are generally conducted to get a personalized story behind the interviewees experience on the topic and in-depth information related to the topic [20]

The interviews are structured based on the interviewee's understanding of the current cost deployment methodology. The interviews are open discussion sessions where there were no strictly framed questions, but the questions discussed surrounds the topic of Cost Deployment and End to End perspective of Volvo Group. This kind of interview gives the author greater degree of flexibility in asking the desired questions bringing out different perspectives around the same topic. The interviews conducted at different plants were with Plant managers, Business controllers, Foreman etc. these interviews were conducted to help the authors understand how Cost deployment and its related operations were carried out. No quantitative data was collected from these interviews, as mentioned earlier it was an open-ended conversation helping the authors get a better and a deeper understanding into the concepts of Cost deployment.

5.4.2 FACTORY VISITS

The second part of data collection method involves visiting the different factories involved in the chosen flow of study during the month of May i.e., Plant A in Sweden, Plant B and Plant C in France. A day is spent at each of these factories to see the flow, understand the process involved and holding discussion sessions with the factory representatives like the Plant Managers, Global and Regional Business Controllers, Operational Mangers etc.

This method also allows the authors to gather the data pertaining to the factory in person and clarifying doubts if there are any areas which might need further introspection or understanding. Knowledge sharing between manufacturing plants is relative to geographical proximity [21].

But on the contrary, the plants B and C though geographical proximate, the level of standardization had a stark difference. The authors were clearly able to understand this during the factory visits. Though the global working language at Volvo Group AB is English, the language at the plants B and C is French and at plant A is English at the top management level, but at shop floor its Swedish. This difference in the functional language between the plants hinders beneficial knowledge transfer [21]

5.4.3 STAKEHOLDER ANALYSIS

Stakeholder analysis aims to analyze and understand the involvement of stakeholders from an organizational point of view or to understand the roles and their relevance to the ongoing project [22].

After securing the knowledge base, the next step is to understand the stakeholder requirements and the prioritized their involvement based on the impact of the thesis to the organization they work in. Conducting interviews is a source of background information and can be described as a systematic interrogation of someone on a certain subject.

The interview can be conducted by phone or in a direct meeting and the answers can be documented either by hand or by any audio medium. Instead, it is important that the selection covers the variation of the population. Therefore, the selection is made by stratification, i.e. the persons to interview are chosen from several categories [22]. Since the selection is not random, it is not possible to draw generalized conclusions about the popularity from which the selection has been made. However, it is possible to explore the area quantitatively.

All the stakeholders involved are interviewed and their inputs are noted down. Stakeholder analysis also involves discussion with Cost Deployment experts at Volvo Group who help in transferring the relevant knowledge base to equip the authors to carry out the thesis with the required precision. Discussions with people involved in pilot projects whose project definitions cross or relate to the ambit of the current thesis. This provides the authors with a firm realization of the expected outcomes and the necessary approach required to carry out the thesis.

5.5 IMPROVISATION

The data gathered is for the entire plants involved, the inbound and the outbound. To relate this data to the current flow of one 11 litre cylinder head, the existing data is subject to improvisation by taking the volumes of the 11 litre cylinder heads produced in Plant A, the volumes of the 11 litre Cylinder heads shipped, volumes of the 11 litre engines produced in PLANT B, the volumes of the 11 litre engines shipped and the volumes of the 11 litre trucks produced.

To further dig deep and find the losses pertaining to only 11 litre cylinder in the entire flow, the ratio of the percentages of the Volume of the CH to the Engines and the trucks is calculated and taken into consideration. The percentage volume is considered after relevant discussions with Automotive experts from Volvo Group.

6 RESULTS

The results loop back to the research questions. The primary objective is to ensure that the results obtained serve the purpose of answering the research questions and address the objectives accordingly. Addressing the first research question as mentioned in section 3, the following result were obtained;

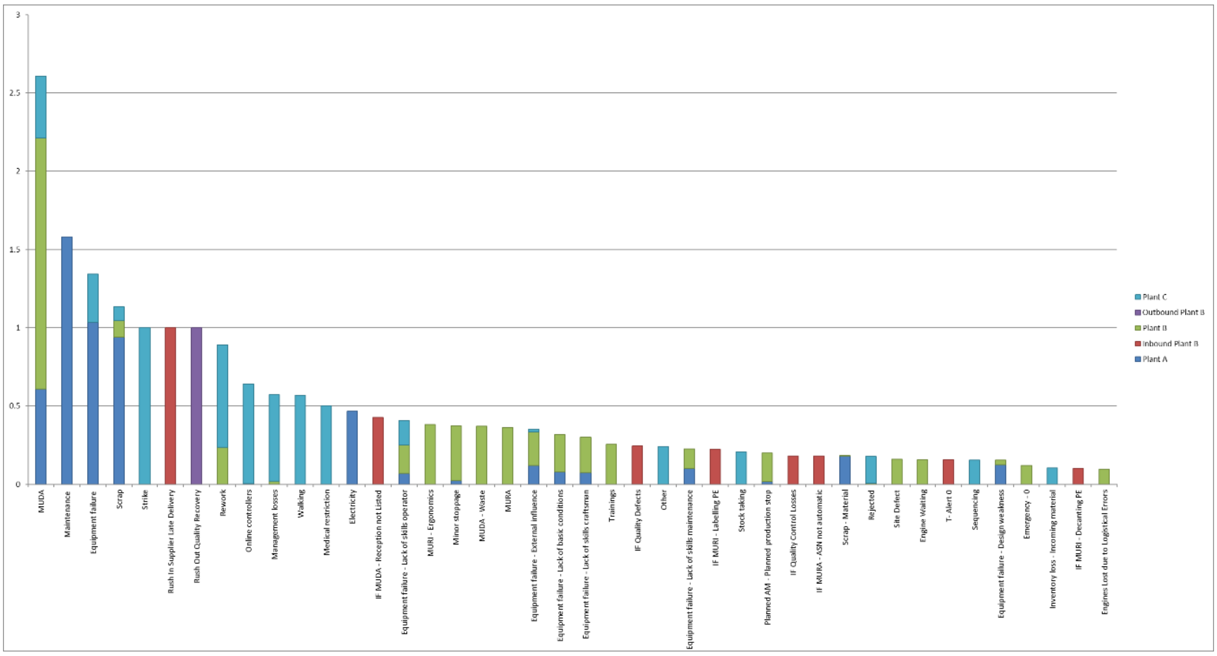

Figure: 8 Plant wise loss contribution for 11 litre Cylinder Head

The plant wise contribution of the losses to the 11 litre Cylinder Head flow from Plant A to Plant C as defined in the scope is shown in figure 8. The highest loss being MUDA. As the cylinder head progresses through the flow, each plant as well as the inbound and outbound logistical processes contribute to the losses, that decrease the total value added by these processes.

The losses may be caused due to human errors, machine constraints, method/process constraints, or material defects, commonly known as 4M's. The entire losses can be grouped into 4M's but to have a better stratification and deeper understanding into individual losses, they should be quantified and stratified.

Instances where large amount of data is analyzed, Pareto analysis is applicable and valuable to focus on the relevant problem areas which assure the highest returns [23] A deeper understanding of the losses enables tackling and initiation of loss reduction initiatives by targeting the major losses and gradually moving down the pareto.

Hence the entire losses contributed towards the 11 litre cylinder head as it moves through the complete flow is visualized in the form of a Pareto for ease in stratification and identification.

Addressing the second research question mentioned in section 3, the following results were obtained.

The figure 9 clearly represents the contribution of losses from each plant in the final flow. As explained in the literature section, the objective of cost deployment is to assign costs to the losses, to prioritize improvement initiatives.

The result obtained is a clear indication that Cost Deployment can indeed be used to identify and stratify the losses from an End-to-End Perspective.

Apart from understanding the highest loss causing factor, the indication of where the loss is being contributed from is also important. Both these parameters are addressed and validated by Cost Deployment Methodology as shown in the figure 9.

The top loss in the E2E flow under this study is MUDA contributed frim Plant A, Plant B and Plant C. The second highest loss is caused by Planned Maintenance – Planned Production stop contributed by Plant A and the third highest loss contribution is by Equipment failure – Interruption in production due to equipment failure or breakdown.

As per the Cost Deployment methodology, the top three are to be assigned resources to initiate improvement and loss reduction activities. Thus, this result, is in par with the research question stated and the Cost Deployment methodology. These results provide a base for recommendations to tackle the top three losses.

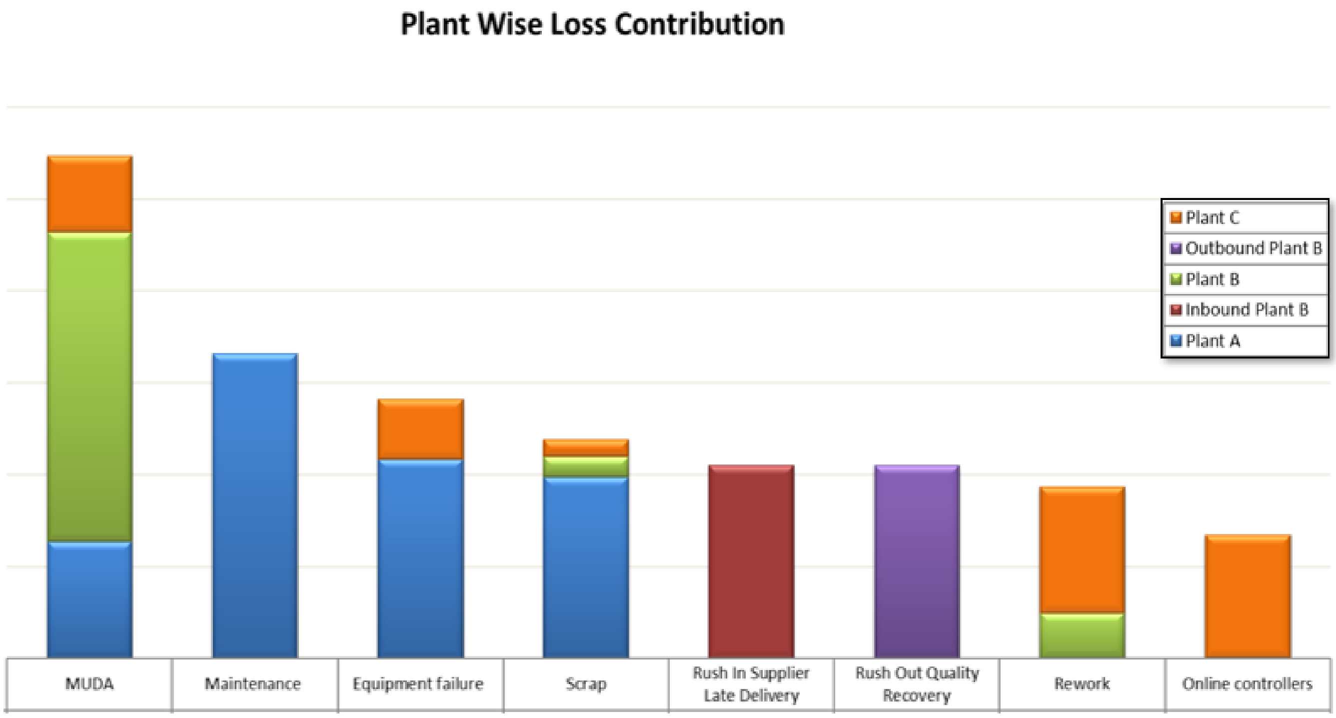

Figure: 9 Plant wise loss Contribution

7 IDENTIFIED GAPS AND IMPROVEMENT SUGGESTIONS

The first step to improve the work with CD at Volvo GTO is to convince the management team about the importance of using CD in the E2E flow and what are the benefits of using it. The team involved needs to be fully devoted to the method and believe that it can make a change. Unless the management is not one hundred percent committed to the method, Volvo GTO will never get the benefits of using CD and it will continue to be a time-consuming method causing more losses than it will Contribute to reduce.

In the beginning it will require both effort and time to fully implement MCD in an End-to-End flow but when that is done, when the concept for data collection is well-functioning and centralized and when improvements are starting to show, CD will run smoother and most importantly; seeing results in terms of saved costs will keep up motivation for continuing.

One of the drawbacks was the lack of standardization as different plants involved used different templates and formats to categorize the losses and its associated costs.

There is significant evidence of language barriers as the plant in Plant A categorizes some losses in Swedish and the plants in Plant B and Plant C have done it in French and English, leading to barriers in standardization as the knowledge sharing mechanisms fail to facilitate seamless knowledge transfer [22]. This is a signal for improvement to make Volvo Group a truly international organization.

8 DISCUSSION

This section describes the structure used to arrive at the mentioned results, the used methodology and supporting logic.

Cost Deployment as mentioned in the literature states assigning costs to losses, but here the data is presented in graphs due to confidential purposes.

Data Collection as explained in section 5 was accumulation of data by knowledge sharing workshops and factory visits. The gathered data were in different formats, and the authors developed a standardized format to combine all the procured data into one single document.

After a brief analysis, the data indicated the need for improvisation mainly because;

- Difference in the data formats
- The data obtained from Plant A is only for 11 litre cylinder head, the data obtained from Plant B is for 11 litre Engine and the data obtained from Plant C is for 11 litre Truck. The inbound and outbound dealt with data for 11 litre Cylinder head and 11 lire Engines respectively

Improvisation was necessary to perform the data analysis so that the data from the plants and the inbound and outbound could be compared for only the 11 litre Cylinder Heads. In order to achieve this, a suitable model was used. This model was drafted by the authors after close consultation with the industry experts at Volvo Group AB.

The following model takes into consideration the Volume of 11 litre Cylinder head and compares the volume constituent percentage of the 11 litre Cylinder head in the 11 litre engine and the 11 litre Truck.

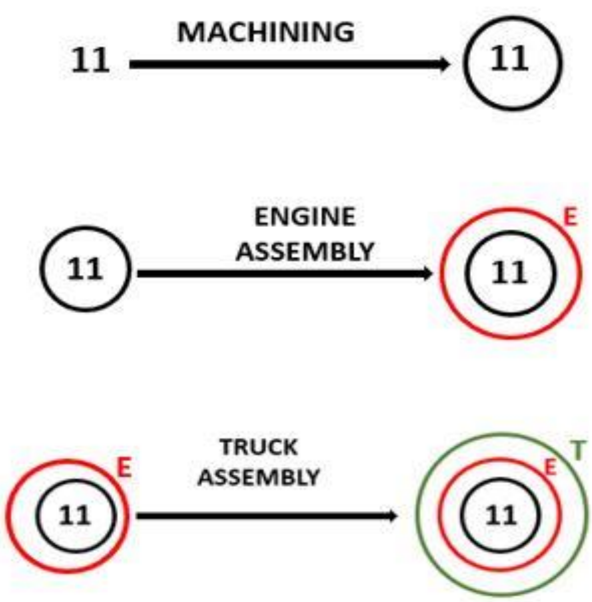

Figure: 10 Model representing Cylinder Head contribution in a Truck

The data in Plant A dealt with 11 litre Cylinder head, therefore this data was taken into consideration in its procured format. Here the volume constituent percentage of the Cylinder Head is 100 % as Plant A deals with only 11 litre Cylinder heads. To find the loss data for one-cylinder head, the entire loss data was divided by the number of 11 litre Cylinder heads produced between January 1st, 2018 to April 30th, 2018. The same is applied for inbound to Plant B as the 11 litre cylinder heads are transported to plant B from Plant A.

The data in Plant B dealt with 11 litre Engines. This data was improvised by referring to the assumption that 11 litre Cylinder head constituted 15% of the volume of a fully assembled 11 litre engine**.** To narrow down the data to one-cylinder head equivalent, the entire loss data of Plant B was divided by the number of 11 litre engines produced between January 1st, 2018 to April 30th, 2018. The same is applied for the outbound from Plant B to Plant C as 11 litre cylinder engines are transported from Plant B to Plant C.

The data in Plant C dealt with 11 litre Trucks. This data was improvised by referring to the assumption that a 11 litre cylinder engine constitute 14% of the volume of a fully assembled 11 litre truck and a 11 litre cylinder head constitutes 15% of the volume of a fully assembled 11 litre engine. To narrow down the data to one-cylinder head equivalent, the entire loss data of Plant C was divided by the number of 11 litre trucks manufactured between January 1st, 2018 to April 30th, 2018.

The data obtained after improvisation is graphically represented in Figure 11.

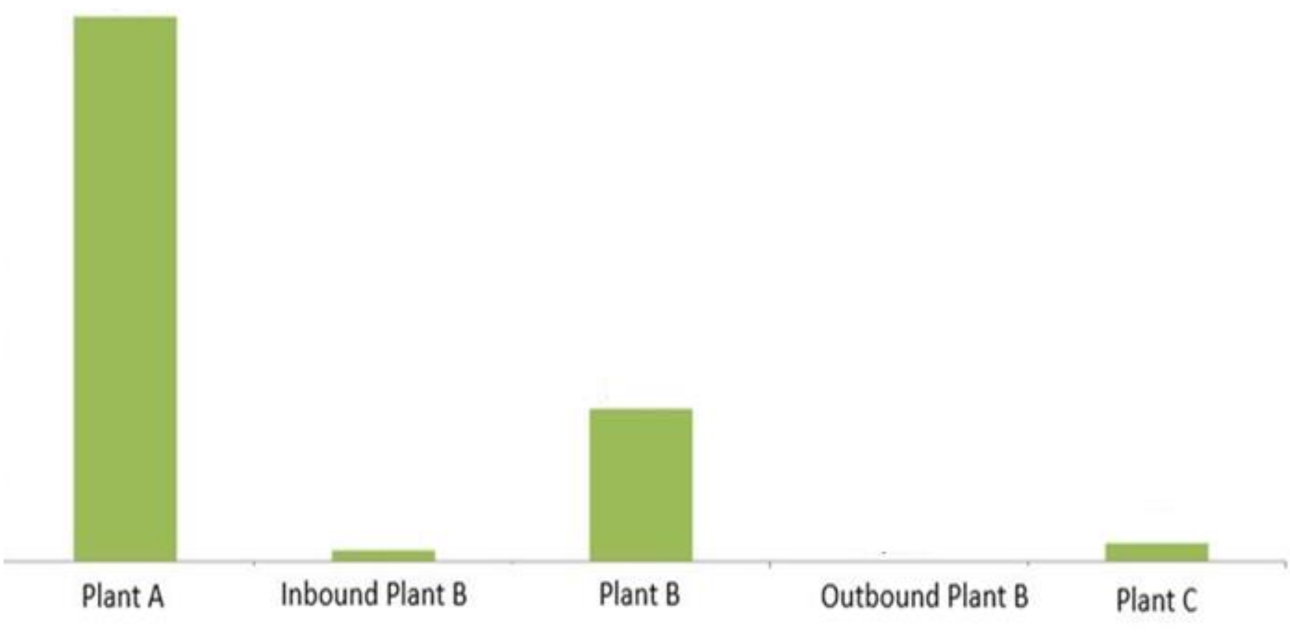

Figure: 11 Loss Contribution Before Normalization

The data thus obtained through improvisation clearly indicates that the loss contribution at Plant A to the entire flow is the highest as it exclusively deals with Cylinder Heads, whereas Plant B and Plant C deals with 11 litre engines and 11 litre trucks respectively.

In order to compare these data on equal terms or to have a common ground, i.e., for one 11 litre Cylinder head across the whole flow irrespective of the manufacturing functionalities of the plants, it was necessary to Normalize the data by using the formula mentioned in section 2.6 described in the literature section.

The data after normalization is graphically represented in figure 12. Now the data across the entire flow is converted to one 11 litre cylinder head equivalent. Using the Normalized data, the relevant results were obtained.

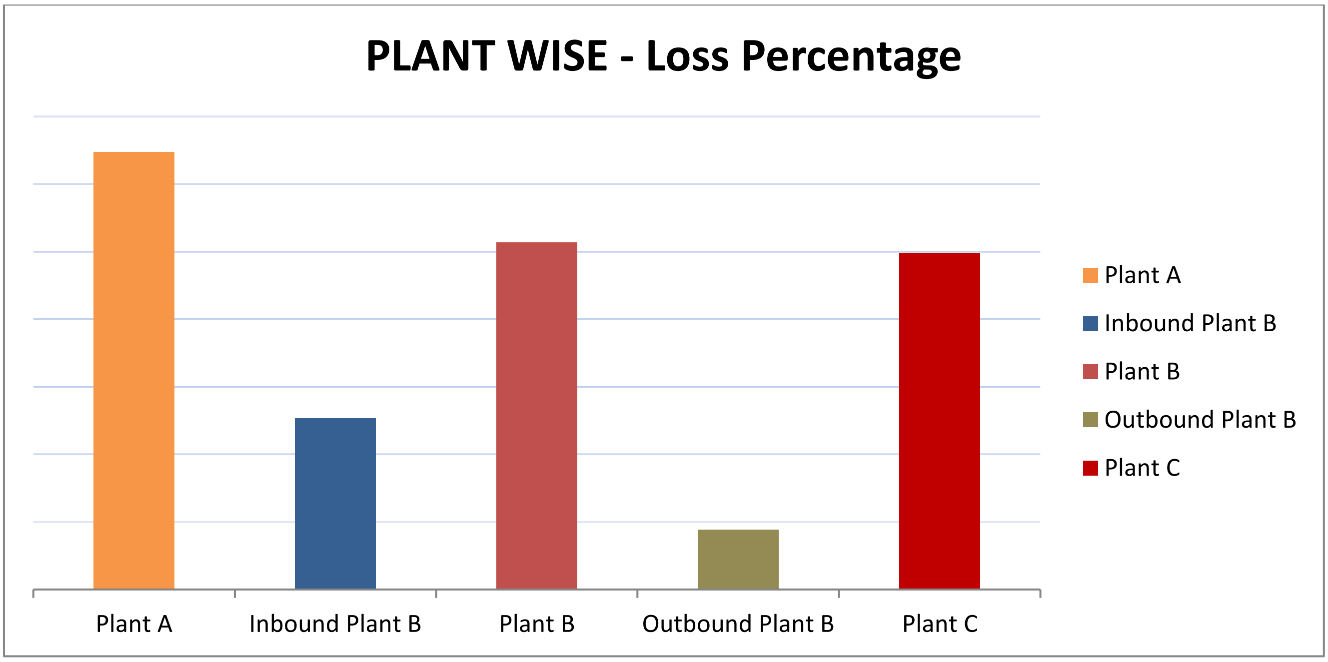

Figure: 12 Loss Contribution After Normalization

Further discussing about the consequences of our findings, it can be said that the company is aware of the importance of Cost deployment, however as mentioned earlier they fail to have a standardized method to collect and compile the data. Therefore, as a consequence of the authors results, the study can be used as a pre-study to collect and compile the data with higher degree of standardization.

It can be said that the suggested model to identify the losses is reliable as it has been approved by Cost deployment experts and Business controllers within the company. Implementing the suggested methods and observing changes or improvements within the organization will help strengthening the model.

There was a big impact with the authors research for the organization as this was a pilot project to identify the losses from an End-to-End perspective, which was not carried out before. The research helped the organization as many closed doors were opened in other words the study helped the company identify the problem areas which they were aware of but never had been quantified before which aided them to concentrate at the problem areas and focus more on them.

The other problems that the authors faced were the lack of data from the Supplier end and the Dealer end. There is very little or no data in these areas due to which the authors had to leave it out of the research. This can be considered as another finding for the company, having relevant data from the mentioned areas could have resulted in a more detailed study when viewed from an End-To-End perspective.

The study carried out could have been carried out in an alternative way which was discussed by the authors in the initial stages of the research. The alternative discussed was to follow a Component by its Unique part number all the way from Plant A to Plant C. But the complexity of obtaining data related to the specific part was very high. Therefore, the authors chose to carry out the study as mentioned in the above sections.

9 RECOMMENDATION

This topic explains the recommendations to tackle the top three losses, improving the classification of losses and the future scope of the thesis.

The results show that MUDA is the highest loss causing contributor in the entire E2E flow. MUDA is subdivided into seven forms of wastes namely [24];

- Transport
- Inventory
- Motion
- Waiting
- Overproduction
- Over Processing
- Defects

In order to tackle MUDA with suitable loss reducing initiatives, it is suggested that a deeper understanding into MUDA to classify them and break them down further is necessary. This will enable the Plants under consideration as well as the Organization to categorize them in the standard cost deployment format for the E2E flow.

The thesis brought forth the necessity to have a global loss bible for Volvo Group AB to refer, log and classify all the losses in the entire organization. This is explained in figure 13

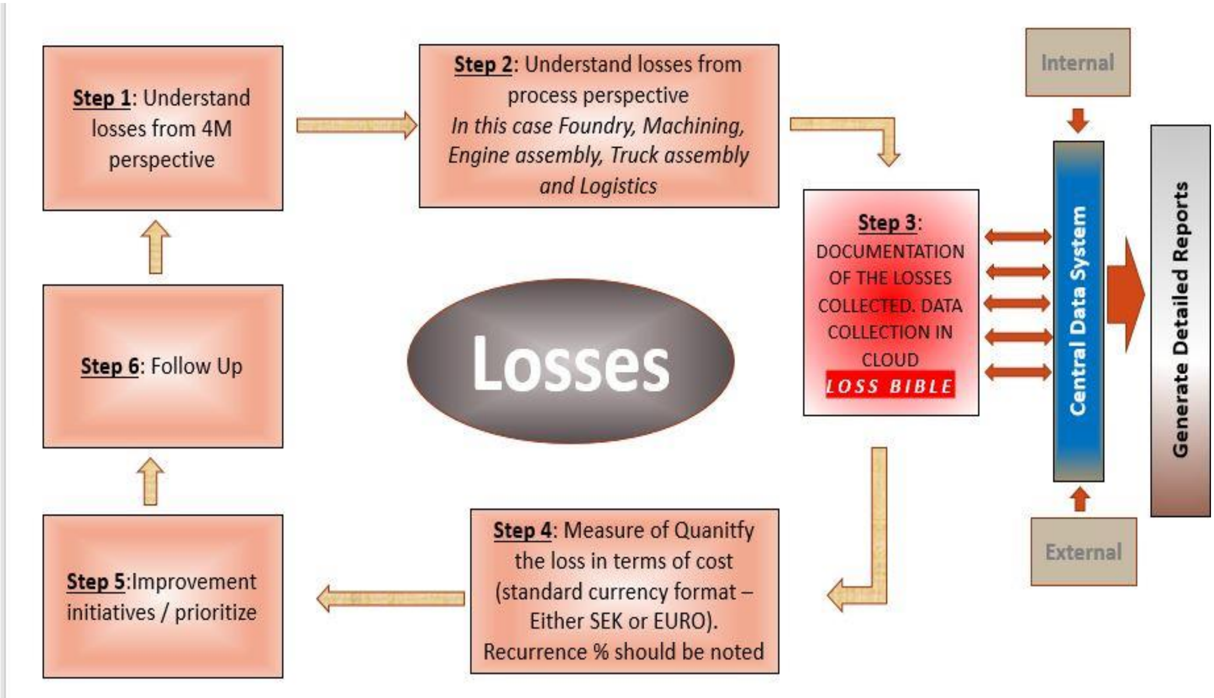

Figure: 13 Recommended model to Classify losses Globally

- Step 1: Understanding the losses from 4M perspective, i.e., man, machine, method or material. Thus, assigning the losses to the right cluster
- Step 2: Understanding the losses from Process perspective. In this study, Foundry and machining, engine assembly and truck assembly. This will further classify the losses according to the process involved.
- Step 3: Documentation and segregation of all the losses collected in a digital cloud. This is the ***Loss Bible.*** The loss bible is connected to a central data system which is linked to both internal suppliers and external suppliers so as to enable them to input the relevant loss data if any. Together, this central data system will generate detailed reports.
- Step 4: Measuring or Quantifying the losses in terms of Cost, to make the loss relatable to every level of the organization. The authors suggest that a standardized currency format should be used to nullify the loss due to exchange or foreign conversion rates.
- Step 5: Improvement activities should be prioritized to tackle the top three losses.
- Step 5: Follow up on the improvement initiatives and include the learnings from the cycle into the first step.

The role of Central Function is vital when carrying out Cost Deployment methodology from an End to End perspective. The role is illustrated in the figure 14

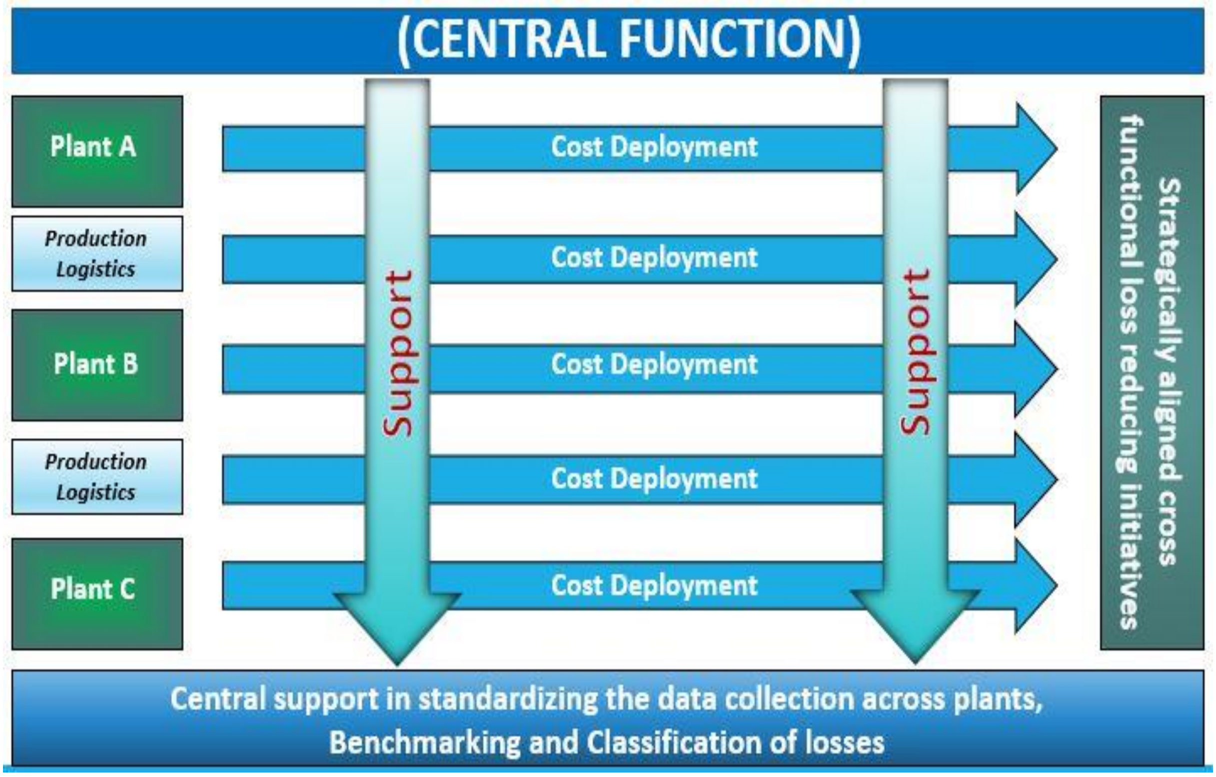

Figure: 14 Importance of Central Function in E2E Cost Deployment Methodology

- Step 1: The Plants A, B and C along with Inbound and outbound logistics will carry out Cost Deployment. The plants should follow a standardized format when using the cost deployment methodology.
- Step 2: The central function or the global team will support the plants in the Cost Deployment Methodology, ensuring that the methodology is standardized and transparent across the entire organization. This will result in central function carrying out the benchmarking and classification of losses from a standardized and centralized perspective.
- Step 3: This approach will lead to the organization having a standardized and strategically aligned loss reducing initiatives which are monitored and transparent across the plants and organization.

Predictive maintenance techniques are implemented to determine the condition of the in-house equipment's and to predict when maintenance activities should be carried out.

The benefits of this technique depend on how it is incorporated in a company, that is if the program concentrates on only preventing a fatal failure then that will be achieved, whereas if there is exclusive focus on the predictive maintenance program being deployed, the cost of implementation increases greatly but unnecessary stoppages due to equipment failure will be drastically improved [25]

The other two losses in the E2E flow under this study is related to maintenance. In order to reduce the losses pertaining to maintenance it is necessary for the global organizations like Volvo Group AB to shift to predictive maintenance. A model describing how predictive maintenance can be carried out using Microsoft Azure is shown in Figure 15.

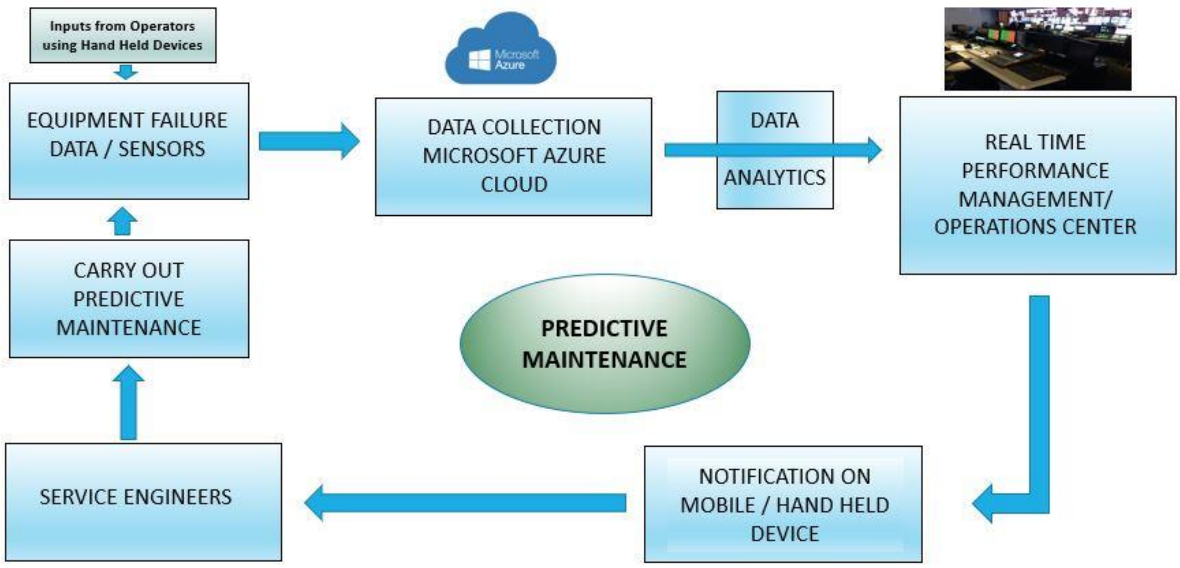

Figure 15 Suggested model for Predictive Maintenance

- Step 1: Production Equipment are fitted with real time data sensors. A provision for this data to be manually fed into the system by the operators using hand held devices is also made available.
- Step 2: The data from the sensors and operators is stored in a cloud i.e., Microsoft Azure.
- Step 3: The data from the cloud can be used to perform real time analytics
- Step 4: Real Time performance management/operations center monitors the real time analytics and predicts the equipment where failure is possible in the near future.
- Step 5: Digital notification regarding the possible equipment failure is sent to the Maintenance team to prioritize maintenance activities and resources.
- Step 6: Digital notification is sent to service engineer's hand-held device, who then carriers out the predictive maintenance.

Thus, loss due to equipment failure can be tackled before the failure occurs.

Finally, one other method to Quantify Losses from End to End perspective is to follow a part number across the entire flow. Interested researchers could validate the results obtained by using the Part Number approach.

10 CONCLUSION

It is understood from the discussions that the authors have fulfilled the purpose of the Thesis which was to evaluate and identify the top three losses in End-to-End Supply chain for Volvo GTO (PTP) and to suggest ways on how the identified problem areas can be improved.

Answers to the research questions summarizes the study carried out by the authors.

Which and where are the main losses in the current supply chain flow?

The study shows that the main loss in the current supply chain flow for 11 litre Cylinder Head was found to be MUDA with contribution from all the three plants. This loss have resulted due to various factors such as human errors, machine/method constraints, etc. Pareto analysis was found to be the effective method to identify the highest loss as it is visual and makes it easy when large amount of data is analyzed.

Addressing the second research question which was,

Can Cost Deployment be used to track the Top loss inducing factors for a single product/component in End-to-End Supply Chain?

As discussed in the theory section the aim of Cost deployment is to assign costs to losses obtained and to initiate improvement activities for the top losses.
The study confirms that Cost deployment can indeed be used to identify and stratify the losses for a single product component. But in order to successfully implement Cost deployment for a single component it is very important to have a common denominator. The study explains on how to obtain a common denominator by Normalization.

To conclude, we can say that the company must align their business needs to product and process development, so that there is a standard method of operation between plants and the entire organization will be able to contribute to the improvement activities and elevate the company to a whole new level.
Furthermore, the importance of using a standardized Cost deployment methodology has been mentioned. If the company puts in effort to implement the suggested standardization methods, the results obtained will be remarkable and will be very beneficial for the company.

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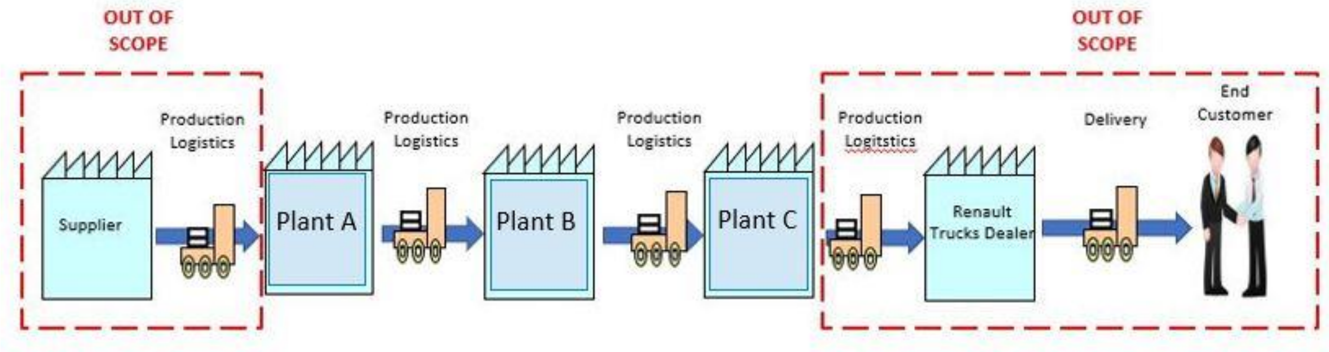
APPENDIX A

E2E FLOW



APPENDIX B

STAKEHOLDERS INVOLVED IN PLANT A, B & C

SENIOR EXPERTS
GLOBAL/REGIONAL LOGISTICS
GLOBAL/REGIONAL VPS
GLOBAL/REGIONAL BUSINESS CONTROLLERS
OPERATIONAL MANAGER
REGIONAL/LOCAL LOGISTICS
REGIONAL/LOCAL VPS
REGIONAL/LOCAL BUSINESS CONTROLLERS