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Data Management in an Operational Context

A study at Volvo Group Trucks Operations

Master thesis (course INFM10) in Information Systems

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Abstract:
The present customer based and data driven world of business, together with the evolving social and technological trends continue to drive product complexity and product variety to a new height, one that is characterized by product customization. In the product realization process, the assembly floor remains the most vital part of the manufacturing process; to cope with the rigorous demands of product complexity and product variety, operators rely heavily on quality assembly instruction in manual assembly operations. Previous studies conducted at Volvo Group Trucks Operations (GTO) revealed the different working processes for creating assembly instructions, due to historical growth and acquisitions of other truck manufacturers. These different working processes are one of the main reasons for the reported quality deviation in assembly operations. This thesis therefore provides the current state analysis of data and information handling in the product realization process. Two research methods, direct observation and Semi-structured interview, were employed to investigate the availability and usage of data and information in the engineering phase and in the assembly phase. The study was conducted at manual assembly stations across three production plants within a case company. The result indicates gaps and differences in opinion of how data is perceived, interpreted and utilized. Hence there are no standard approach on how data and information is managed in the manufacturing engineering IT systems and assembly information systems within all levels of the organization.

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Martin O. Enofe

Dedicated to the loving memory of my father Mathias O. Enofe; you are always on my mind…. never to be forgotten.
Reminisce your legacy is what I owe you…. you laid the foundation for this work; I am just building on it.

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List of abbreviations

DM - Data Management

AI - Assembly Instruction

IT - Information Technology

IoT - Internet of Things

CPS - Cyber Physical System

GTO - Group Trucks Operations

CAD - Computer Aided Design

PDM - Product Data Management

AVG - Automatic Guided Vehicle

BoM - Bill of Material

DCN - Design Change Note

ICT - Information Communication Technology

ECN - Engineering Change Notice

GPN - Global Production Network

IIoT - Industrial Internet of Things

DAMA - Data Management Association

EDM - Engineering Data Management

CAM - Computer Aided Manufacturing

GAIS - Global Assembly Instruction Strategy

DIKW - Data, Information, Knowledge, Wisdom

1 Introduction

In this thesis, issues concerning data and information management (based on the initiative of industry 4.0 “smart factory”) within manufacturing assembly information systems are discussed. This chapter will introduce the reader to the background of the study and research area, together with the problem definition that has been identified with respect to the specified area. The identified problem will further be discussed scientifically and formulated into research questions, which will be the bases of the study. The purpose of the study, relevance and delimitations will also be defined and presented. Lastly, an overview of the thesis structure is shown accordingly.

"Organizations that do not understand the overwhelming importance of managing data and information as tangible assets in the new economy will not survive."

Tom Peters, 2001 (Mosley et al., 2009, pp. 1)

1.1 Background

In an ever-evolving global world, Information Technology (IT) and Information Communication Technologies (ICT) has advanced rapidly; facilitating the way people, organizations/ businesses communicates and connects with each other (ITU, 2015). The technological revolution is virtually transforming everything, from everyday living, to businesses, and even the way data and information is being collected, managed and conveyed, and utilized (Lechman, 2015). Global development has also been driven immensely by ICT revolution, cutting across every businesses and organization, creating an innovative platform for competition, characterized by an increasing concession for information, knowledge, agility and connectivity (Hanna, 2010). To quote Hanna (2010) ICT revolution “is so profound and pervasive that it challenges many traditional economic concepts that are rooted in incremental thinking. (….) The information and communication revolution – perhaps the most pervasive and global technological revolution in recent human history” (Hanna, 2010)

“ICTs encompass all those technologies that enable the handling of information and facilitate different forms of communication among human actors, between human beings and electronic systems, and among electronic systems. These technologies can be sub-divided into: capturing technologies, storage technologies, processing technologies, communication technologies and display technologies” (Hamelink, 1997, No 86, pp. 3).

As technology development continues to experience an unprecedented growth, manufacturing companies are continually faced with the challenging needs to optimize production and information processes (Vollmann et al., 2005) due to the ever increasing competition in the market, economy and global development, and the need to keep market shares (Lee et al., 2014). These new and complex technologies have led an increasing numbers of varieties of manufacturing standards that do not only affect the industry or market but also innovation and technology diffusion (Tassy, 2000).

In the present technology-based and data driven world of business, data have swiftly become the raw material of production, an innovative source for enormous socio-economic value (Tene and Polonetsky, 2013). The flow of data and information between databases, information systems, processes etc., conveys the capability that can make an organization to be cost effective, efficient and more importantly competitive (The MITRE Corporation, 2016). Consequently, effective data management throughout its lifecycle provides a foundation not just for effective and robust processes but also for a competitive edge in the global market (Lee et al., 2014; The MITRE Corporation, 2016). This market is connected electronically and also dynamic in nature. Thus, companies try to improve their level of agility with an objective of being flexible and responsive to meet customers and changing markets requirements (Chandrasekhar and Ngai, 2003). In an effort to protect market position, expand customer base and gain market shares, companies have started offering diversified product in the form of mass customization to meet the need of customers (Johansson et al., 2016). Mass customization is a manufacturing strategy which aims to deliver customized products/ services at a reasonably low cost, based on the requirements and specification of individual customer (Coletti and Aichner, 2011) a strategy that is regarded by large number of companies as a means to attain competitive advantage (Da Silveira et al., 2001).

1.2 Problem definition

Social economic activities have been broadened globally due to technological development (Chandrasekhar and Ghosh, 2001). This rapid development and recent advancement of modern ICT can be considered as drivers for globalization (Johansson et al., 2015). This has given companies the platform and opportunities to grow rapidly on the global marketplace (Johansson et al., 2015) and also the possibilities to acquire other manufacturers, in a view to be closer to the markets (Delin and Jansson, 2015). According to the research carried out by Delin and Jansson, (2015), companies have started to broaden its business through the acquisition of other companies and off-shore production, which however has led to variances in company's operational activities. To quote Johansson et al. (2015) "globalization is one of the reasons companies have hard times creating global standards when product types and brands historically have been different".

Presently, one of the top priorities for virtually every company is to improve operational competitive advantage (Manrodt and Vitasek, 2004) this is fundamental because gaining competitive advantage is perceived as increasingly significant, giving emphasis to new product creation and the challenging need to react to changing markets (Fowler, 1995). Fundamentally, a means to attain and sustain competitive advantage is through internal process management and global standardization (Manrodt and Vitasek, 2004) one of the reasons for this is that companies now find it difficult to compete solely on products functionality and cost alone (Fowler, 1995). According to Johansson et al. (2016) companies have also broadened their customer base through globalization and access to new markets by the introduction of products that are customized according to the requirements of each customer, otherwise known as mass customization.

Volvo Group Trucks Operations (GTO) currently offers customized product, in form of mass customization. Mass customization is Volvo GTO core business strategy, and through development and acquisitions of other manufacturers over the years, Volvo Group now offers a wide range of other trucks brands (e.g. Renault trucks, Mack trucks, UD trucks, Eicher, etc.) produced in 43 different plants around the world, with the philosophy of offering highly customized trucks according to the need of its customers. This acquisition strategy has led to an expansion of the customer base and penetration into new markets. However, as these developments (growth in customer base and new markets penetration), and product customization continue to increase, the complexity of the manufacturing process also intensifies. These have led to a mix of working processes in the manufacturing and execution process of these varieties of products offered by Volvo GTO.

Volvo Group Trucks faces challenges on the implementation of global industrial systems due to acquisition of different manufacturers in recent years (Johansson, 2016). This historical growth has led to diversity and development of different manufacturing and assembly process with the different brands of the Volvo GTO (Delin and Jansson, 2015). As part of GAIS - Global Assembly Instruction Strategy II project (a continuation of GAIS1 project) with the aim to standardize manufacturing preparation process of assembly instruction across global operations, a study was conducted by Johansson et al. (2015) on the use of data and information in manual assembly instructions of heavy vehicles. This study is a continuation of the national study conducted during the spring of 2014, within the Global Production Network (GPN). The study indicates that diversity exists in how assembly instructions are created, and this diversity not only exists within the GPN, but also within production sites. Thus, there is need for the implementation of global standard or strategies for assembly work instruction due to different approaches to manufacturing preparation of assembly instruction in different production sites, different systems being utilized in the process, and variation in execution of assembly operations. To create these standards according to the initiatives of the future industry for example industry 4.0, current use of data and information in the product realization processes of manual assembly need to be studied.

1.3 Research questions

Based on the nature and scope of this study, the research was approached from the perspective of data and information, which is available, used and important to the operator for the assembly operation, along with the information flow in the product realization processes. Therefore, the research questions for the thesis are;

> ***RQ1*** **- How is data and information currently utilized in the manufacturing preparation process and the execution of manual assembly operation?**
>
> ***RQ2*** **- What is the significance of data management in manufacturing operations?**

1.4 Purpose

This research is carried out in an academic and an industrial context; thus, the purpose of this thesis is to empirically explore how data and information is used in the manufacturing preparation IT systems and assembly information systems for manual assembly operations, so as to outline design requirements for imminent information systems for manual assembly operations.

The findings of this research will strive to contribute to the process of standardization for future assembly information systems across global operations. More so, ascertain the significance of data management in an operational context.

1.5 Delimitation

Data and information management is primarily discussed throughout the study. Data in this thesis is defined as facts, figures or symbols, while information represent data that has been interpreted and processed to be useful in order to provide meaning (Bellinger et al., 2004). In order for information to be created or to happen, data must first exist. Thus, "data is the prerequisite for the creation of information and knowledge" (Kans, 2008). Although, data and information is often used interchangeably in most studies as it will also be used in this thesis, it is however worthwhile to state the distinctive difference between the terms. This study therefore focuses on data and information handling in the assembly information systems for the preparation of manual assembly instructions within Volvo GTO production plants (responsible for the manufacturing of heavy duty vehicle and heavy duty vehicle components) in Sweden. More so, the empirical data for this study was gathered within these plants. Therefore, other functions and operations within the production process will not be considered, and thus, delimited, as emphasis is only on the preparation of manual assembly instruction and processes.

1.6 Thesis disposition

The outline of the thesis comprises of six chapters, with the research questions used as a connecting thread within the study. Each chapter gives a brief description of the content, thus, aiding the reader's understanding of what to expect in each chapter. Figure 1.1 shows the structure and disposition of this thesis.

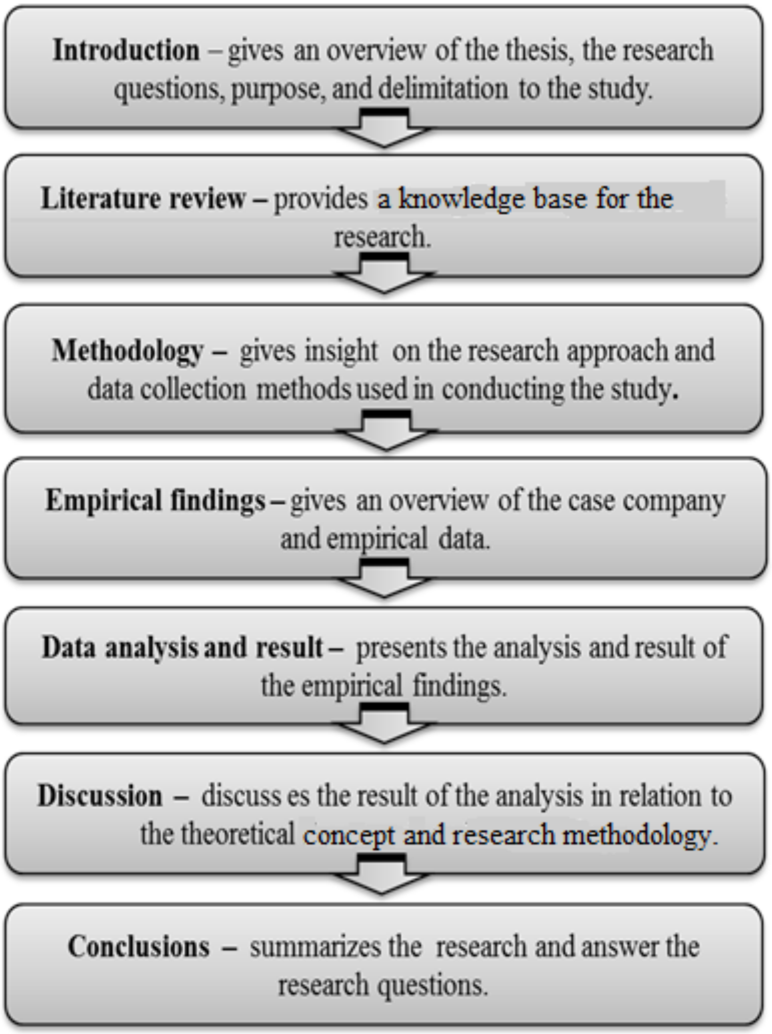


Figure 1.1 Thesis disposition

2 Literature review

The literature review provides a strong knowledge base for this research. This chapter aims to present the theoretical background to help the reader understand the context of the thesis. It introduces the concepts of Data and Information Management in manufacturing operations, as well as an overview of data management in the industry of the future (industry 4.0) using previous research articles and literature.

2.1 Data and Information overview

According to data is recognized as an indispensable enterprise asset in the modern information era, thus data and information are the lifeblood of the contemporary economy. However, data and information are easily confused and are often used interchangeably (depending on the context) but there is a subtle difference between the two. It is therefore important to look at them separately as an entity, and understand the difference and relationship between the two. There are many definitions of data in dictionaries, articles or textbooks, which basically refers data as "a body of facts or an item of information". According to the Data Management Association (DAMA) data is "a representation of facts as text, numbers, graphics, images, sounds or video" (Mosley et al., 2009).

Data, Information, Knowledge, and Wisdom are closely related, from the perspective of the DIKW model (as seen in Figure 2.1). However, this thesis focuses on the management of data and information, hence; emphasis will be on data and information.

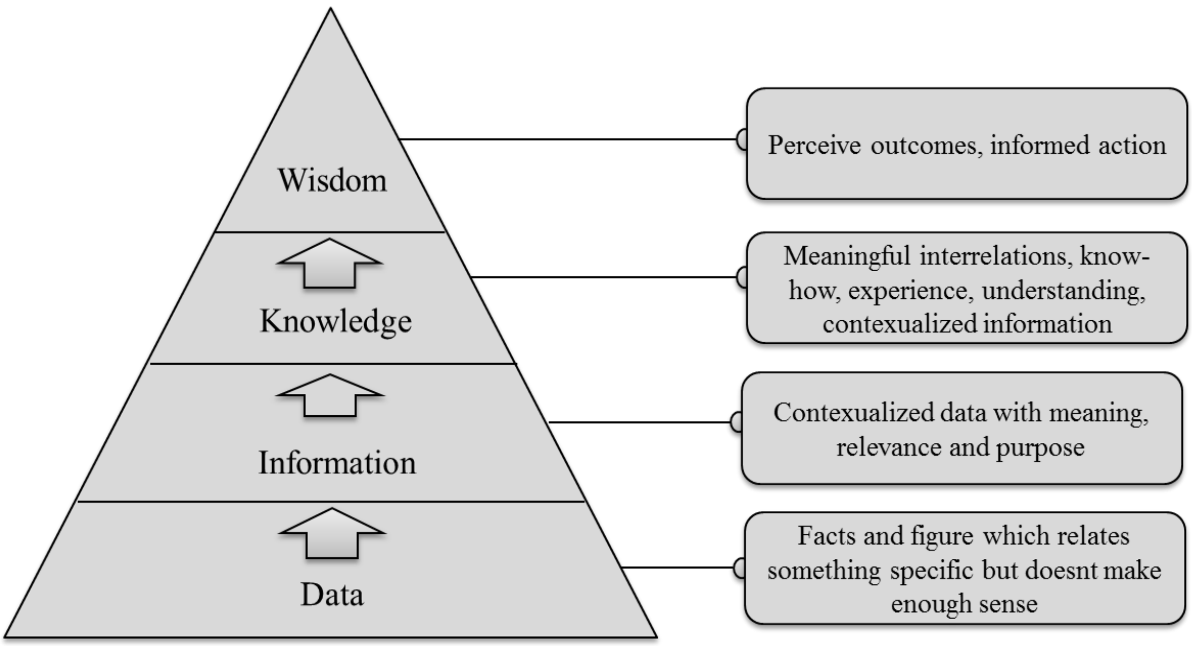


Figure 2.1 Data, Information, Knowledge, Wisdom (DIKW) model (Ackoff, 1989)

Information on the other hand is data that has been put in context, i.e. information is created when data is processed or interpreted in order to give meaningful or useful information. Data is therefore the foundation of the DIKW model, which stands for Data, Information, Knowledge, Wisdom, and describes the hierarchy between them (see Figure 2.1.) the beginning of a continuum – from data, to information, then to knowledge, and ultimately to wisdom, which is the shared understanding (Mosley et al., 2009; Gordon, 2007).

> "This principle of sharing information and building on discoveries can best be understood by examining how humans process data. From bottom to top, the pyramid layers include data, information, knowledge, and wisdom. Data is the raw material that is processed into information. Individual data by itself is not very useful, but volumes of it can identify trends and patterns. This and other sources of information come together to form knowledge. In the simplest sense, knowledge is information of which someone is aware. Wisdom is then born from knowledge plus experience. While knowledge changes over time, wisdom is timeless, and it all begins with the acquisition of data" (Evans, 2011, pp. 6).

Data according to (Mosley et al, 2009) is the raw material, which when interpreted or processed, constantly creates information in various forms that guides or is used for decision-making. Thus, information is an essential business asset used basically in every areas and levels of business or enterprise, because it supports daily operations and practices, whether administrative, management or making strategic decisions (Gordon, 2007). From the context of a computerized information system, the relationship between data and information is shown in Figure 2.2.

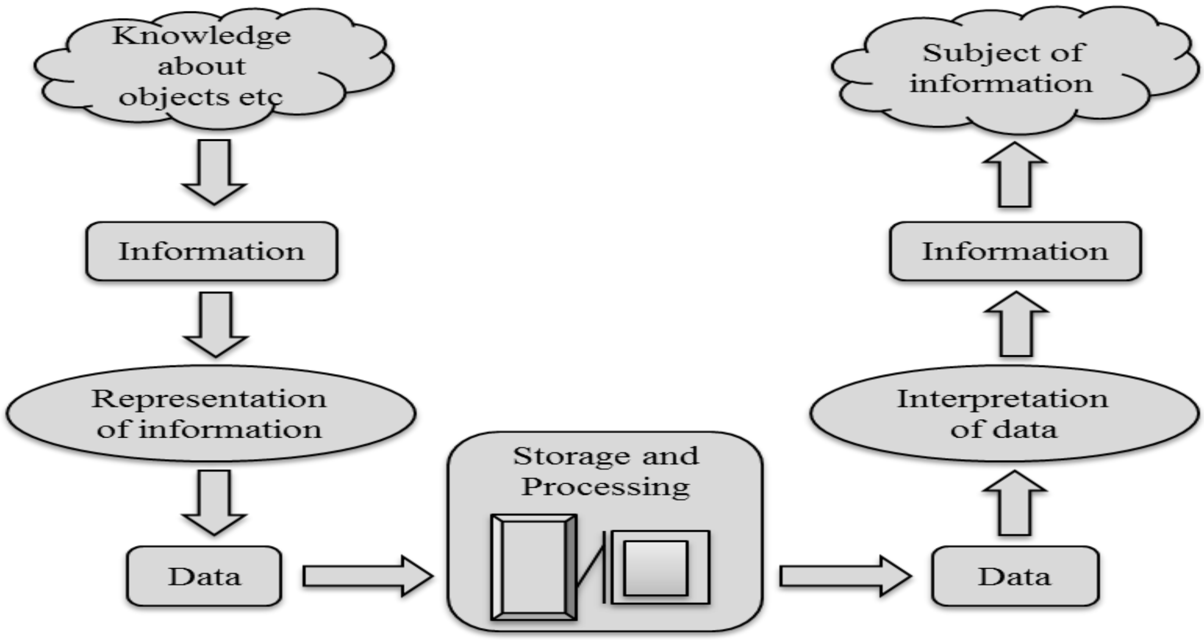


Figure 2.2 Relationship between Data and Information (Gordon, 2007)

The needed information is extracted by the system user, based on knowledge of specific phenomenon, and put in the system. The information is converted into data in order to be stored and processed. When information is desired by another user, the data is interpreted so that it is meaningful and useful to the user, according to the context and needs (Gordon, 2007)

2.2 Data Management

Data management (DM) is a very broad scope covering different functional areas. According to DAMA, data management is "the development of, execution and supervision of plans, policies, programs and practices that control, protect, deliver and enhance the value of data and information assets" (Mosley et al, 2009).

In today's business environment, an essential and distinctive feature of any organization or business is increased emphasis on data and its management. DM is as important to an organization as the management of other resources, and encompasses all activities that are related with administering and controlling how an organization use data internally, together with planning and implementing the processes and systems used by the organization to perform or accomplish these tasks (Fowler, 1995). In the same vein, Gordon (2007) stated that data management is a corporate service that facilitates the delivery of information services through control or organization of the classifications and utilization of reliable and relevant data as it is a broad function that is characterized by data definition to ensure sharing between information systems and thus become a corporate resources (Gordon, 2007).

2.2.1 Importance of Data Management

The essentials and benefit of DM cannot be overemphasized as it occurs at virtually every levels of an organization. It can be argued that computer systems basically provide rudimentary capabilities for systematic data structure; however, it is of essential needs to employ data management approaches when such systems are shared between people and business units (Fowler, 1995).

One key benefit of DM (as related to business) is the value-added information availability obtained through data sharing between the distinct IT systems, as well as improved data quality (Gordon, 2007) which leads to improved efficiency in organization operations and competitive advantage. Other benefit of data management (as related to information technology and systems) is an upturn productivity in system development and cost saving, through the reuse of information and data analysis products (Gordon, 2007).

2.2.2 Relationship between Data Management and Information Management

Data administrative, database administrative and repository administration are three distinctive roles within the DM function. The relationship between these three roles and data management, together with the wider concept of information management is shown in Figure 2.3.

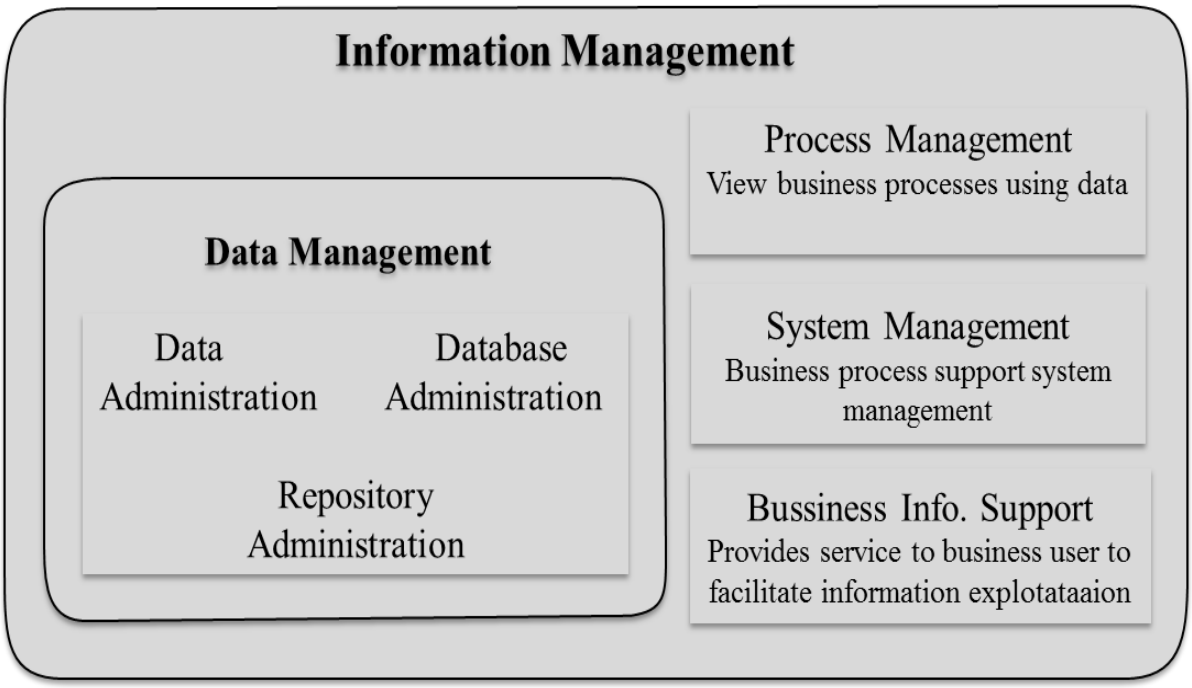


Figure 2.3 Connections between Data and Information Management (Gordon, 2007)

However, other roles from the perspective of information management, which are not within the scope of data management, are process management, system management, and business information management (Gordon, 2007). Accordingly, Information management among others (e.g. Enterprise data management, Enterprise information management, Data resources management, etc.) is generally synonymous with DM (Mosley et al, 2009) due to their close relationship, thus it is almost impossible to mention one without the other.

Evidently, data management happens in many levels of an organization, thus sustaining control of data requires that it is controlled or structured in a systematic way (Fowler, 1995). As stated by DAMA, DM is the business function which involves the planning for, controlling and delivering data and information assets, taking into account the discipline of development and supervision, policies and procedures which control and enhance data and the importance of information resources (Mosley et al., 2009).

2.2.3 Relationship between Data Management and Enterprise Architecture

As Gordon (2007) puts it, if any organization that is adequately perceptive to implement DM, there is a good chance that such organization has embraced the concept of enterprise architecture. Enterprise architecture involves the understanding and perceptiveness of different elements the enterprise is made of. This element includes people, information, processes, communication, and most significantly, how these elements interrelate. Thus, the implementation of enterprise architecture is of fundamental importance in order to define how these elements collaborate to meet organization business needs and strategic goals (Gordon, 2007). The Enterprise Architecture in relation to data management and operations, according to Zachman (2008) is shown in Figure 2.4.

Classification Names / Audience Perspectives	What *DATA*	How *FUNCTION*	Where *NETWORK*	Who *ORGANIZATION*	When *SCHEDULE*	Why *STRATEGY*	Classification Names / Model names
Executive Perspective (Business Context Planners)	Inventory Identification	Process Identification	Distribution Identification	Responsibility Identification	Timing Identification	Motivation Identification	**Scope Contexts** (Scope Identification Lists)
Bussiness Mgmt Perspective (Business Context Owners)	Inventory Definition	Process Definition	Distribution Definition	Responsibility Definition	Timing Definition	Motivation Definition	**Buss. Concepts** (Business Definition Models)
Business Mgmt Perspective (Business Logic Developers)	Inventory Represen-tation	Process Representation	Distribution Represen-tation	Responsibility Represen-tation	Timing Represen-tation	Motivation Representation	**System Logic** (System Represntation Models)
Engineer Perspective (Buss. Physics Builders)	Inventory Specification	Process Specification	Distribution Specification	Responsibility Specification	Timing Specification	Motivation Specification	**Technology Physics** (Tech.Specificati on Models)
Technician Perspective (Buss. Component Implementers)	Inventory Configuration	Process Configuration	Distribution Configuration	Responsibility Configuration	Timing Configuration	Motivation Configuration	**Tool Componts** (Tool Configuration Models)
Enterprise Perspective Buss. Component Implementers)	Inventory Instantations	Process Instantations	Distribution Instantations	Responsibility Instantations	Timing Instantations	Motivation Instantations	**Operations Instances** Implementation **The Enterpise**
	Composite Integrations **Inventory Sets**	→ **Process Flows**	← Alignment **Distribution Networks**	→ **Responsibility Assignments**	← **Timing Cycles**	Composite Integrations **Motivation Intentions**	

Figure 2.4 Enterprise Architecture framework (Zachman, 2008)

The Enterprise Architecture is divided into areas from different perspective of an organization. The first five rows of the Enterprise Architecture are;

1. **The Executive perspective** - view of the business context planners with models for each column that document the scope of the enterprise
2. **The Business management perspective** - view of the business concept owner with models for each column that document the business concepts within the enterprise (business definition models)
3. **The Architecture perspective** - view of the business logic designers with models for each column that documents the system logic within the enterprise the system representation models
4. **The Engineer perspective** - view of the business physics builders with models for each column that document the technology of the enterprise, the technology specification models.
5. **The Technician perspective** - view of the business component implementers with models for each column that document the tools of the enterprise, the tool configuration models (Gordon, 2007).

The sixth row, which is the Enterprise perspective, represents the functioning enterprise of the framework. The framework for Enterprise architecture involves data, information, and/ or data and information specification at different levels of an organization. Consequently, close collaboration and co-operation between data management function and enterprise architecture development owner is crucial (Gordon, 2007).

2.3 Product Data Management

Product Data Management (PDM) involves both the processes, which are used to manage the product data and the computer systems that are used to implement and execute these processes (Fowler, 1995). Another widely used term within the manufacturing field is the Engineering Data Management (EDM), which is the use of autonomous database systems to manage data across multiple, heterogeneous design and engineering application (Fowler, 1995) these systems provide a level of governance over product definition data that is impossible from Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) application (Fowler, 1995). Figure 2.5 depicts this relationship and management of data between different systems.

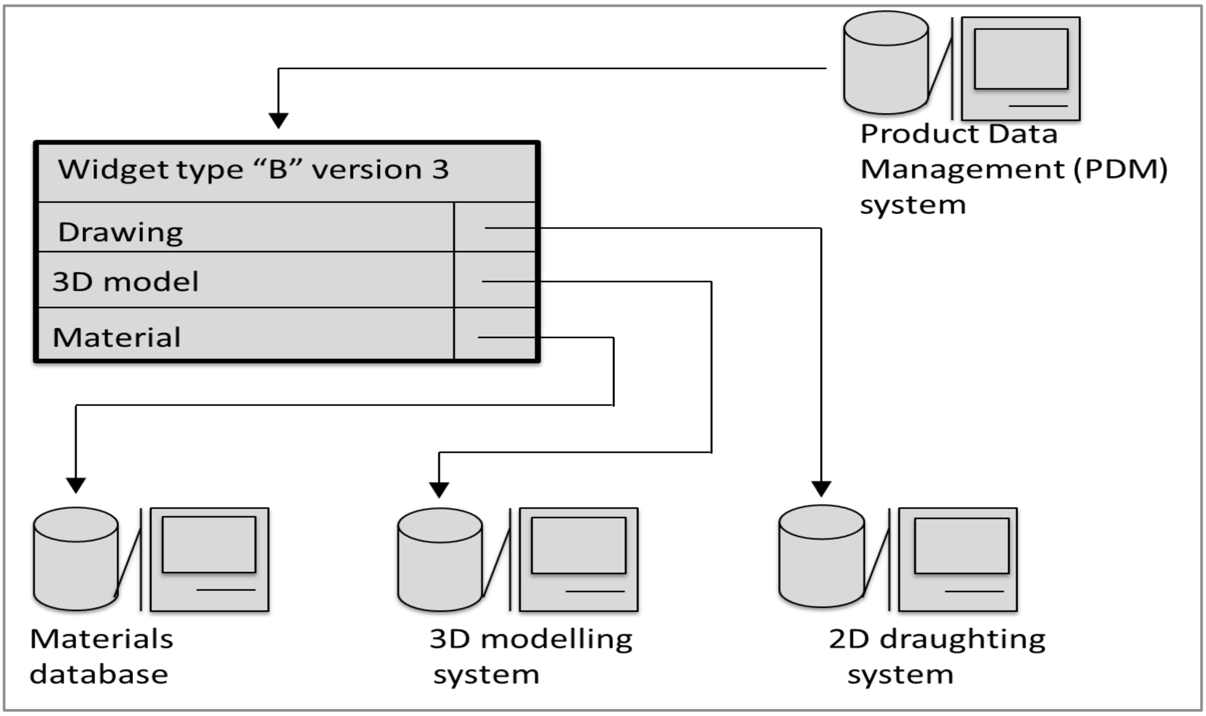


Figure 2.5 Data Management in diverse systems (Fowler, 1995)

PDM system is used as an enabler to define and manage the relationship between CAD systems (which may be used to create different illustrations properties of a product), in terms of a product in which they relate, as well as the fulfillment of the requirement for the logical identification of product data elements within a heterogeneous system and the physical location of those data elements within one or more systems (Fowler, 1995).

2.4 Data and Information Management in Future manufacturing

As industries continue to move in accordance with the initiatives of industry 4.0, data is increasingly being used to make strategic decision in real-time, as well as also revealing new trend in customer behavior (Igor et al., 2016) whereby customers are becoming increasingly influential in product development leading to a new trend in manufacturing. Manufacturing industries are currently facing a growing amount of data and this trend is bound to continue because of the continuous advancement of digitalization of business processes, data output, among others (Stich, 2015). Manufacturing is entering new data-driven era, an era wherein data will most definitely play a significant role at all levels (Sill, 2016).

The fourth industrial revolution, which is touted as industry 4.0 "Smart factory" is about exploiting the overwhelming power of data (big data, predictive analytics, artificial intelligence), and also includes smart manufacturing (Waycott, 2016). According to the Smart manufacturing Leadership Coalition (SMLC), Smart manufacturing is "the ability to solve existing and future problems via an open infrastructure that allows solutions to be implemented at the speed of business while creating advantaged value." It is a data driven paradigm (a future state of manufacturing) that advocates real-time data or information communication and sharing across ubiquitous networks, with the sole objective to create manufacturing intelligence across all aspect of the factory (O'Donovan et al., 2015). The authors argued that the objective of both smart manufacturing and traditional manufacturing and business intelligence is quite comparable, in the sense that it focuses on the transformation of raw data to knowledge. They however stated that given the excessive focus of smart manufacturing on real-time collection, aggregation and sharing of knowledge across physical and computational processes to produce an efficient continuous operating intelligence stream, makes it delineate from traditional manufacturing intelligence (O'Donovan et al., 2015). Smart manufacturing pursue the extension of manufacturing techniques to include autonomous, adaptive processes and to incorporate these processes into modern information technologies (Sill, 2016) thus, manufacturing can be seen as an intensified manufacturing intelligence application in which every areas of the factory is monitored, optimized and visualized (O'Donovan et al., 2015).

2.4.1 Industry 4.0

Widely regarded as the fourth industrial revolution and the factory of the future, industry 4.0 is an advanced information and communication technology (ICT) enabled industry "smart factory" of intelligent and interconnected production systems driven by for core elements, the Cloud technology, internet of Thing (IoT), Intelligent Machines, and Big Data (Khan and Turowski, 2016). According to Kagermann et al. (2013) Industry 4.0 refers to "the technological evolution from embedded systems to cyber-physical systems" representing a paradigm shift from a centralized production to decentralized production (Kagermann et al., 2013). The goal of industry 4.0 according to Jazdi, (2014) is the development of a digital factory, which is characterized by smart networking, mobility, flexibility, customer integration, and new innovative business models.

According to Kagermann et al. (2013), manufacturing and the world economy since the end of the 18th century has been shaped by three major technological revolutions. The first industrial revolution was the introduction of water and steam-powered mechanical manufacturing facilities. The second period was the beginning of electrically powered industrial mass production based on the division of labor. The third industrial revolution was the introduction of electronics and IT in industrial process, paving the way for automation in manufacturing. Today, we are experiencing the fourth industrial revolution (based on Cyber-Physical Systems) that promises to connect production systems and network connectivity in an IoT, one which is characterized by the integration of intelligent ICT into manufacturing systems (Kagermann et al., 2013). Industry 4.0 connects embedded systems production technologies and smart production processes to pave the way for an innovative technological era (Kagermann et al., 2013) thus the future of industrial manufacturing will be famed by the importance of product customization through augmented mass customization (Hu et al., 2011). Figure 2.6 shows the industrial manufacturing evolutions since the end of 18th century.

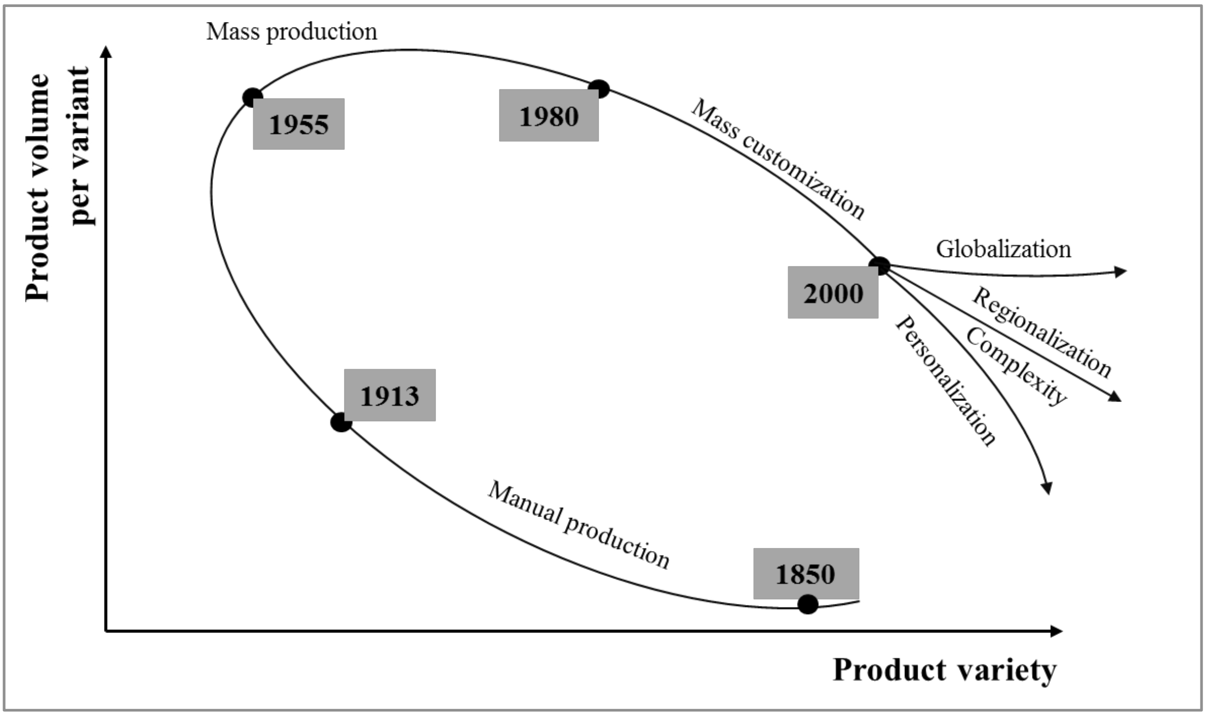


Figure 2.6 Evolution of the manufacturing paradigm (Hu et al., 2011)

Manufacturing evolution or industrialization began in the 18th century, where craft production was prevalent. Under craft production era, individual products (with details to customer information) were produced at a very high production costs. This high costs associated with individual products, led to an era of mass production in the 19th century, whereby little or no customers details was needed to produce a product. However, from early 1980's, industries started adopting mass customization. Mass customization enables product to be produced according to customer specification and requirement, and at an equitable cost.

The future of manufacturing characterized on product complexity and personalized products, as shown in figure 2.6. Thus; data and information mining (Data Management) will play a significant role, due to the connection between the customer product requirements and manufacturing environment (Hu et al., 2011).

2.4.2 Data Management and Industry 4.0

There have been increased applications of advance technologies on production processes due to increased product complexity, new trend in consumer behavior (with regards to product requirements), and the competitive pressure in the dynamic global economy (Khan and Turowski, 2016). These new trends have been made even more visible since the advent of big data and analytics. In real-time, smart manufacturing together with big data has propelled visibility to whole new level. Hence, with the visible real operational environment, production, supervisors, and operators can make improved and more informed decisions. Thus smart manufacturing is more about collecting data, processing and managing it to make meaningful information and knowledgeable decisions (Waycott, 2016). To quote Pat Gelsinger (Chief Executive Office, VMware Inc.) “Data is the new science. Big data hold the answer”.

Data management in Industry 4.0 focuses on the application of interconnected systems, otherwise known as Cyber-Physical System (CPS) with Data Acquisition and Big Data Analytics as the core elements (Lee et al., 2014). Presently, the business world is data-driven, and large amount of data is being generated and collected daily in manufacturing environment (for example, shop floor). Data from machines, sensors, processes, product, quality, maintenance, etc., all contributes to the increase of the amount of data being generated (Khan and Turowski, 2016). This explosion of the amount of data will continue to increase as the development and rapid use of Industrial Internet of Things (IIoT) devices increases. Peter Hartwell, a senior researcher at HP Labs: stated "With a trillion sensors embedded in the environment, all connected by computing systems, software and services, it will be possible to hear the heartbeat of the Earth, impacting human interaction with the globe as profoundly as the Internet has revolutionized communication". Cisco IBSG predicted that there would be 50 billion Internet connected devices (IoT) by the year 2020 (Evans, 2011) opening new windows of opportunities and new use cases in every sector (Khan and Turowski, 2016).

Internet of Things (IoT) or IIoT integrates machine learning and big data by harnessing the power of sensor data and automation (Waycott, 2016). According to Evans, (2011) the amount of raw data that is available for processing has dramatically been increased by the emergence and development of IoT, together with the ability of the Internet to communicate this data, will consequently enable and ease the advancement of people even further. Due to the fact that, the more data is created or generated, the more obtainable is knowledge and wisdom (Evans, 2011). Data management and analytics will play a significant role because big data will lead the way (i.e. inform people and organization on what to do) for effective decision that will affect manufacturing efficiency and improved performance.

3 Methodology

The methodological approach and the research design of this study are discussed in this chapter. The research strategy was first discussed, followed by the data collection techniques and data analysis process with emphasis and justification as to why the author has adopted the research method or approach. Finally, an explanation of how the research quality and ethics was ensured is discussed.

3.1 Research strategy

A well-crafted and appropriate research strategy should be an enabler for answering a research question or questions, as well as attaining the research goal. Research strategy therefore is characterized by a set of pre-defined steps to approach a problem so as to fulfil the purpose of the study (Saunders et al., 2007). Three main conditions (i.e. Form of research questions, control of behavioral events, and focus on contemporary events), which are associated with different research strategies (e.g. Experimental, field survey, archival/ secondary data analysis, history, and case research) as stated by Yin (2009), will assist in the evaluation of the kind of strategy that is most appropriate in conducting a research. As a result, case research strategy is a more suitable research strategy for this study because the studied phenomenon in this research is a description of a continuous process of the Volvo Group Operations. Besides, it is an effective strategy to explore "how" and "what" questions (Yin, 2009). Referring to Voss et al. (2002), case research is a method that utilizes cases studies as its basis by enabling the phenomenon to be studied in its natural settings from the understanding gained through observation of the actual activities, and allowing the "why", "how" and "what" questions to be answered with relatively full understanding nature and complexity of the phenomenon. The research questions in this study aims to examine a phenomenon, thus, adopting a case research strategy will allow a holistic understanding of the complexity of data and information management within manufacturing preparation and assembly processes, which are inseparable from an operational context (Yin, 1989).

3.2 Research design

According to Bhattacherjee (2012) the nature of a research is largely determined by the purpose of the study. This thesis research questions and purpose clearly indicates a descriptive form of research design because the study will not only strive to increase the understanding of the use of data and information in the manufacturing process and IT systems for assembly work instruction, but also attempt to find out the significance about data and information management within the studied object. This corresponds with Dhawa (2010) that it is essential for researchers to clearly describe a phenomenon under evaluation, and the population sample under investigation, when carrying out a research.

Generally, a research design is characterized by three different forms; exploratory, descriptive, and exploratory (Robson, 2002), which enables a well-defined research design, depending on the research area and its purpose (Bryman and Bell, 2007). Descriptive research design is more appropriate and most applicable for this kind of research because of its purpose to empirically increase the knowledge base. Descriptive research design focuses on finding facts or result about a particular subject or object of study that is not clearly defined (Yin, 2003) and answers the question (in the form of "what", "how", "why", etc.) as clearly stated with the research questions.

3.3 Research approach

The research approach to a study is usually directed by a well-formulated research question (Bhattacherjee, 2012). This thesis therefore takes a deductive standpoint because the theoretical concept and research questions were formulated using existing theories that have been developed within the field under study. Hence, the deductive approach adopted for this study will ensure that the existing theories are used to assess the research questions. There are different research approaches (see Figure 3.1) that can be utilized when relating theories with empirical data (Spens and Kovács, 2006) depending on the nature of the study.

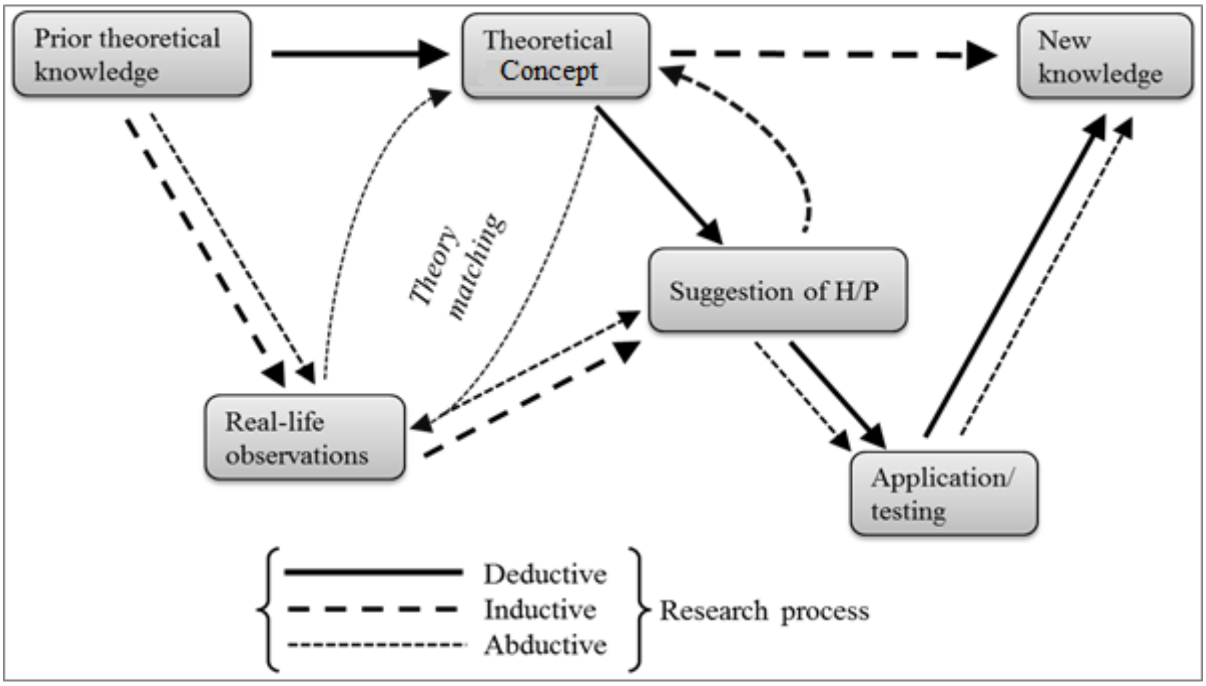


Figure 3.1 Different research approaches (Spens and Kovács, 2006)

The deductive approach was appropriate for this study, so as to have a profound discussion with participants whom are fully involved in the manufacturing data and information handling, in pursuit to fulfill the purpose of the research.

3.3.1 Qualitative data

This research has a qualitative approach based on the nature of the study, which is to get a deeper understanding of the current situation at the case company (i.e. the utilization of data and information in manufacturing preparation and assembly process). By adopting a qualitative research approach for this study, a holistic and comprehensive picture of the complexity of data management in manufacturing and assembly processes, which is characterized by multiple sources of data, is developed (Recker, 2013).

3.3.2 Quantitative data

Although this research is fully qualitative in nature, however, numerical data was collected during direct observation and mouth-to-mouth conversation with operators and team leaders. The quantitative data was to determine the importance (with regards to scaling responses from the operators and engineers) of some qualitative data in the assembly instruction. Likert Scale was used to ascribe quantitative value to the qualitative data on the assembly work sheet, so as to determine which data is important and less important within the available data at the shop floor. Thus, numerical data was also collected in that regard.

3.4 Data collection method

When planning or conducting a case research, the first step according to Yin (2002) is to identify the kind of method one should use in collecting the required data for the research. Data for the research was collected through literature review of previous research within the research area, observation using the traditional "Pencil and paper method", and semi-structured interview with respondents so as to gain an insight of the studied phenomenon. This is in connection of the view of various authors, for example, (Bryman and Bell, 2007; Yin, 2009) of the different methods of collecting data according to the nature of the research. Knowledge is fundamental to any cause, and in order to gain the required knowledge of the specified problem and answer the research questions, three methods were used. First, a literature review was conducted. Second, a direct observation, and third, an interview was carried out with the operators, production leaders, and the responsible production engineers within the area of interest. The reason for using the stated methods is based on triangulation – use and combination of different methods (e.g. direct observation, interview) in studying the same phenomenon, which according to Voss et al. (2002) is the underlying principle of data collection in case research. More so, the use of multiple sources of data on the same phenomenon increases data reliability (Voss et al., 2002).

3.4.1 Literature review

This research explore how data and information is handled in the manufacturing preparation and manual assembly operations, by investigating the available data and information to the operator and how the available data is actually utilized by the operators for carrying out assembly operations. Conducting an extensive literature review in the area of data and information management, particularly in manufacturing operations, was the first step taken in writing this thesis. In order to find the appropriate article and books for this study, different research database (e.g. Google Scholar, Lund University Library, and Chalmers University Library) was used. Key words like data and information management, smart manufacturing, smart factory, manufacturing operations, were used as search criteria. This is in view to narrow down the scope of the research topic. This was important in order to gather relevant theories, concepts, and previous findings that were relevant to this research, and to in order to gain meaningful insight of the research area. Thus, literature review was the starting point of this thesis (Recker, 2013).

3.4.2 Observation

The next step was conducting a direct observation of assembly workflow at the shop floor in order to understand how data and information is used in assembly operations. The main reason behind the observation method is to know exactly what data and information is available within the shop floor, and to gain an insight (from the operator's perspective) on what data and information is actually used for assembly operations. The observation was conducted by using the traditional pen and paper technique (which is basically having pencil and paper to document findings from observation and mouth-to-mouth conversation with operators, team leaders, etc.) to really capture primary (both qualitative and quantitative) data, which is available within the assembly line. This was necessary so as to determine the difference between available data and actual used data by the operators, and as one of the basic requirements for this thesis (Yin, 2002; Bryman and Bell, 2007). The observation was not centered on any procedures or framework as there is no guideline on how to conduct a direct observation in a case research, it was however conducted in such a way that it correlates with the answer the research question (Newcomer et al., 2015).

3.4.3 Semi-structured interview

As a result of the complexity of the research area, a semi-structured interview was performed with different respondents, for example, Production engineers, Technicians and introduction engineers. The main objective of conducting a semi-structured interview is to engage in a discussion that could result to numerous questions and answer, rather than a direct answer (Saunders et al., 2007). Hence, interviewing several personnel in these areas ensured that required data (relating to what data and information, processes and IT systems used in the preparation and creation of assembly instruction used by the operators at production sites) was gathered.

Several interviews were conducted with personnel from different plants within the organization. Personnel with a deep knowledge and insight within the manufacturing area of the organization were interviewed. The reason for conducting at least two interviews from each plant is to have a different perspective of the research area. In addition, very few had a holistic understanding of the research area. Thus, by interviewing more than one personnel within the organization, a more detailed and holistic understanding of the problem was established (kuzel, 1992). The interview was conducted conversationally face-to-face and through Skype (around the topic of research) with one respondent at a time, with a blend of closed- and open-ended questions. This was complemented by follow-up (e.g. "what", "how", "why") questions through e-mail, which clearly describes the descriptive nature of this research, as well as the semi-structured interview (Newcomer et al., 2015). The interview was conducted in such a way that ethical issues (informed participation, confidentiality, anonymity, etc.) regarding research study, as provided by Bhattacherjee (2012) was observed. Questions were asked in such a manner that it does not pose a threat or discomfort to the respondents, so that the main purpose of conducting the interview was achieved. As stated by Yin (2003), conducting a case research interview requires maintaining concurrently two distinguishing levels at the same time, so as to fulfill the purpose of the interview and to ask questions that do not pose any form of inconveniences to the respondent.

3.5 Data analysis method

Two steps were adopted when analyzing the data that was collected during direct observation and semi-structured interview. This was performed simultaneously with the data collection because of the qualitative nature of the research, and to ensure that the collected data was organize progressively, so as to obtain relevant information and arrive at a meaningful conclusion (Coffey and Atkinson, 1996).

The first step taken in acquiring primary data for this research was direct observation. Data collected through observation was voluminous; hence analysis of the data was required. One suitable method for performing an analysis in a qualitative case research is the data reduction method. Data reduction was preferred appropriate for this research because it is a continuous process of data analysis, which involves streamlining, abstracting, transforming and organizing the data so as to reduce the collected data to the most relevant data for the research, thus, a final conclusion can be reached (Miles and Huberman, 1994).

The documentation and recordings form the semi-structured interview with the respondents was transcribed into text in order to ensure a detailed analysis and examination of the collected data, determine the overall quality of the interview and how it relates with the research objectives (Kvale, 2007; Corbin and Strauss, 1990). Besides, the interview analysis was necessary to enable proper interpretation of the text within the context in which the interview was constructed (Bhattacherjee, 2012).

3.6 Research quality criteria

The purpose of conducting any research is to contribute to the body of science and increase knowledge about the particular area. Thus, the research quality must be measured. Heale and Twycross (2015) referred to this as scientific rigor – a concept most applied to qualitative research because of its non-experimental nature. Guba (1981) highlighted the following criteria for assessing reliability of a research.

- **Credibility of the study** – degree to which "confidence in the truth of the findings for the subjects and the context in which the study was undertaken" has been established.
- **Applicability** – degree to which the research finding can be applied to other contexts or settings.
- **Consistency** – an extent to which the research findings would be consistent if investigation was repeated in same context.
- **Neutrality** – degree to which the research findings are a function of the study.

3.6.1 Reliability

Reliability of a study is concerned with its consistency and credibility of the research findings (Kvale & Brinkmann, 2009) that clearly emphasizes that the same findings of the particular research should be attained when performed in the same context. Regardless of the number of times the study is repeated. This is performed in order to minimize any forms of error or biases in a case research (Yin, 2003). In order to evaluate the quality of this research and ensure that the study is consistent, multiple interviews were conducted (even with respondents with the same job title) so as to guarantee that the data collected was reliable and applicable for the proposed study (Bhattacherjee, 2012)

3.6.2 Validity

Validity in a qualitative research is concerned with the extent to which a measure characterizes the construct that is to be measured (Bhattacherjee, 2012). It emphasizes the credibility of a research finding, and whether or not the collected data for the research measures what it is supposed to measure (Recker, 2013). The validity for the study was ensured by carefully reviewing the interview questions with experts and supervisors in manufacturing engineering and technology development that have a holistic insight about the research area before the commencement of the data collection (Yin, 2009). Furthermore, the interview questions were also designed in such way that it was easy for the participants to grasp because if the interview questions were difficult to understand, responses and feedback might be incomplete, which can lead to bias of the findings. Conclusively, all interviews were recorded, as just taking notes during interview would not be enough, with regards to validating the collected data (Bhattacherjee, 2012; Recker, 2013).

3.6.3 Ethics

Ethical issues should be considered when conduction a research due to the unethical ways science has been manipulated and research activities been performed in a contrasting way to that of the norms of scientific conduct (Bhattacherjee, 2012). Ethics for the research was assured according to the guidelines of ethical principle (voluntary and informed participation, confidentiality and anonymity, disclosure, analysis and reporting) proposed by (Bhattacherjee, 2012).

- **Voluntary and informed participation** – all participants in this study were informed about the intended purpose of the study, and were allowed to participate voluntarily. The interviewees were further informed in advance of the research purpose before the interview was planned, and immediately before the interview was conducted. A request to record the conversation was also put forward.
- **Confidentiality and anonymity** – the participants were informed beforehand of the anonymity of their names in the report; hence, the interview is totally anonymous. As it was necessary in order to protect their interest and future wellbeing, and keep their identity confidential.
- **Disclosure** – the research goal and purpose was thoroughly explained to the participants (interviewee) of the study, in order for them to know what the report plans to achieve, so they could decide whether or not to participate in the study.

- **Analysis and reporting** – misrepresenting information and questionable claims during the analysis were totally avoided, thus, the findings and results were reported, as they were uncovered.

3.7 Summary of the research method

The research methodology employed in writing and conducting this thesis is summarized in Figure 3.2 below. These methods were deemed suitable for this research because of the nature of the study. The author employed these methods (Table 3.1), so as to achieve the primary purpose of why the research was conducted.

Research methodology	
Research strategy	Case research
Research design	Descriptive
Research approach	Deductive, Qualitative
Data collection method	Literature review, Direct observation, Semi-structured interview
Data analysis method	Data reduction
Quality criteria	Reliability, Validity, Ethics

Table 3.1 Summary of research methodology used

4 Empirical data

A brief introduction of the case company Volvo GTO is presented in this chapter, followed by empirical data gathered through observation and interviews with different personnel within the Trucks and Powertrain organization.

The data for the analysis was gathered from two different organizations within one entity of the company. Due to the complexity of the manufacturing process and different operation involved, and in view to narrow down the scope of the observation process, a number of activities which characterizes heavy vehicle manufacturing and assembly where selected. These activities include Equipment Controlled Assembly, Media Routing and Clamping, Hole Pattern Recognition, Hidden Assembly, and Riveting. The data matrix for these activities, based on collected data and information from direct observation and interview is presented in Appendix B1 B2, B3, B4, and B5, respectively. These activities were fundamental in selecting the stations where the direct observation technique was carried out.

In order to fully capture data and information used within these selected activities, assembly and pre-assembly working stations were considered suitable for this study. These stations also represents where the aforementioned activities is being carried out. A total of 13 assembly and pre-assembly station where selected across 3 production and assembly plants (which represents manual assembly of complete vehicle, engine and transmission) within the case company. A total of 32 operators participated during the direct observation, where interaction with the operators was also made.

The investigation was planned and carefully carried out in all the 13 stations, so as to identify the data and information that is available for the operators, and how the operators actually use this information in real-time. The operators were also asked to rate the importance of the data and information available to them for assembly operations, using the Likert scale. The rating was from1 to 5, (1 being not important, 2 – slightly important, 3 – fairly important, 4 – important, and 5 – very important).

Furthermore, a total of 10 different interviews were also conducted with production engineers/ technicians within the organizations, who are responsible for different activities in the manufacturing process and the creation of assembly work instruction. In the same vein, the engineers/ technicians were asked to rate the importance of the data and information used for assembly operations. To further differentiate between the organizations, the organizations will be represented by production plant A, B, and C, respectively.

4.1 Company profile

Group Trucks Operations (GTO) is the truck industrial entity within the Volvo Group. Volvo Group comprises of ten business areas, i.e. Volvo Trucks, UD Trucks, Renault Trucks, Mack Trucks, Group Trucks Asia and JVs, Volvo Construction Equipment, Volvo Buses, Volvo Penta, Governmental Sales and Volvo financial service solutions. The group is one of the world's leading manufacturers of trucks, buses, construction equipment, and marine and industrial engines. The group has approximately 100,000 employees, with manufacturing and assembly plants in more than 20 countries worldwide.

Volvo GTO is responsible for truck manufacturing, which includes Cab and Vehicle assembly, powertrain production (Engines and Transmission), Logistics services, Parts distribution and remanufacturing. GTO has a global industrial footprint and manufactures state-of-the-art products of the brands off the Volvo Group, with 43 plants and 55 distribution centers within the organization. The organization also includes approximately 30,000 employees in 33 countries.

Cab & Vehicle assembly

GTO Cab and Vehicle Assembly Cab over engine (Trucks) is responsible for the manufacturing and assembly of cabs, complete trucks and knock-down kits for the Volvo, Renault and UD brands in Europe, Middle east and Africa. One of largest plant located in Tuve (Gothenburg) is responsible for manufacturing and assembly of complete heavy-duty trucks and provides overseas material. There are approximately 2000 employees in Tuve plant.

Powertrain production

GTO Powertrain production is one of the world's largest manufacturing of heavy-duty engines for commercial vehicles, and provides diesel engines and transmission systems to the Volvo Group business areas. Powertrain production also remanufactures and renovates a range of products, and has facilities in Skövde, Köping, amongst others.

The facility in ***Skövde*** produces and supplies diesel engines and components to the Volvo Group. The assembly line is one of the world's largest diesels producing units' segments 9-18liters, i.e. 115,000 engines production capacity annually. The facility has approximately 2800 employees. The facility in ***Köping*** produces transmission systems – gearbox (e.g. I-shift and Powertronic) and marine drives, within the Volvo Group. The facility has approximately 1,450 employees.

4.2 Volvo GTO Information systems

The Group Truck Operations utilizes different IT systems to carry out its manufacturing operations. These systems are either developed in-house or from different IT suppliers. Some of the systems that is relevant for this study and used for the manufacturing preparation (Engineering) and manufacturing execution (assembly) processes are described below.

KOLA - derived from "KOnstruktionsdata LAstvagnar", which stands for Design data truck, is a Product Data Management (PDM) system, which is developed in-house by Volvo IT, and used by Volvo Group, mainly within product development to document product offering and design solution. It is a product development tool that has been designed to provide the engineering department with the ability to see their design solutions from a common perspective. KOLA is the core system that holds or houses all information about trucks with reference to and relation between parts and digital models. The information in KOLA is organized in several structures, which together makes the whole system. KOLA is made up of logic structures, such as item structure, variant structure, and item to variant structure.

SPRINT - a manufacturing preparation system, which is developed in-house by Volvo IT, contains almost all information relating to the production of the vehicle. SPRINT is a tool to deliver a quality assured production structure to the assembly process. Its essential function is to ensure accurate and precise material is at the preferred place, and in the right time, together with the accompanying assembly instruction. It is used for the manufacturing preparation (before the product reaches serial production) to keep track of the flow of material, tool data, structure of the factory, operator structure and instructions. All production data (except the BoM, which is from KOLA system), is entered manually into the SPRINT system by the production engineer during the latter stage of the product development process. The data in the SPRINT system is kept up-to-date during the entire product lifecycle.

BEMS – derived from "BEredning Monterings Säkring", is a manufacturing preparation system used by production engineers to prepare assembly instruction for Assembly Assurance System (AAS). Its features among other, includes, sets of operation sequence (BoM sorting), assembly instruction to product specification connection, manual input of text and illustration, real-time update of instruction and resending, equipment preparation and linkage to the operation, etc.

MONT.AAS - Assembly Assurance System is an assembly instruction display system used by the operators to control or execute assembly operations. It controls the shop floor equipment and guides the operators through every steps of the assembly process. It features, among others, real-time instruction for operators, assembly tools ordering and activation, and displaying pictures and icons for better visualization.

GM-FMD - Global Manufacturing Master Data is an application used by Cab and Vehicle organization of the Volvo Group Trucks Operation to gather data from a number of applications in order to create a Part Master for the manufacturing preparation of a heavy vehicle. When the Part Master is created, it is passed onto other application that needs the Part Master information to carry out their operations.

MOMS – derived from "Material och Monterings Styrning", is a product preparation management system (developed in-house by Volvo IT), which is used for the manufacturing preparation of assembly instruction.

4.3 Process and preparation of assembly instruction

According to the conducted interview, the preparation and process leading to assembly instruction begins with customer's order. This is often (if not typically) characterized by three elements, which is customer requirements, product improvements, and quality requirements. Depending of the three elements, the process begins with the design of the components according to specifications and requirements, together with the possible assembly ergonomics of the product. When the design is completed, a DCN is created. DCN (Design Change Note), also referred to as ECN (Engineering Change Notice) is a document which contains the validation for changes that is made to a system or component after the original design of the component is finalized. It authorizes the changes to a specific design throughout the prototype and lifecycle phases of a product.

Once the DCN or ECN is created, all proposals are reviewed to ensure that it fulfills the set requirements and its suitability for manufacturing. Depending on if the DCN review is flagged satisfactory or unsatisfactory, a detailed time setting and analysis (e.g. process time of a specific operation) based on CAD files or modules is performed. Otherwise, if the review is unsatisfactory the design change or request is performed through a system or application known as PROTUS. The PROTUS system is a tool that allows test prototype specification, support prototype building and report assembly deviations, support prototype testing, and report problems linked with the production or manufacturing process. This is done in order to report or adjustment the requested design change. This is followed by balancing (determining where certain components is suitable on the production line), station marking, which is basically performing station readiness and assigning components with regards to station and operator. These activities leads to or facilitates the creation of preparation of the assembly instruction in SPRINT – a manufacturing preparation system or the BEMS – a manufacturing preparation system (depending of the organization, e.g. Cab & Vehicle assembly or Powertrain production), which is then presented in different systems (SPRINT AI and MONT AAS) to the operators for assembly operations at the shop floor. Three main systems/ application i.e. PROTUS, KOLA and SPRINT are used by the engineers (production engineer/ Technical preparation engineer) to ensure that information for assembly instruction is accurate and precise, in Cab & Vehicle assembly production plant.

5 Data analysis and results

The analysis of the collected data is presented in this chapter. It presents a cross-case analysis of the gathered data from different plants. The analysis chapter (in addition to exploring and comparing the data from different production plants) serves as the bases to answer the research questions. The study questionnaire, which serves as a bases for the analysis can be seem in Appendix C.

As earlier mentioned, this dissertation aims to explore the data and information, which currently used in the manufacturing preparation processes and manufacturing execution system of Volvo GTO. Thus, the analysis of the gathered data through observation and interview (semi structured interview) is the current state analysis. The current state analysis is completely based on interpretation and explanation of the data and information collected during direct observation and interviews. Questionnaire used in conducting the observation and semi-structured interview can be found in Appendix C1 and C2 respectively.

5.1 Availability and used data for assembly operations

Data collected during direct observation from the selected stations (Table 5.1) focuses on two main aspects (from the operators and engineer's perspective) 1, the availability and usage of data and information by the operators, and 2, the importance of the available data and information for assembly instruction. The corresponding gaps between the available and used data are however, also highlighted. It entails what is available to the operators for assembly activities and what data is actually used (in real time) by the operator from the available data at the assembly floor. Value of the availability of data and information at the station and / or plant is in percentage, and the unavailability of data and information at each plant is left blank. Certain parameter or attributes with high and low value in the usage and gap column is selected, in order to give a good account of the current state analysis of data and information management in the manufacturing preparation and execution process of an assembly instruction.

		Plant A			Plant B			Plant C		
Parameter	Type	Available	Used	GAP	Available	Used	GAP	Available	Used	GAP
Product ID	Digital/Physical	1,00	0,92	0,08	0,50	0,50	0,00	1,00	0,33	0,67
Work Instruction	Digital/Physical	1,00	0,58	0,42	0,50	0,00	0,50	1,00	1,00	0,00
Part Name	Digital/Physical	1,00	0,92	0,08	0,75	0,25	0,50	1,00	0,00	1,00
Part Number	Digital/Physical	1,00	0,88	0,12	0,75	0,25	0,50	1,00	0,67	0,33
Quantity	Digital/Physical	1,00	0,80	0,20	0,75	0,25	0,50	1,00	0,33	0,67
Pick-to-light	Light display	0,04	0,04	0,00	0,50	0,50	0,00	1,00	1,00	0,00
Part Number	Pick-2-Light	0,04	0,04	0,00	0,25	0,00	0,25	1,00	1,00	0,00
Part Name	Pick-2-Light	0,04	0,04	0,00	0,25	0,00	0,25	1,00	0,33	0,67
Quantity	Pick-2-Light	0,04	0,04	0,00	0,25	0,25	0,00	-	-	-
Standard Operation Procedure	Physical	0,80	0,52	0,28	0,75	0,75	0,00	1,00	1,00	0,00
Truck Type	Physical	1,00	0,04	0,96	-	-	-	-	-	-
Sequence Number	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Serial Number	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Assembly Line	Physical	1,00	0,00	1,00	-	-	-	-	-	-
CI	Physical	1,00	0,00	1,00	-	-	-	-	-	-
VDM (Variant Driven Module)	Physical	1,00	0,40	0,60	-	-	-	-	-	-
C1	Physical	1,00	0,00	1,00	-	-	-	-	-	-
C2	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Emb (Emballage)	Physical	1,00	0,00	1,00	-	-	-	-	-	-
UP (User Point)	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Time Study	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Comment	Physical	1,00	0,76	0,24	-	-	-	-	-	-

Table 5.1 Data availability and usage for assembly operation at respective plants

Production plant A

From the table (Table 5.1), the parameter or attribute, Product ID (often referred to as Chassis number in Plant A) is available to all operators at every station, and has a 92% usage value by the operators. The Product ID is a key attribute, and serves as the main reference point for assembly instruction and operations because it is connected to all assembly or sub-assembly components and operations performed by the operators. For example, before operations begin at any station, the first information on the assembly instruction that the operator makes reference to is the Product ID. This is very important because it enable the operator to identify the assembly components and the right vehicle to carry out the work operations. The importance of the product ID to assembly operations was also confirmed by almost all the operators at the selected stations.

In contrast, information for assembly operation, represented by the attribute Work Instruction (which consists of Comment and VDM - Variant Driven Module) is another parameter that should have a higher percentage of usage (than the recorded average value of 58%) because it provides the operators with the information on what operation(s) to perform and how it should be performed. Judging by the gap of (0, 42), it clearly shows that almost half of the operators do not pay attention to assembly work instruction when performing assembly operations because, according to the information gathered during observation, the available information is occasionally presented inadequately for certain operations or sometimes very difficult to interpret or understand, as a result of the complexity of the assembly work instruction. It was further gathered that the "Comment" and "VDM" section of the assembly work instruction sometimes contains repeated information, making it not appealing to refer to when in need of information for assembly execution. In general, an assembly operation within the selected stations, which is performed by the operators, is mainly based on prior knowledge of the operation. This was also confirmed by the operators and technicians (when asked) that most of the operators has been working in the station for quite some time, hence, knows what to operation to perform with little or no work instruction as a guidance.

The SOP - Standard Operation Procedure is another attributes that are available to virtually every operator's (80%) at the stations. The SOP provides information in the form of pictures text, and/ or graphics, and supports assembly operations by offering the operators with additional assembly information when needed. Nonetheless, 52% of the operators refer to SOP whenever additional information for operations is required because they often go to the team/ group leader for clarification. Besides, the SOP, as noticed from the observation, was last updated almost two decades ago, which perhaps explain why the team leader is a preferred option for clarification and additional information for a specific product or operation e.g., the Variant member.

In addition, Parameters such as Truck Type Sequence Number, Serial Number, Assembly Line, Core Instruction (CI), C1/ C2, Emballage, User Point, and Time Study, are information that is available on the assembly instruction, and also available to all operators. However, these information is not used by the operators, except one station using the information "Truck Type" (out of the 25 stations observed) in plant A. Judging from the gap of (1,00) in all listed attributes, it suggest that there is an information overload of the assembly work sheet. Both the operators and engineers suggested that such information should not be available on the assembly instruction, as it adds little or no value to the assembly operations being carried out.

Production plant B and plant C

The two production Plants (Plant A and B) is group together because they both uses the same ways and means (digital systems) to prepare and present their assembly work instruction. Based on the interview and observation, there appears to be no significant information overload in the assembly instructions (as in production Plant A) due to the fact that certain parameters (e.g. Truck Type Sequence Number, Serial Number, Assembly Line, Core Instruction (CI), C1/ C2, Emballage, User Point, and Time Study) in the assembly instruction in Plant A is unavailable (Table 5.1) and thus, left blank.

Data of Work Instruction is available in both Plant B and Plant C, but the usage value varies respectively. In Plant B, the Work Instruction is available on half of the stations (50%) but none of the operators in these stations uses it because, as mentioned by the operators, assembly operation is mostly based on knowledge. In Plant C, however, the same Work Instruction is available in all the stations (100%) and also used by all operators in stations (Table 5.1). This is particularly interesting, considering the fact that both plant (B and C) uses the same digital system in presenting their assembly instruction, and more importantly, operators and the responsible engineers from both plants stated that assembly operations are mainly based on knowledge, except for novice operators, of course.

This difference figures in usage indicates that there is inconsistency in how operators perceived the usage of Work Instruction Data. There could be several reasons responsible for this inconsistence; one possible reason that can explain this could be the positioning of the digital assembly instruction system, representing different human engineering design in both plants. For example, in Plant B, the assembly instruction system is placed behind (180° degree) the operator, and the kitting carriage containing the assembly parts and the components to be assembled is joined to the Automatic Guided Vehicle (AVG) that transports the product. With the operator facing the AVG during operation, along with the kitting carriage attached to it, the operator is somehow reluctant to look on the Work Instruction on the assembly instruction system (because operations are based on prior knowledge) as the operator would have to turn 180 degrees in order to be able to look on it and/ or use it. This is very difficult for the operator and inconvenient in terms of ergonomics operator has to turn all time.

In Plant C, however, the assembly instruction system is placed in front of the operator, and the kitting carriage containing the assembly parts and the components to be assembled is not joined to the Automatic Guided Vehicle (AVG) that transports the product, but placed behind the operator. With such scenario, the operator is forced to glance at the Work Instruction (even though the operation is based on prior knowledge) because the assembly instruction system is directly opposite him. This setup makes the operators to assume that the Work Instruction is used (as shown in Table 5.2) when not actually using it in real-time. Another possible reason for the indication of Work Instruction being used in Plant C could be that the operators that were interviewed during direct observation are novice operators. Hence the earlier statement by the operators and engineers that assembly operation is mainly based on knowledge, except for novice operators, of course.

The Pick-by-Light systems (Light displays) often referred to as Pick-to-light is available and also used by all operators in both production plant (Table 5.1). Pick-to-light system, as the name implies, uses the light indicator to direct the operators to a specific part location, as well as quantity of the parts to pick, making it easier for the operators to pick the right parts to be assembled, as well as which work tools to use. The system maximizes part picking; enhance accuracy and productivity, thus, an enabler for effective and efficient assembly operations.

The SOP is another attribute in the assembly instruction that is completely used in all the station that it is available to, judging by the 100% usage rate. The function of SOP is to provide the operators with additional information for assembly operations. However, though ii is used by to operators when additional assembly information is required to complete a specific task, the operators usually, if not typically, refer to the Team leaders or preferably the assembly operations experts (known to then as "Andon") for such information. The "Andon(s)" are usually on hand when needed or call upon, in order to avoid assembly operations bottleneck.

Conclusively, the Product ID, although it is available and used in both Plant B and Plant C, it is however used for quality control and improvement purposes (compare to its purpose in Plant A, which serves as a reference number) hence, the differences in its usability.

5.2 Importance of data for assembly operations

Based on the operators and engineers/ technicians perspective, the importance of different attributes data and information available on the assembly instruction and the computation of the mean figure for all responses from the observation and interview, the operators and the engineers in the respective production Plants appears to have a different and compelling views, as seen (Table 5.2).

		Plant A			Plant B			Plant C		
Parameter	Type	Operator	Engineer	GAP	Operator	Engineer	GAP	Operator	Engineer	GAP
Product ID	Digital/Physical	4,68	5,00	**-0,32**	5,00	1,00	**4,00**	2,33	1,20	**1,13**
Work Instruction	Digital/Physical	3,16	3,60	-0,44	3,50	3,00	0,50	4,33	3,60	0,73
Part Name	Digital/Physical	4,36	1,00	**3,36**	2,33	1,80	**0,53**	1,00	3,20	**-2,20**
Part Number	Digital/Physical	3,56	4,60	**-1,04**	2,33	2,40	**-0,07**	2,33	2,80	**-0,47**
Quantity	Digital/Physical	4,12	1,80	**2,32**	2,33	3,20	**-0,87**	1,33	4,40	**-3,07**
Pick-to-light	Light Display	5,00	5,00	0,00	5,00	5,00	0,00	5,00	5,00	0,00
Part Number	Pick-2-Light	1,00	5,00	-4,00	1,00	1,00	0,00	5,00	5,00	0,00
Part Name	Pick-2-Light	5,00	5,00	0,00	1,00	1,00	0,00	2,33	3,00	-0,67
Quantity	Pick-2-Light	5,00	1,00	4,00	1,00	5,00	-4,00	-	-	-
Standard Operation Procedure	Physical	3,40	5,00	-1,60	5,00	3,00	2,00	3,33	5,00	-1,67
Truck Type	Physical	1,16	1,40	-0,24	-	-	-	-	-	-
Sequence Number	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Serial Number	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Assembly Line	Physical	1,00	1,00	0,00	-	-	-	-	-	-
CI	Physical	1,00	1,00	0,00	-	-	-	-	-	-
VDM (Variant Driven Module)	Physical	2,60	3,40	-0,80	-	-	-	-	-	-
C1	Physical	-	-	-	-	-	-	-	-	-
C2	Physical	-	-	-	-	-	-	-	-	-
Emb (Emballage)	Physical	1,00	1,00	0,00	-	-	-	-	-	-
UP (User Point)	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Time Study	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Comment	Physical	3,72	3,80	-0,08	-	-	-	-	-	-

Table 5.2 Importance of data for assembly operation at respective production plants

Production plant A

The attribute Product ID (Table 5.2) is high in importance, based on the rating score, from the operators (4,68) and engineers (5,00) perspective in Plant A. This is due to the fact that the Product ID serves as the main reference point for assembly instruction and operations, as mentioned earlier in previous chapter. Therefore, it is no surprise that both the operators and engineers rate the Product ID as very important, judging from the score.

The Part Number and Part Name are two very important attributes on the assembly instruction based on the operators and engineers ratings. The operators' rates both Part Name (4,36) and Part Number (5,56) as important because these attributes enable them to identify the part and components, as well as providing the required information off the component to be assembled. Interestingly though, the engineer and/ technicians rates Part Number (4,60) very important and Part Name (1,00) not important. The reason for the weighty difference (as gathered from the interview with the engineers) is that the Part Number is a vital attribute that serves as an identification of all parts and components, thus, it connects all operations and processes in the manufacturing engineering and manufacturing preparation systems. The Part Name, though it also available in the preparation systems, it adds little or no importance, hence, the slightly low rating.

Production plant B, and C

The Product ID in Plant B, and Plant C, has a varying rating (Table 5.2) between operators and engineers, because the purpose of the attribute (Product ID) is not completely defined, from the operator perspective, as perceived during direct observation. However, the engineers are certain that the Product ID is mainly for quality control and continuous improvement purposes, and to not add any importance to the assembly instruction nor aid the assembly operations.

The ratings on Part Number from operators (2,33) and engineers (2,40) in Plant B, and operators (2,33) and engineers (2,80) in Plants C, is considerably balanced, as the values does not indicates any significant difference in opinion or focus of operation. Therefore, the operators and engineers do not have varying interpretation of the importance of the data represented by Part Number. The rating on Part Name, from both Plants point of view, which raises concerns because both Plant uses the same assembly instruction systems. It is unclear as to why the operators and engineers have a varying view and interpretation on the attribute, as the data collected through observation and interview cannot particularly clarify this. However, one potential reason could be as a result of the pick-to-light system, which is available for part picking or preference. In this way, the operators do not attach much importance to the Part Name or Part Number in order to carry out assembly operations as the Pick-to-light system has simplified the difficulty of searching through those parameters on the instruction work sheet.

5.3 Information model and data mapping

Based on the information received during interviews with different personnel in different function of the organization, the information model is mapped, according to UML – Unified Modeling Language, together with the different information systems involved in the manufacturing preparation of an assembly instruction and execution of an assembly operation. Data and information flows through these systems in the preparation process, which result in the assembly instruction that is available to operators for assembly operations.

Assembly instruction information model for plant A

The process of preparing assembly works instruction starts when an order is placed. The first businesses unit is the Product Ordering and it houses the entity CPO – Central Planning Office, which is responsible for placed orders by customers for a specific product. The CPO receives and distributes all customer orders to the right supplier. For the preparation of the assembly instruction, the CPO sends the Variant String to SPRINT - a Manufacturing Preparation System for assembly instruction, which resides in the manufacturing preparation unit of the business process. Figure 5.1 shows the process to an assembly instruction.

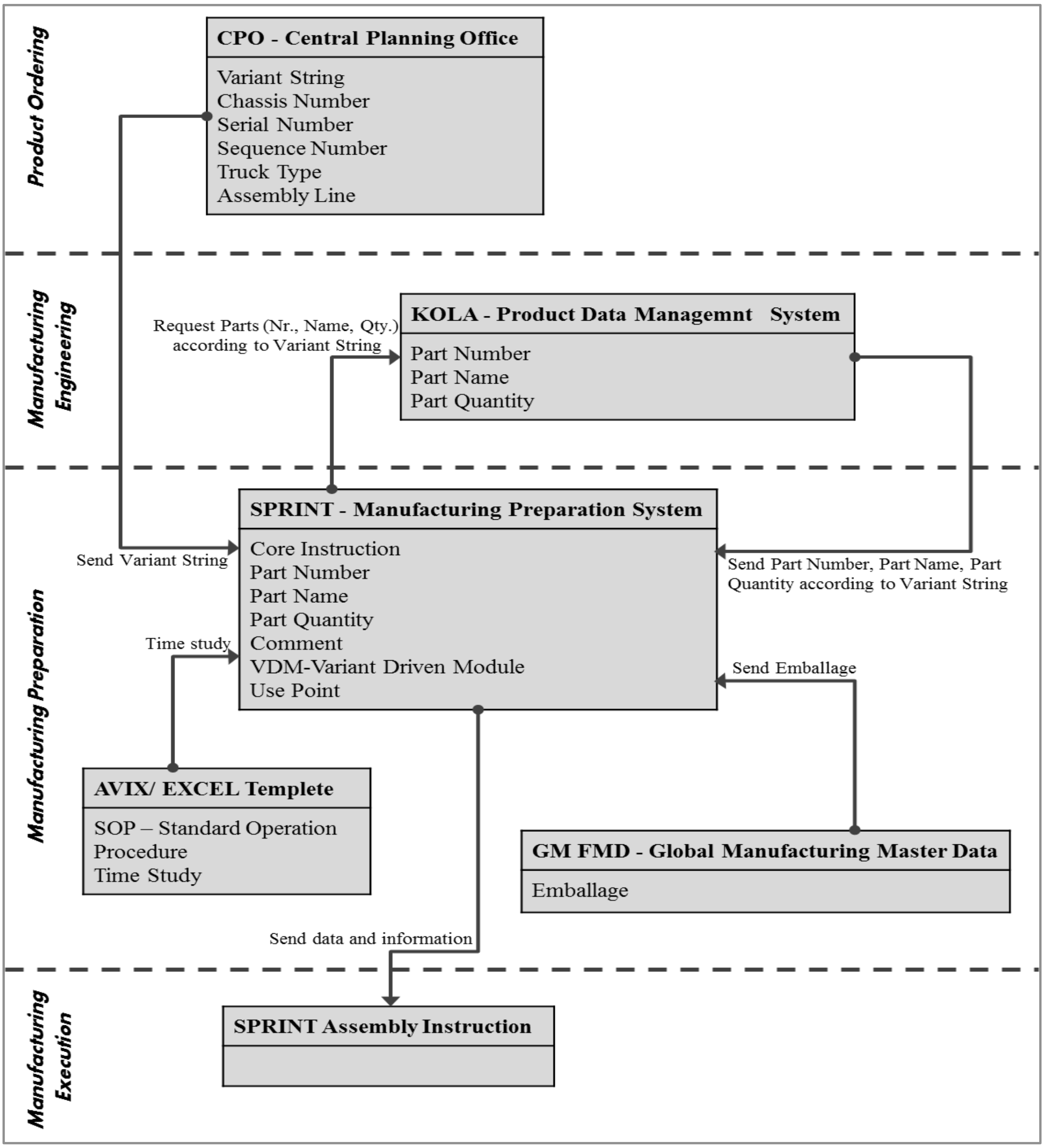


Figure 5.1 Information model of Assembly Instruction process in Plant A

The SPRINT system receives the variant string from CPO, and uses the data to request Part Number, Part Name, and Part Quantity (according to Variant String) from the KOLA system. The KOLA system is a PDM – Product Data Management system, with attributes Part Number, Part Name, and Part Quantity, and it is stationed under the Engineering unit. The SPRINT system uses the Variant String to connect with the Part Number in KOLA systems, which then send back the requested data accordingly.

All data used by engineer for the manufacturing preparation and assembly instruction in the SPRINT system (apart from the Variant String which is sent directly from CPO) is gotten from KOLA system. Hence, the SPRINT system is a mirror of KOLA, and a platform that enables the engineers to input and edit VDM text, graphics, and other information that is essential to the operators for assembly operation purposes, because the engineers cannot input or make changes to data in KOLA system. SPRINT and AVIX/ Excel systems are the two systems and application the engineers uses to processed, interpreted and add context to data (Mosley et al., 2009; Gordon, 2007) thereby creating meaningful and useful information for the operator. The development and transformation of data other entities are mainly performed in the SPRINT system, and AVIX/ Excel systems, as a supporting application. When this preparation is completed, the data and information is sent as a SPRINT Assembly Instruction, which the operator uses in executing assembly instruction.

The AVIX application and Excel template is also manufacturing preparation system where the SOP – Standard Operation Procedure is created. It also contains the Time Study, which is the time for a specific assembly operation. The data (Pictures, Graphics, etc.) is then sent to the SPRINT system.

The GM-FMD – Global Manufacturing Master Data is a manufacturing preparation system, and that contains the Emballage data. This data is sent to the SPRINT system, and use for the logistics of parts and components.

The SPRINT Assembly Instruction is a paper document in print (often refer to as SPRINT AI) containing every data and information from all entity in the information model (Figure 5.1) and it is used for carrying out daily assembly operations at the shop floor (see Appendix A1).

Assembly instruction information model for plant B and C

As in the assembly instruction preparation process in Figure 5.1, the process steps in Figure 5.2 also begin with the CPO receiving customer orders and sending the Variant String to MOMS, in order to start the assembly instruction preparation process. The MOMS system is a product preparation system, and it is positioned within the manufacturing preparation area of the system map or business unit. MOMS then request Part data from the KOLA system by connecting the Variant String, received from CPO, with Part Number, Part Name, and Part Quantity, in KOLA system. The corresponding data is the send back to MOMS from KOLA system, which is in the Manufacturing Engineering unit.

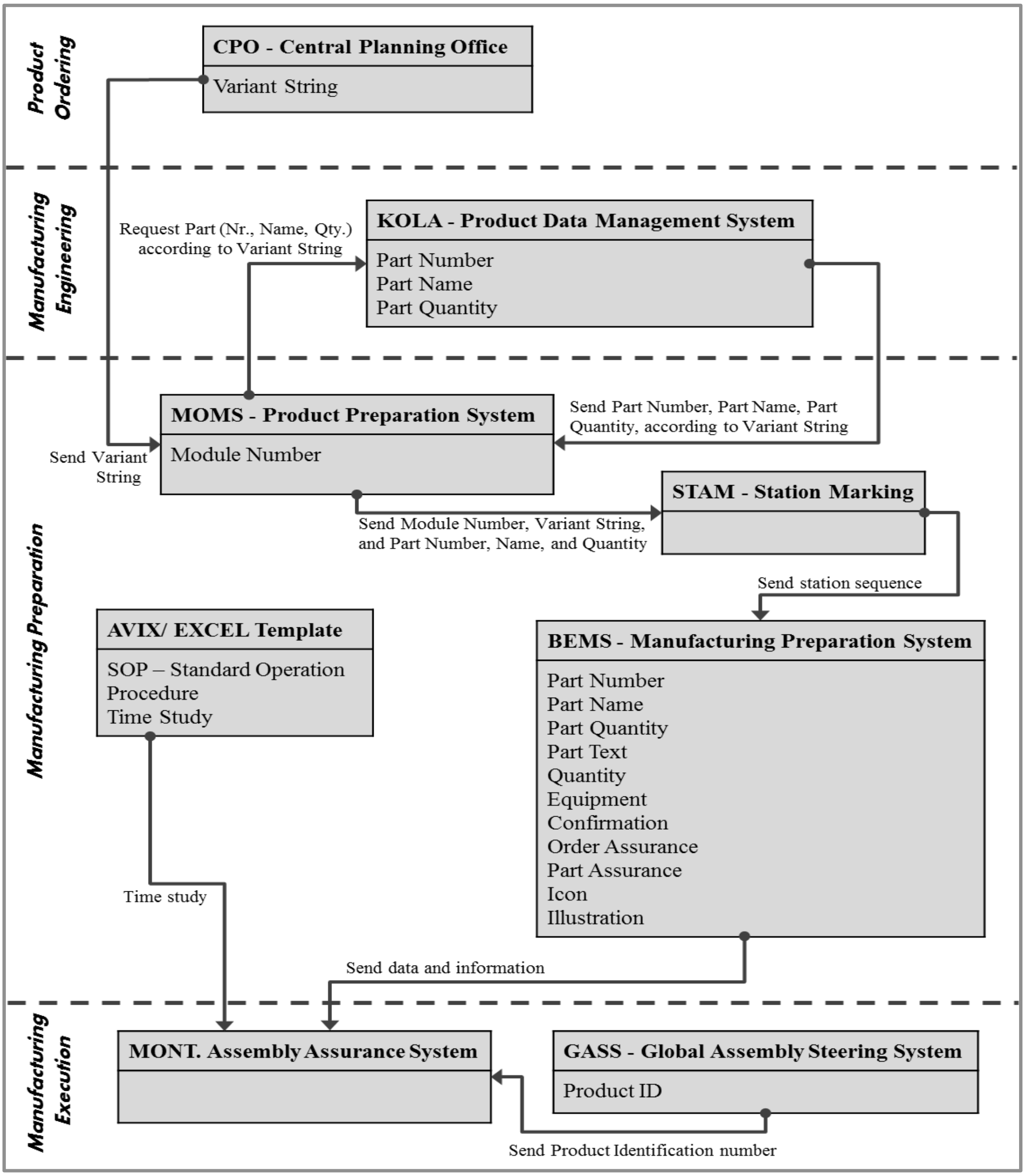


Figure 5.2 Information model of Assembly Instruction process in Plant B, and C

On receiving the data from KOLA, the MOMS system assign the Module Number to the data received from CPO and KOLA system, and sent it to STAM – Station Marking. STAM, a manufacturing preparation system, then assign Part Number, Name, and Quantity to the appropriate station, and send the station sequence to BEMS, within the manufacturing preparation unit.

BEMS is a manufacturing preparation system where assembly instruction is prepared before delivery in to the operator. Similar to activities in the SPRINT system (Figure 5.1), text, pictures, graphics, and other interactive instruction for the assembly operation is added and edited. Text description for the assembly operation is added to instruction in BEMS based on quality meetings and discussion with team leader, as well as operator. Pictures necessary for assembly operations are also added to the assembly instruction in BEMS. But before the pictures are added in the BEMS, the pictures are prepared or created with the application known as IFP – Illustration for Production; otherwise the picture will not show in MONT Assembly Assurance System. When this preparation is completed, the data and is sent to the MONT Assembly Assurance System - MONT.AAS (Appendix A2) as an Assembly Instruction which the operator uses in executing assembly work or operations.

AVIX/ Excel application is use to create the SOP – standard Operation Procedure in created in, before being sent to the Assemble Instruction. The GASS system is a manufacturing execution system that houses the Product Identification. GASS send the Product ID data directly to the MONT.AAS for Assembly Instruction.

The Assembly Instruction (MONT.AAS) is a digital display system (simply refer to as MONT by the operators) contains every data and information from all entity in the information model (Figure 5.2) and it is used for executing daily assembly operations in both production Plants (A and B).

Differences and similarities between the information models

A holistic view of the assembly instruction preparation process is shown in (Figure 5.3). Comparing both information model (Figure 5.1) and (Figure 5.2) shows that although production plant A uses different information systems in the manufacturing preparation of an assembly instruction and execution of an assembly operation, to that used in production plant B and C, the processes to an assembly instruction are quite similar. Data for preparing an assembly instruction (with regards to specific parts or components) comes from the KOLA, a product development tool used by the engineering departments to assess and understand product design from a collective and corporate perspective.

The assembly instruction in production Plant A is presented in a traditional way (i.e. physical system) of printed A4 paper (Appendix A1), whereas the assembly instruction production plant B and C is presented through a digital display platform (Appendix A2), which is the MONT.AAS. In production plant A, process to an assembly instruction is initiated by an order from customer, which is received by the CPO to create the Variant String that is sent to SPRINT. Data transformation is performed in the SPRINT manufacturing preparation system, which keeps track of the material flow, tool data, factory structure, operator structure and instructions, etc. This application/ system enables production engineers to define the steps involved in assembling a vehicle. All data and information (VDM text) required to provide a distinctive and definite production structure that leads to the assembly process. The time required for the operator in order to fulfill it task or a specific assembly operation is also documented in the SPRINT system, before it is being sent as an assembly instruction (SPRINT AI) to the assembly floor. See Figure 5.3.

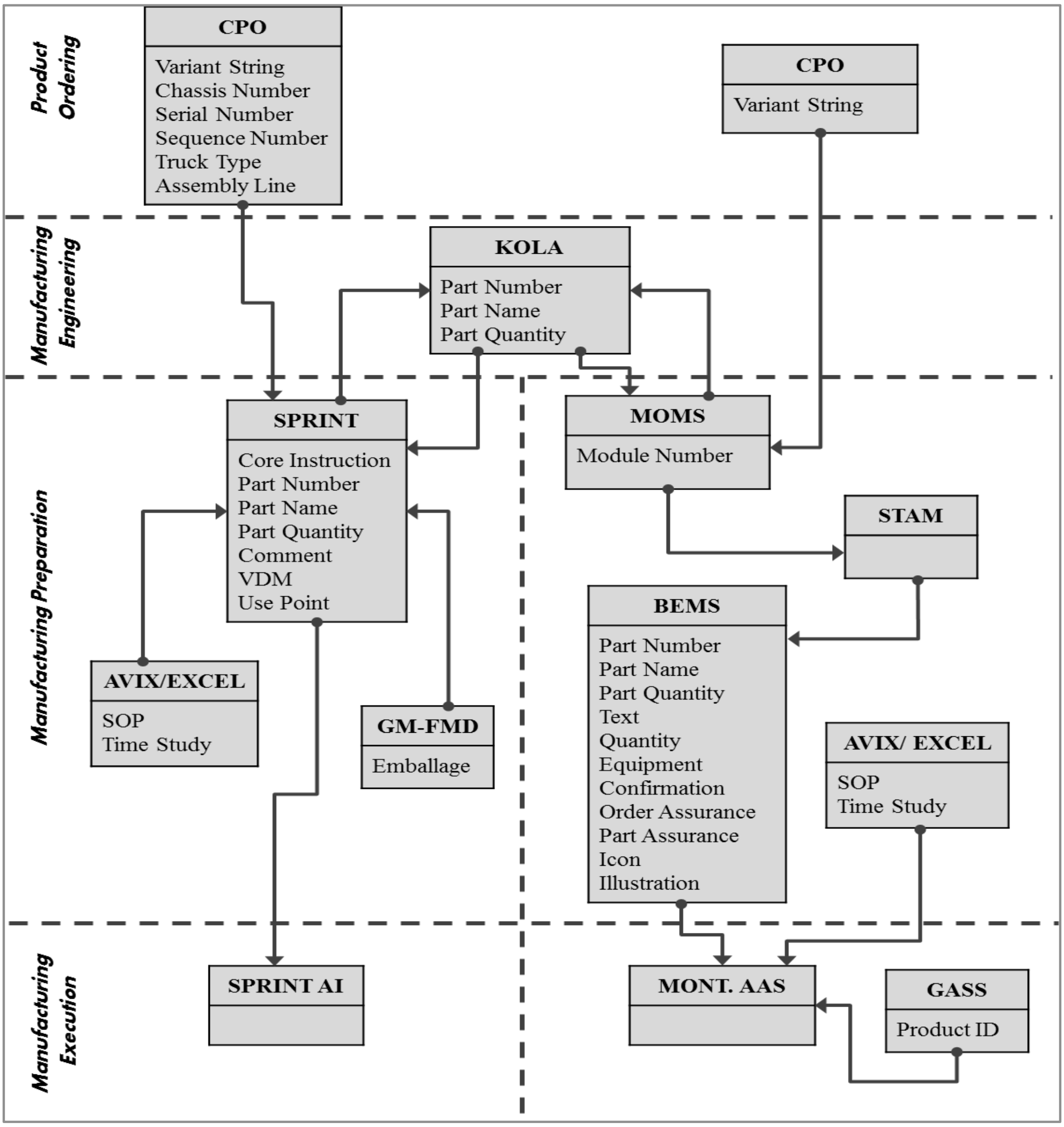


Figure 5.3 Information model of Assembly Instruction process in Plant A, B, and C

In production plant B and C, the CPO also initiates the process to an assembly instruction by sending the Variant String as well. However, the Variant String is not sent directly to the system, which keep track of the flow of material/ components, tool data, operator and instructions, etc., where the data transformation is executed, but to a different system called MOMS. See Figure 5.3. Data transformation is performed in MONT.BEMS; a manufacturing preparation system, which is used to design the flow of operation on the assembly, floor, and creates assembly instruction for the operators.

6 Discussion

This chapter discusses the result of the analysis, in relation to the theoretical concept and the research methodology.

6.1 Current situation

The study focuses on the current state analysis and use of data and information in manual assembly instruction preparation and execution. The result reveals that there are differences in methods employed by the investigated production plants, with regards to computers systems for assembly instruction preparation process, and systems used in the execution of assembly operations. The observation and interview disclosed that both the operators and the engineers have a different view and understanding of data and information use for assembly instruction, a confusing and conflicting crossroad of manufacturing operations, torn between efficiency and effectiveness.

In one of the production for example, several information provided to the operator on the Assembly Instruction is sparingly used (or not used at all) because of its complexity in perception of assembly instruction data. This is evident by the variation in usage and importance value in Table 5.1 and Table 5.2 respectively. Such information overload causes the operator to be less apprehensive of the assembly instruction when searching for the right information for a specific operation. The acclaimed assembly operations are mostly based on knowledge, as disclosed by the operator during the observation of the assembly workflow, can further explain this.

The operators and engineers seem to be caught up in their own internal conflict as the result of the weighted importance ascribed to assembly operations data (Table 5.2) indicates. The operators and engineers disclosed (especially in one of the plants) that assembly instruction is sometimes difficult for new operators (beginner) to interpret due to lack of proper training on how to read the assembly instruction. New operators are instead placed directly on the assembly line to learn from fellow operators who may have more knowledge about the assembly instruction and operation. Such practice is one of the many reason of quality issues arising from assembly operation (Johansson et al., 2016). Operators and engineers continually echoed the statement "assembly operations are mostly based on knowledge" during observation and interview at the three production plants, especially from the perspective of an expert operator. However, results from two of the production plants reveal that there is still variation in values of certain parameters. Although it can be argued that one of the production plants uses a different systems for assembly operations execution, hence the difference in usage value from the plants (Table 5.1).

Interestingly, the parameter "Work Instruction" in Table 5.1 depicts varied usage value within the production plants (B and C), which uses the same system for assembly operations. Such discrepancy in values can be attributed to the design of the station in both plants. In one of the plants, the stations are designed in way whereby the operator presumed to use the assembly instruction because the digital assembly instruction is positioned directly opposite the operator and across the product being assembled. With such design and positioning, the operator is presumably forced to look at the assembly instruction. This is specifically true because as assembly work is being performed, the operator cannot afford not to look at the assembly instruction, therefore, pretending to use it. This may be the underlying reason for the 100 percent usage value of assembly instruction (as indicted by the operators) even though it is not used in reality due to the earlier assertion that assembly operations are mostly based on knowledge.

In the other production plant, the stations are designed in contrast to the one described above, as a result, the operator is not obligated to look at or use the assembly instruction because the digital assembly instruction is positioned behind the operator. Such design allows the operator to easily boycott or bypass the assembly instruction when executing assembly operation, with respect to the operator working based on prior knowledge of the operation. In addition, the design of station creates difficulties for the operator. As one operator mentioned that it is very inconvenient to turn around every time, in order to look at the assembly instruction. This is an ergonomically related issue, which is not often addressed properly.

Certain other parameters, for example, Product ID, Part Name, Part Number, SOP on the assembly instruction were rated higher by the operator than the engineers, and verse versa (Table 5.2) in terms of importance to the assembly operation because, Product ID, for example is used in one of the plants (Plant A) as an identifier by the operators to locate the right Parts or components, the exact assembly instruction, and the actual work piece on which the operation is to be executed. This is a special parameter in the assembly instruction for the production plant, hence, the high value of importance from both operators and engineers. Whereas, the two other production plants uses the Product ID for quality and continuous improvement purposes as shown by the low value of importance in Table 5.2 especially from the engineers perspective.

The value of importance relating to Part Name and Part Number echoed a sentiment from the operators and engineers see Table 5.2. Critical study of these sentiments reveals that the operator rates Part Name as important (in comparison to the engineers' ratings) because to identify and locate the assembled parts. Whereas, the engineers is more inclined to the Part Number because it is the correlation through different systems in preparation process of the assembly instruction. On the other hand, operators and engineers of production plant B and plant C, have a different view of these parameters due to the pick-by-light system primarily used as an alternative for locating and picking the right parts to be assembled, as well as which tools to use for execution. Therefore little or no importance is attributed to Part Name and Part Number.

Overall, some values concerning usage (Table 5.1) and importance (Table 5.2) of data relating to certain parameter (for example Quantity) seem differing and inconsistence, regardless of the systems used, processes, production plants or the acclaimed assembly operations mainly base on prior knowledge. Such inconsistency in understanding and judgment from both operators and engineers is difficult to explain due to the scope of the present study. Hence, further study need to be conducted so as to determine the underlying reasons behind such difference in perception.

6.2 Data management in operational context

The bedrock of any manufacturing organization is the shop floor or production line. In production environment, large amount of data (product data, process data, logistic data, machine data, etc.) is generated and collected on a daily bases in the shop floor. The value of these data is characterized by the meaningful information one can derive from it (Gordon, 2007; Khan and Turowski, 2016) thus, effective data management constitute the foundation on which reliable information is built upon. With the ever evolving data driven world off business, which is characterized by the continuous customer influence on product development and requirement (product customization) reviewing how data is perceived, interpreted and utilized, will not only provides the platform for effective and robust operations, but also facilitates the understanding of different trends in customer's behavior and ways of meeting their needs (Lee et al., 2014).

Data management in manufacturing operations environment focuses on collecting real-time data and interpreting it to give knowledgeable meaningful information (according to the context) and communicating this information through systems and processes so as to achieve improved efficiency in operations, increased productivity in system development, cost effectiveness through reuse of information, and gaining competitive advantage (O'Donovan et al., 2015; Gordon, 2007).

6.3 Chosen methodology

Employing direct observation and semi-structured interview as the primary data collection methods during this study has proven to be the appropriate method because it revealed some interesting facts and developments that were not formerly thought of before the study. Specifically, the direct observation technique proved to be an effective way to understand how data and information is being perceived, interpreted and utilized (with regards to assembly operations) in the production or assembly floor. Besides, it enabled interaction with the operators regarding how the perceive and interpret data presented to them on the assembly instruction.

The semi-structured interview, which was aided by questionnaire, was suitable in gathering additional data on the assembly instruction and the preparation process of assembly instruction because it open the door for a friendly but professional conversation during the interview. Not only was semi-structured interview suitable for this kind of study, due to the complexity of the studied phenomenon, but also enabled several questions to be asked in succession, rather than a direct question and answer.

7 Conclusions

This chapter summarizes and concludes the research by attempting to answer the research questions, from the perspective of the study's empirical findings and discussions.

Data management in manufacturing operations has been discussed in this study, focusing on the use of data and information in the manufacturing preparation and execution process and IT systems of assembly work instruction. The study shows that even though the same systems and process are being used within the same organization, there is disparity on how data and information is perceived, interpreted and utilized manufacturing engineering and shop floor operations. Conclusively, the research questions to this study will be answered in a short and clear manner.

***RQ1* - How is data and information currently utilized in the manufacturing preparation process and the execution of manual assembly operation?**

The current situation analysis of manufacturing preparation and execution of assembly instruction indicates that manual assembly work at the production plants is executed mainly based on prior knowledge of the work function, regardless of data available for assembly operations. Operators as perceived, use data and information on assembly instruction sparingly during direct observation performed at the assembly floor. The difference (gap) between operators and engineers from different production plants, with regards assembly instruction information (Table 5.2), further indicates conflicting views when it comes to utilizing assembly instruction data and information for manual assembly operations. The use of data and information in the manufacturing preparation process of assembly instruction in production plants also differs, as a result of different manufacturing preparation systems or applications being used.

***RQ2* - What is the demand for data management in manufacturing operations?**

With increased product complexity and the continuous application of advance technologies in manufacturing, the demand for data management in manufacturing operations is a compelling one. The advent of big data and analytics has driven the business world to a new height and paved the way for new opportunities for companies to explore. In manufacturing environments, this development is continually facilitating product and process flexibility (as a means to meet customers' demands) through rapid development and the use of interconnected devices in an IIoT ecosystem. Cisco predicted Internet devices alone to reach more than 50 billion by the year 2020 (Evans, 2011). With the IoT propelling real time visibility in operational environment, production engineers and operators will be able to make informed decision that will enhance flexibility in production and assembly processes.

With the impending industry 4.0, the emphases of data management on CPS, together with data acquisition and analytics will play a significant role because big data will be an enabler for information to assist engineers and operators in making effective decision that will transform manufacturing operations and enhance cost effective production efficiency (Lee et al., 2014).

7.1 Relevance of the study

Manufacturing models are changing rapidly due to technological advancement, customer based and data driven business world. Customers are becoming more and more involved in the realization of a product as a result of product customization and personalization. This study is of relevance to both the scientific society and the industry. As technology continues to advance rapidly, research and technology development at enterprise level has gained more attention over the years. However, technology used at operational or production level is relative low in advancement as compared to enterprise level (Khan and Turowski, 2016). In product realization process, the production or assembly floor is the most vital part of the manufacturing process, and therefore need to be able to support and handle these changing manufacturing trends and the dramatic increase in product complexity and product variation.

The imminent move towards Industry 4.0, where new technology will be developed and connected in an IoT and CPS ecosystem, leading to a more automated and autonomous manufacturing industry, has raised more questions than answers with respect to data management at operational level due to large amount of data that is generated by different machines sensor, processes, etc. on the assembly line/ floor. The shift from mass production to mass customization has resulted in an increased product variety and complexity in manufacturing processes and manual assembly operations. Manual assembly systems and operation need to be able to handle and support high product variety and complex manufacturing processes because assembly is an essential part of manufacturing process that ensures products to be realized, by putting together part components and subassemblies to make the end product (Johansson, 2016; Hu, 2011).

Additionally, data acquisition and big data analytics (a core elements of data operation management and data warehousing and business intelligence management in the data management framework) is fundamental to drive the factory of the future, which will be characterized by agility and responsiveness and harnesses new and innovative technology by finding patterns in large amount of data that will be generated by these technology, and consequently make autonomous decisions.

7.2 Recommendations

Results from the conducted observation and interview during the course this study suggest that participants have a different viewpoint regarding assembly instruction and the way that it is being presented. Therefore, some improvement suggestions based on this study are stated as follows.

- Ergonomically standardize the stations design in order ensure total attention to the assembly instruction by the operators during operation. This is in reference to the issue of assembly instruction usage at production plant B and Plant C.
- Have an appropriate assembly instruction data training (certificate training) so as to ensure operators can easily interpret data and in the process make useful and meaningful information for assembly execution purposes.
- Have a more standardize working process or procedure in the preparation of assembly instruction process
- More emphasis on ensuring that core content of assembly instruction is presented to the operator(s). For example, there seem to be a lot of unrequired information on the SPRINT AI, which to not add value to assembly operations but rather create some difficulties and a sense of confusion for the operator (especially novice operator) when searching for information. Thus, it will be more work efficient and cost effective to cut it down to more specific information required for the operation.

7.3 Suggestion for future study/ research

This study discusses and outlines the current use of data and information, by identifying the gaps between operators and in the manufacturing preparation and execution systems of manual assembly operations. Hence, future research should lay emphasis on the assessment of information needs and requirements in manual assembly operations. This is a fundamental so as to improve future assembly instruction and information usage during assembly operations, thereby improving quality in manual assembly work.

Appendix A: Assembly Instruction samples

Page XX of XX

Assembly Instruction Report Creation Date XXXX-XX-XX

ALL Montör 1 Avlastning AAL

Chassis Number	Sequence Number	Serial Number	Truck Type	Assembly Line
X XXXXX	XX-XX-X.XXX	XXXXXXXXXX	XX XXX X	XX

Hämta telfer **CI** XXXXX

Kalla på telfer för chassilyft.

Rörpaket **CI** XXXXX

Part	Qty	Description	C1	C2	Comment	Emb	UP
XXXXXXXX	1	RÖR CAB HEATER			Drag ej. Monteras på lösen, UTSIDA RAM	P3	XXXXX
XXXXXX	2	FLÄNSSKRUV M8*25				0	XXXXX
XXXXXX	2	FLÄNSLÅSMUTTER				0	XXXXX

Montera plugg till vattenrör (UEAS/EAS-SD) **CI** XXXXX

Part	Qty	Description	C1	C2	Comment	Emb	UP
XXXXXXXX	1	ANSLUTNING			Monteras till pip på vattenrör	0	XXXXX

Avklammning höger ramsida **CI** XXXXX

Klamma av befintliga klammor till ledningsmatta. Klammpunkt framför motorfäste till ändbalk.

Framför motorfästet skall kabelmattan placeras så nära insida ram som möjligt,
detta för att undvika skav från startmotor.

Klamma av sidomarkeringskablage, fram och fram-mitten, höger sida. Klamma av höger klamma på konsol växellådsbalk.

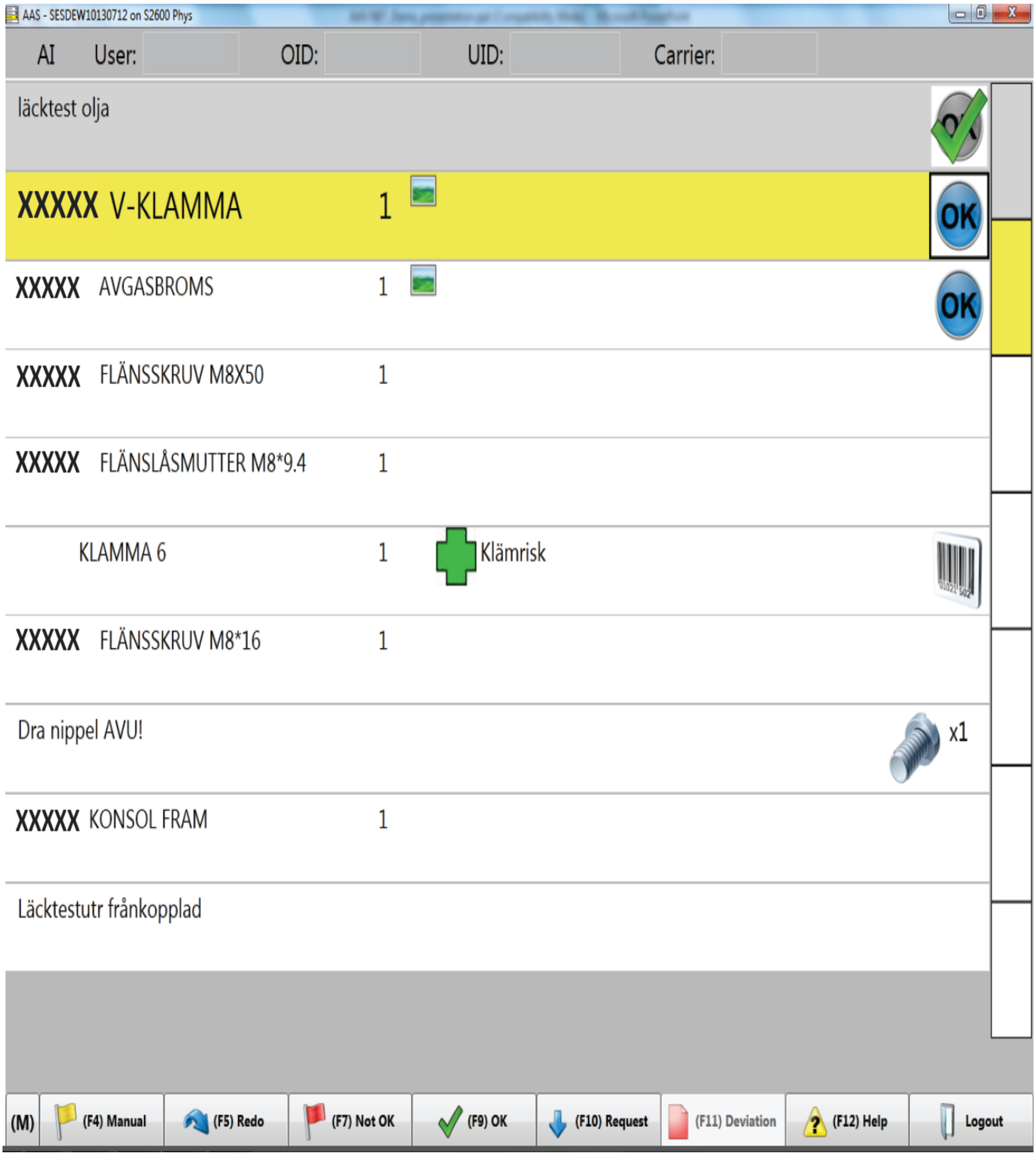
Klamma av sidomarkerings-kablage, bak (MARKL-SR).

Klamma av sidomarkerings-kablage, överhäng (MARKL-SR).

Avlastning chassi, koppla lyftöglor. **CI** XXXXX

Se Handhavandeinstruktion Chassilyft_vändare

Appendix A1 SPRINT Assembly Instruction



Appendix A2 MONT Assembly Assurance System

Appendix B: Data matrix of selected assembly stations

		Equipment controlled Assembly (Plant A)						Equipment controlled Assembly (Plant B)						Equipment controlled Assembly (Plant C)					
Parameter	Type	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP
Product ID	Digital/Physical	1,00	1,00	0,00	5,00	5,00	0,00	-	-	-	-	-	-	1,00	0,00	1,00	1,00	1,00	0,00
Work Instruction	Digital/Physical	1,00	0,00	1,00	1,00	5,00	-4,00	-	-	-	-	-	-	1,00	1,00	0,00	5,00	3,00	2,00
Part Name	Digital/Physical	1,00	1,00	0,00	5,00	1,00	4,00	-	-	-	-	-	-	1,00	0,00	1,00	1,00	3,00	-2,00
Part Number	Digital/Physical	1,00	1,00	0,00	5,00	5,00	0,00	-	-	-	-	-	-	1,00	1,00	0,00	3,00	2,00	1,00
Quantity	Digital/Physical	1,00	1,00	0,00	5,00	1,00	4,00	-	-	-	-	-	-	1,00	0,00	1,00	1,00	4,00	-3,00
Lamp	Pick-2-Light	1,00	1,00	0,00	5,00	5,00	0,00	1,00	1,00	0,00	5,00	5,00	0,00	1,00	1,00	0,00	5,00	5,00	0,00
Part Number	Pick-2-Light	1,00	1,00	0,00	1,00	5,00	-4,00	1,00	0,00	1,00	1,00	1,00	0,00	1,00	1,00	0,00	5,00	3,00	2,00
Part Name	Pick-2-Light	1,00	1,00	0,00	5,00	1,00	4,00	1,00	0,00	1,00	1,00	1,00	0,00	1,00	0,00	1,00	1,00	3,00	-2,00
Quantity	Pick-2-Light	1,00	1,00	0,00	5,00	5,00	0,00	1,00	1,00	0,00	1,00	5,00	-4,00	0,00	0,00	0,00	0,00	0,00	0,00
SOP	SOP	1,00	1,00	0,00	1,00	3,00	-2,00	-	-	-	-	-	-	1,00	1,00	0,00	3,00	5,00	-2,00
Truck Type	Physical	1,00	1,00	0,00	5,00	2,00	3,00	-	-	-	-	-	-	-	-	-	-	-	-
Sequence Numbe	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Serial Number	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Assembly Line	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
CI	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
VDM (Variant Dri	Physical	1,00	0,00	1,00	1,00	5,00	-4,00	-	-	-	-	-	-	-	-	-	-	-	-
C1	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
C2	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Emb (Emballage)	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
UP (User Point)	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Time Study	Physical	0,00	0,00	0,00	0,00	1,00	-1,00	-	-	-	-	-	-	-	-	-	-	-	-
Comment	Physical	1,00	0,00	1,00	1,00	5,00	-4,00	-	-	-	-	-	-	-	-	-	-	-	-

Appendix B1 Equipment Controlled Assembly

		Clamping and Media Routing (Plant A)						Clamping and Media Routing (Plant B)						Clamping and Media Routing (Plant B)						Clamping and Media Routing (Plant C)					
Parameter	Type	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP
Product ID	Digital/Physical	1,00	0,78	0,22	4,11	5,00	-0,89	1,00	1,00	0,00	5,00	1,00	4,00	1,00	1,00	0,00	5,00	1,00	4,00	1,00	1,00	0,00	5,00	1,00	4,00
Work Instruction	Digital/Physical	1,00	0,44	0,56	2,33	5,00	-2,67	1,00	0,00	1,00	2,00	3,00	-1,00	1,00	0,00	1,00	2,00	3,00	-1,00	1,00	1,00	0,00	3,00	3,00	0,00
Part Name	Digital/Physical	1,00	0,78	0,22	4,11	1,00	3,11	1,00	0,00	1,00	3,00	1,00	2,00	1,00	0,00	1,00	3,00	1,00	2,00	1,00	0,00	1,00	1,00	3,00	-2,00
Part Number	Digital/Physical	1,00	0,67	0,33	1,00	5,00	-4,00	1,00	0,00	1,00	3,00	2,00	1,00	1,00	0,00	1,00	3,00	2,00	1,00	1,00	0,00	1,00	1,00	2,00	-1,00
Quantity	Digital/Physical	1,00	0,44	0,56	2,78	1,00	1,78	1,00	0,00	1,00	1,00	3,00	-2,00	1,00	0,00	1,00	1,00	3,00	-2,00	1,00	1,00	0,00	2,00	4,00	-2,00
Lamp	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	0,00	5,00	5,00	0,00
Part Number	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	0,00	5,00	3,00	2,00
Part Name	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	0,00	5,00	3,00	2,00
Quantity	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	-	-	-
SOP	SOP	0,78	0,56	0,22	3,00	5,00	-2,00	1,00	1,00	0,00	5,00	3,00	2,00	1,00	1,00	0,00	5,00	3,00	2,00	1,00	1,00	0,00	4,00	5,00	-1,00
Truck Type	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sequence Numbe	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serial Number	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assembly Line	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CI	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VDM (Variant Dri	Physical	1,00	0,78	0,22	5,00	5,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emb (Emballage)	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UP (User Point)	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Time Study	Physical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Comment	Physical	1,00	0,78	0,22	3,00	5,00	-2,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix B2 Clamping and Media Routing

		Hole pattern recognition (Plant A)						
Parameter	Type	Available	Used	GAP		Operator	Engineer	GAP
Product ID	Digital/Physical	1,00	1,00	0,00	1,00	5,00	5,00	0,00
Work Instruction	Digital/Physical	1,00	0,64	0,36	0,29	3,57	5,00	-1,43
Part Name	Digital/Physical	1,00	1,00	0,00	1,00	5,00	1,00	4,00
Part Number	Digital/Physical	1,00	1,00	0,00	1,00	5,00	5,00	0,00
Quantity	Digital/Physical	1,00	1,00	0,00	1,00	5,00	1,00	4,00
Lamp	Pick-2-Light	-	-	-	-	-	-	-
Part Number	Pick-2-Light	-	-	-	-	-	-	-
Part Name	Pick-2-Light	-	-	-	-	-	-	-
Quantity	Pick-2-Light	-	-	-	-	-	-	-
SOP	SOP	0,57	0,57	0,00	0,57	2,86	3,00	-0,14
Truck Type	Physical	1,00	0,00	1,00	-1,00	1,00	2,00	-1,00
Sequence Number	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Serial Number	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Assembly Line	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
CI	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
VDM (Variant Driven Module)	Physical	1,00	0,29	0,71	-0,43	2,14	5,00	-2,86
C1	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
C2	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Emb (Emballage)	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
UP (User Point)	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Time Study	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Comment	Physical	1,00	1,00	0,00	1,00	5,00	5,00	0,00

Appendix B3 Hole Pattern Recognition

		Hidden Assembly Plant A						Hidden Assembly Plant B						Hidden Assembly Plant C					
Parameter	Type	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP	Available	Used	GAP	Operator	Engineer	GAP
Product ID	Digital/Physical	1,00	1,00	0,00	5,00	5,00	0,00	0,00	0,00	0,00	-	-		1,00	1,00	0,00	5,00	1,00	4,00
Work Instructior	Digital/Physical	1,00	0,75	0,25	4,00	1,50	2,50	1,00	1,00	0,00	5,00	3,00	2,00	1,00	1,00	0,00	3,00	3,00	0,00
Part Name	Digital/Physical	1,00	1,00	0,00	5,00	1,00	4,00	1,00	1,00	0,00	1,00	1,00	0,00	1,00	0,00	1,00	1,00	3,00	-2,00
Part Number	Digital/Physical	1,00	1,00	0,00	5,00	4,00	1,00	1,00	1,00	0,00	1,00	2,00	-1,00	1,00	0,00	1,00	1,00	2,00	-1,00
Quantity	Digital/Physical	1,00	1,00	0,00	5,00	3,00	2,00	1,00	1,00	0,00	5,00	3,00	2,00	1,00	1,00	0,00	2,00	4,00	-2,00
Lamp	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	0,00	5,00	5,00	0,00
Part Number	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	0,00	5,00	3,00	2,00
Part Name	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	1,00	1,00	0,00	5,00	3,00	2,00
Quantity	Pick-2-Light	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	-	-	-
SOP	SOP	1,00	0,00	1,00	1,00	3,00	-2,00	1,00	1,00	0,00	5,00	3,00	2,00	1,00	1,00	0,00	4,00	5,00	-1,00
Truck Type	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Sequence Numb	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Serial Number	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Assembly Line	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
CI	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
VDM (Variant Dr	Physical	1,00	1,00	0,00	5,00	1,00	4,00	-	-	-	-	-	-	-	-	-	-	-	-
C1	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
C2	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Emb (Emballage	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
UP (User Point)	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Time Study	Physical	1,00	0,00	1,00	1,00	1,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-
Comment	Physical	1,00	0,50	0,50	3,00	2,00	1,00	-	-	-	-	-	-	-	-	-	-	-	-

Appendix B4 Hidden Assembly

		Riveting (Plant A)						
Parameter	Type	Available	Used	GAP	GAP	Operator	Engineer	GAP
Product ID	Digital/Physical	1,00	1,00	0,00	1,00	5,00	5,00	0,00
Work Instruction	Digital/Physical	1,00	0,75	0,25	0,50	4,00	1,50	2,50
Part Name	Digital/Physical	1,00	1,00	0,00	1,00	3,67	1,00	2,67
Part Number	Digital/Physical	1,00	1,00	0,00	1,00	5,00	4,00	1,00
Quantity	Digital/Physical	1,00	1,00	0,00	1,00	4,67	3,00	1,67
Lamp	Pick-2-Light	-	-	-	-	-	-	-
Part Number	Pick-2-Light	-	-	-	-	-	-	-
Part Name	Pick-2-Light	-	-	-	-	-	-	-
Quantity	Pick-2-Light	-	-	-	-	-	-	-
SOP	SOP	1,00	0,50	0,50	0,00	3,00	3,00	0,00
Truck Type	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Sequence Number	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Serial Number	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Assembly Line	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
CI	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
VDM (Variant Driven Module)	Physical	1,00	0,50	0,50	0,00	3,00	1,00	2,00
C1	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
C2	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Emb (Emballage)	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
UP (User Point)	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Time Study	Physical	1,00	0,00	1,00	-1,00	1,00	1,00	0,00
Comment	Physical	1,00	1,00	0,00	1,00	5,00	2,00	3,00

Appendix B5 Reverting

Appendix C: Observation questionnaire

(Plant A)

1. Where do you get the data?
- We get the data from SPRINT System.

2. What data is available for you to perform your task?
- Data and information for the specified assembly operation, for example, Chassis Number, Part Number, Part Name, Part Quantity, Task Description, Comments, Assembly Positioning, Truck Type, Sequence Number, Serial Number, Assembly Line, Core Instruction, Emballage, User Point (UP) and Time Study etc., are available to every operator at the assembly floor.

3. What data do you use to perform you task?
- Although every assembly data and information (as mentioned above) is available but the operators do not actually use these data because operation is based on knowledge. Operators use their knowledge gained from working at the station over time. However, Chassis Number, which serves as product identification for the operator. The Chassis Number is the first thing an operator looks for in assembly instruction before he/ she begins an operation because it enables the operator to easily identify the truck and sub-components that goes together in a particular operation. It also gives the operator a certain assurance that the right sub-components or parts are being assembled on the right truck.

4. Please can you give the data a weight? From scale of 1 to 5 (1= not important, 5= very important)
- Yes. Chassis Number - 5, Part Number - 4, Part Description - 3, Part Quantity - 4, Part Name – 1.

5. Does the data provide the required information?
- Yes it provides the required information except when there is a special kind of truck (variant), then additional information is required.

6. Where do you get additional data, if required?
- We get additional data from the team/ group leaders and the SOP (Standard Operational Procedures) document showing details of the engineering process.

7. Does the presentation of the data lead to the required information?
- It does for an experienced operator. But for new operator the presentation of data on the assembly instruction is often very difficult to read or interpret because there are so many data and information on the assembly instruction

8. Is there any possible improvements you could suggest for the Assembly Instruction?
- Take aware unnecessary information, as there is an information overload on the assembly instruction. Present only the data and information that is necessary or required for the operation.

(Plant B & C)

1. Where do you get the data from?
- The data is gotten from MONT Assembly Assurance System.

2. What data is available for you to perform you task?
- All data needed to carry out a specific operation, for example, part number, part name, part quantity, task description, etc., are available to the operator.

3. What data do you use to perform you task?
- Normally we use data from the MONT Assembly Assurance System. But the assembly operations are based on knowledge because we basically repeat the same operation or procedure everyday. And when an operator has been working in a particular station for a period of time, it comes natural on what to do in assembly operations.

4. Please can you give the data a weight? From scale of 1 to 5 (1= not important, 5 = very important)
- Yes. Identification Number - 1, Part Number - 4, Part Description - 3, Part Quantity - 4, Part Name – 1.

5. Does the data provide the required information?
- Yes. But it can still get better as we always try to work towards continuous improvement. However, for new operators, the knowledge of an experienced operator is needed for assistance and direction during operation.

6. Where do you get additional data, if required?
- Additional data / information (if needed) is gotten for the assembly expert, known as "Andon". They are usually present at the shop floor to provided assistance whenever it is needed. We also get additional information from SOP – Standard Operational Procedures, a document showing the engineering process in details.

7. Do the presentation of the data lead to the required information?
- Yes it does, I would say. But data is rarely used because assembly operation is based on prior knowledge, as a result of accumulated experience overtime.

8. Is there any possible improvements you could suggest for the Assembly Instruction?
- I think there are so many unnecessary data and information in MONT system, which is probably not needed during operations, as it does not add any positive value to the assembly operations. Instead more focus should be on the data that is required to perform the operation at hand.

Appendix D: Interview transcript

(Plant A)

1. Before starting the interview, what do you understand by data and information?
- Not so much to be honest.

2. Can you identify your role in the key activity process?
- My role (within the key activities leading to an assembly instruction) is to create assembly work instruction in the SPRINT system, (a Manufacturing Preparation System) and ensure that the documentation is correct. I also share information regarding the final assembly with the group leader or team leaders at the shop floor area.

3. Where do you get the data and information to create an assembly instruction?
- All the data and information for creating assembly work instruction is gotten from KOLA, a Product Data Management (PDM) system. These data is documented in SPRINT system by the technical preparation engineers, in the right core instructions.

4. Is there any transformation of the data done?
- Yes there is data transformation in the form of text description, VDM (Variant Driven Module) and pictures. Because the data received from the technical preparation engineers are basically part number and part name.

5. What applications or systems do you use/ know to receive, transform and send data?
- The main systems I use to receive, transform and send data is the KOLA System, SPRINT System and the PROTUS – a system used in writing the design change or request if the product review is not suitable for production, so as to ensure that the assembly instruction is accurate and precise. The SPRINT system is the mirror of the KOLA system, and serves as a platform where the production engineers can add and edit text description, input the information that is necessary for the operator to carry out assembly operations.

6. What are the requirements/needs at each step of the process?
- The requirement needed at each steps of the process is the data we get from KOLA System, where the technical requirement of the component is documented.

7. Can you weight the data on an assembly instruction according to its importance to assembly operations? (1= not important, 5= very important)
- Yes I can. Chassis Number - 5, Part Number - 4, Part Description - 3, Part Quantity - 4, Part Name – 1.

8. What are possible future improvements from your perspective, in the context of the assembly instruction?
- Future improvements world be to reduce the information on the SPRINT assembly instruction to a more specific information, required for a specific assembly operation. Because there are quite a lot of unnecessary information on the assembly instruction which are seldom used. Also, have or work more on standardized working process/ procedures.

(Plant B & C)

1. Before starting the interview, what do you understand by data and information?
- I think it is basically part number, part name, etc., that is further used for the preparation of assembly Instruction. Laugh!

2. Can you identify your role in the key activity process?
- I contribute to balancing by giving input on station time, cycle and standard time. I also gives input to station making of components which is assigned to the station based on balancing information at the assembly floor. My main responsibility is ensure that documentation of information regarding the component for assembly is correct the BEMS - a Manufacturing Preparation System. And then share the final assembly information / instruction with the group leader or team leaders at the shop floor area.

3. Where do you get the data and information to create an assembly instruction from?
- All the data and information for creating assembly work instruction is gotten from KOLA - a Product Data Management (PDM) system. These data is documented in BEMS system by the technical preparation engineers, in the right core instructions.

4. Is there any transformation of the data done?
- Yes there is data transformation in the form of text description, and pictures, because the data received from the technical preparation engineers are basically part number and part name. The text description in MONT Assembly Assurance System, which is used by the operators during operations are added or included in the MONT system based on quality discussion meeting with the assembly team leaders and operators.

5. What applications or systems do you use/ know to receive, transform and send data?
- The main systems I use to receive, transform and send data is the KOLA System, BEMS System and the PROTUS – a system used in writing the design change or request if the product review is not suitable for production, so as to ensure that the assembly instruction is accurate and precise. The BEMS system is where we the production engineers can add and edit text description, input the information that is necessary for the operator to carry out assembly operations.

6. What are the requirements/needs at each step of the process?
- The requirement needed at each steps of the process is the data we get from KOLA System, where the technical requirement of the component is documented.

7. Can you weight the data on an assembly instruction according to its importance to assembly operations? (1= not important, 5= very important)
- Yes I can. I will assign a weighted value based on the importance to assembly operations.
Part Number - 3, Part Description - 2, Quantity - 4, Part Name – 3, Identification Number - 1

8. What are possible future improvements from your perspective, in the context of the assembly instruction?
- There are not so much improvements needed I would say, because it quite easy to follow and understand during operation. However, there are some information on the Mont Assembly Assurance System, which I think is not used during operation.

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