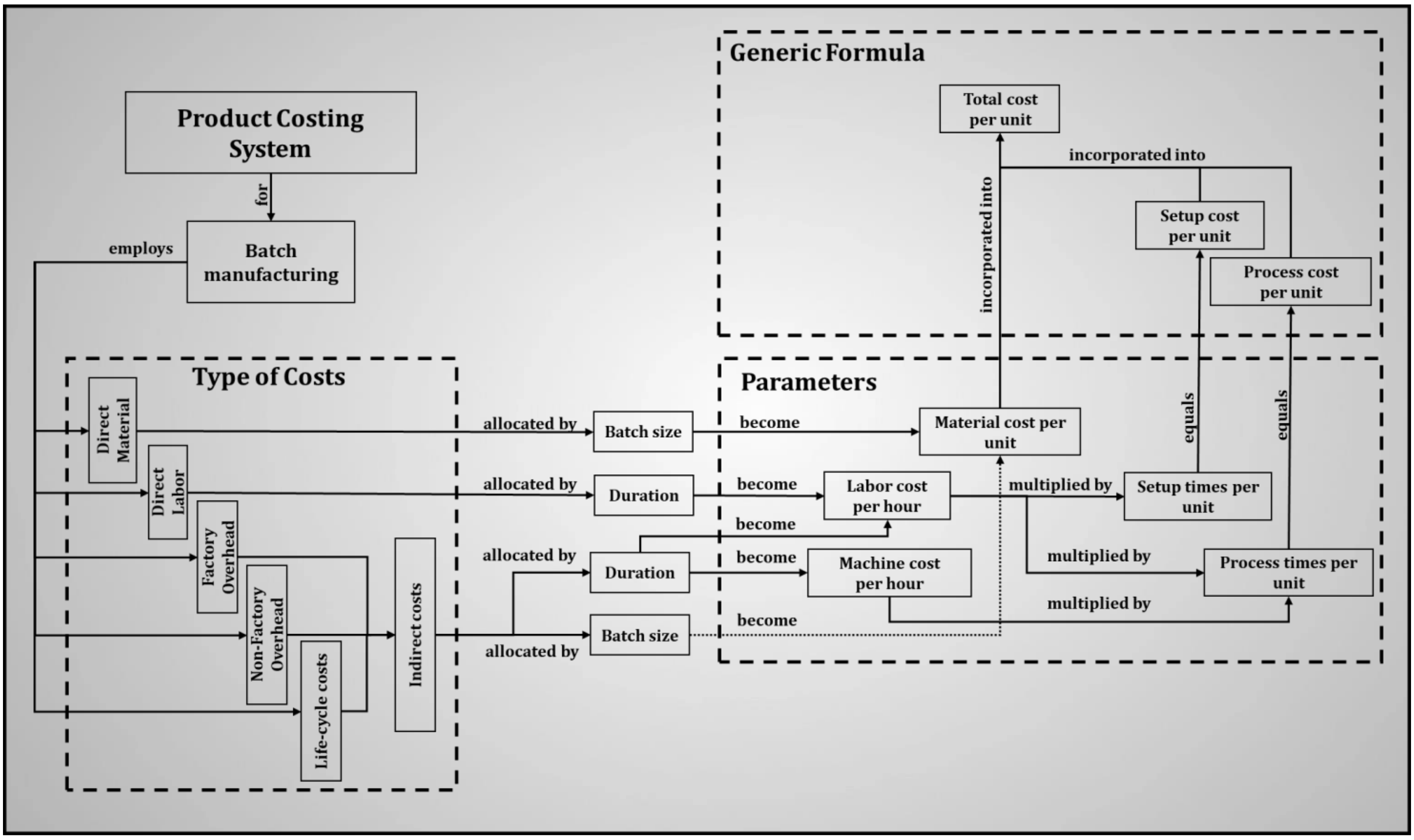

Generic Product Costing System for Batch Manufacturing Operations

Master's thesis in Production Engineering

ARIO DEAN WIRAWAN

VIJAYAGANESH REDDY KOTA

Department of Industrial and Materials Science

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2018

MASTER'S THESIS 2018

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Abstract

Internet of Things (IoT) is emerging topic thanks to the rapid development of information and communication technology (ICT). Manufacturing sector is one example projected to gain major economic impact from IoT implementation. To examine the use case of IoT application at manufacturing sector, case study on a batch manufacturing enterprise in Sweden was performed. The aim of the study was to develop a generic product costing system for batch manufacturing operations. The system was to be used as reference in developing application on demonstration facility at Stena Industry Innovation Lab.

Case study was chosen as research strategy due to its nature to answer research questions with "how" starting the sentences. Furthermore, case study allows the researchers to focus on actual events (i.e. business processes of the case object) with minimum or no attempt of manipulation being imposed. Interviews and observations were used to collect the qualitative data from the case object, which was presented in utter anonymity to secure its confidentiality.

Notable findings from this study were comprehensive diagrams of business processes, cost unit accounting templates with numerical examples, and models of product costing systems. It was discovered that generic product costing system for batch manufacturing operations employed material cost per unit, labor cost per hour, machine cost per hour, batch size, standard times, and actual times as costing parameters. Cost per unit product was obtained from the sum of setup cost per unit, process cost per unit, and material cost per unit.

Key words: product costing, case study, generic

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Next, I, Ario, would like to honor the Ministry of Finance of Republic of Indonesia, who had granted the LPDP scholarship to complete my master study. It had been a pleasure to be awarded such prestigious accolade.

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Ario Dean Wirawan & Vijayaganesh Reddy Kota

Gothenburg, 2018

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1. Introduction

The chapter has four sections (background, aims, research questions, and project delimitations) introducing the initiatives of this thesis work.

1.1. Background

Internet of Things (IoT) is emerging topic thanks to the rapid development of information and communication technology (ICT). High-quality internet connection and smart, connected products (SCPs) will enable business owners to make better decisions based on high-resolution insights from real-time operations (Porter & Heppelmann, 2014).

The span of business under IoT coverages is forecasted to be vast. Manufacturing sector is one example projected to gain major economic impact from IoT implementation (Al-Fuqaha, et al., 2015). Various manufacturing companies have started to realize this trend and set their eyes to make the most out of the opportunity (Accenture, 2015). To examine the use case of IoT application at manufacturing sector, case study on a batch manufacturing enterprise in Sweden, The Electronic Enterprise, was performed. A generic product costing system is expected from the study.

A thorough investigation upon business processes at The Electronic Enterprise' plant in Sweden is to be accomplished. The investigation covers economic practices such as cost estimation and cost accounting. Production systems and information systems management at The Electronic Enterprise are also to be put under scrutiny. The product costing system will be used as reference in developing application on demonstration facility at Stena Industry Innovation Lab.

1.2. Aim

This master thesis work aims to develop a generic product costing system for batch manufacturing operations.

1.3. Research Questions

Research questions (RQ) for this thesis work are given by the following list:

- RQ1: How does The Electronic Enterprise perform product costing nowadays?
- RQ2: How does a generic product costing system for batch manufacturing operations be created based on case study at The Electronic Enterprise?

1.4. Delimitations

Following limitations are applied toward the project:

- The Electronic Enterprise is presented in utter anonymity. Confidential information is not to be revealed. The Electronic Enterprise holds the censorship rights for every corporate-related information before being displayed in this thesis report.
- Only one case object (The Electronic Enterprise) which is examined extensively on this thesis work. Thus, the generalizability of the resulted product costing system still can be enhanced through future researches.
- The product costing system is created as part of digital production testbed development at Stena Industry Innovation Lab. This proposition reduces the complexity of the system due to the difference in scale between facilities at the laboratory and The Electronic Enterprise.
- Demonstration of complete product costing application at SII Lab's demonstrator facility is not part of the thesis work. Thus, it will not be presented in this report.

2. Methodology

The chapter of methodology demonstrates the techniques and research approaches being used to answer the research questions of the thesis work.

2.1. Case Study Approach

The research questions which start with "how" imply the necessity to perform explanatory research which leads to three main research strategies as options: experiment, historical, and case study (Yin, 2002). Beside the type of research questions, those strategies are also evaluated in accordance with these other criteria: control of the researchers toward the actual behavioural events and the emphasize upon contemporary events versus historical phenomena. As the research will focus on actual events of business practices at The Electronic Enterprise with minimum or no attempt of manipulation included, case study is chosen as research strategy for this project.

The decision to utilize case study influences the data collection methods. Case study allows systematic interviews and direct observations as the means of collecting data. The holistic view of the research methodology is displayed in Figure 1 below. Rectangles symbolize processes while parallelograms represent inputs and outputs.

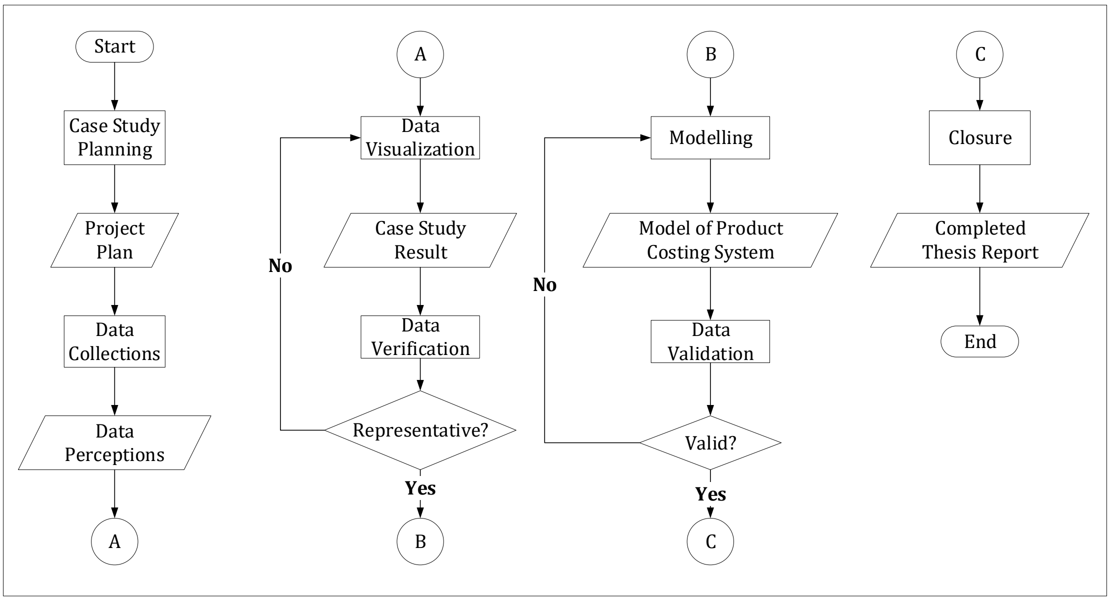


Figure 1 Research Methodology Flowchart

2.2. Data Collections

Qualitative data are collected from The Electronic Enterprise.

2.2.1. Interviews

There are two main types of qualitative interviews: structured and semi-structured (Mason, 2002). Structured interviews are done based on the self-prepared questionnaires. They offer broader perspectives from the acquired answers. Meanwhile, semi-structured interviews give brief understandings on-the-spot when accompanied with simultaneous observations.

Planning for a semi-structured interview does not require a great detailed or meticulous effort. Nevertheless, interviewers need to be able to think and ask questions spontaneously without any pre-designed sequence of questions. Advantage of semi-structured interview is that it makes the interviewees feel to be involved within a "conversation with purpose" (Mason, 2002).

Interviews for this thesis work mostly constitute open-ended questions. Closed-ended questions are minimized to avoid giving the interviewees limited choices for answers (i.e. binary "yes" or "no" answer). On the other hand, the open-ended questions may cause embellishment and misinterpretation of what the interviewees had said (Bryman, 2012a). For this reason, tape recordings are used for partial reconstruction of the interviews, to capture more detailed information at any time by going back through listening.

The interview sheet is available at Appendix A.

2.2.2. Plant Observations

During the case study, participatory observation is performed. It is a method of data generation which makes the researcher involve her/himself in a set of environments to analyse the setting by experience and sensing in a very good range of magnitude (Bryman, 2012b).

Stronger emphasize is placed on the demonstration of product costing by The Electronic Enterprise's operation control officer. The calculation flows and procedures are to be grasped during this phase. Then, observations toward production runs at the shop floor is also considered critical to map the operation tasks for process modelling in a more detailed level.

2.2.3. Ethical Considerations

The Electronic Enterprise is concerned on the protection of their business and intellectual properties. Thus, the following ethical violations in social research are highly avoided (Bryman, 2012c):

- Harm to participants such as physical harm, harm to participants development, or loss of self-esteem.
- Lack of informed consent upon issues such as willingness to have recorded interviews, willingness to showcase demonstration, and whether to be informed of all research processes or not.
- Invasion of privacy such as illegal disclosure of confidentiality and anonymity of the data. Pseudonyms in the report and transcribed scripts are used to make The Electronic Enterprise to be non-identifiable without any changes upon the essence of the information.

This thesis work also takes the research guidelines from Chalmers University of Technology into consideration. Rules of scientific honesty are thoroughly followed to guarantee the originality of the thesis work. Every source obtained from scientific data bases, periodical publications, books, and web articles are referenced accordingly without any attempt of manipulation. At last, this thesis work is performed to promote sustainability measures (social, economy, and environmental) in industrial practice.

2.3. Data Visualizations

Data visualization processes are based on the results from interviews and plant observations at The Electronic Enterprise.

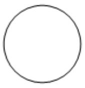
2.3.1. Process Modelling

Process modelling is a technique to organize and record flow of data across processes within a system (Whitten & Bentley, 2007a). It is a part of logical models which aims to give pictorial representations of what the existing (*as-is*) systems do.

A modelling tool called data flow diagram (DFD) is used to depict the flow of data throughout The Electronic Enterprise' relevant business processes. It provides a good way to communicate with stakeholders without technical background about information systems development, mostly system owners and users.

DFD is built upon four elements: external entity, data store, process (logic), and data flow. A graphical format given by (Wieringa, 2003) is used in this project due to its adequate contrast of shapes that represent the elements of DFD. The description of these elements is given in Table 1 below (Whitten & Bentley, 2007a).

Table 1 Data Flow Diagram Graphic Description

No.	Element	Symbol	Descriptions
1.	External entity	Rectangle 	External entity describes a person, organization, or other system that interact with the system of interest (SOI) but is not within the system's scope. In other definition, external entity is also called the system's environment.
2.	Data storage	Open rectangle	Data storage represents the inventory of data which can be retrieved and edited by authorized users.
3.	Process (logic)	Circle 	It is the actual process or logic that is captured during requirement analysis. Processes or logics of the SOI are responsible in transforming one form of data flow into another.
4.	Data flow	Arrowed Line 	The arrowed line represents the input or output from a process that circulates within the scope of SOI.

2.3.2. Costing Parameters Determination

This step is closely related with the cost unit accounting methods at The Electronic Enterprise. The costing parameters are identified from example of calculations demonstrated by the operation control officer.

This step will assure the completeness of costing parameters required to perform accurate cost unit accounting at The Electronic Enterprise. Furthermore, cost parameters determination will provide foundation for creating the generic product costing system.

2.4. System Modelling

The model's creation covers two domains: production systems and costing methods. The first domain examines the type of manufacturing operations that is executed by the organizations or the system-of-interest (SOI). For instance, The Electronic Enterprise as an electronic goods manufacturer will certainly belong to one group of production system categories. Once this domain is settled, the next step is to scrutinize the costing methods.

The arrangement of costing methods follows this list of categories:

1. Scope of costs involvement;
2. Cost centres;
3. Allocation of indirect costs; and
4. Degree of traceability.

The framework from Fisher & Krumwiede (2015) has major contribution for the aforementioned-categories.

3. Theoretical Framework

This chapter presents the theoretical background that supports the creation of the product costing system within this thesis project. The framework overview covers the fundamentals of product costing, production systems, and information system categories.

3.1. Product Costing

Product costing is a subject that lies within management accounting field of expertise (Balakrishnan, et al., 2012). It is a form of assessment on consumed costing elements for the realization and depreciation of goods and services (Ehrlenspiel, et al., 2007). Corporations have necessities to implement product costing for these specific purposes (Fisher & Krumwiede, 2015):

- to determine cost of goods sold or performed services for financial reporting;
- to assess profitability for strategic analysis consideration; and
- to improve control upon operational costs.

In practice, product costing is mostly reliant on the existence of information system to handle the data of costing elements such as: transaction records from purchasing and sales, operation records from production floor, or records of corporation payroll (Wouters & Stecher, 2017). Thus, classification is required for data management purpose. Ehrlenspiel, et al., (2007) presents these perspectives of product costing: types of costs, cost centres, and cost units accounting. Each perspective is further described in the following subsections.

3.1.1. Types of Costs Perspective

This perspective criterion is determined by the type of production factors being consumed. Costs types used in practice are abundance in number and variety. Ehrlenspiel, et al., (2007) presents the example of costs types based on German Industrial Standard (DIN 32 990) as displayed in Table 2. These types of costs can be arranged in an alternative configuration, which is given by Fisher & Krumwiede (2015) which falls into the classes given in Table 3.

Table 2 Generic Type of Costs in Manufacturing Company

No	Class	Sub-class	Practical Examples
1.	Material costs	Direct material	Raw materials; Purchased parts
		Auxiliary material	Cleansers; Package
		Operating material	Fuel; Electricity
2.	Capital costs	Depreciation	
		Interest on capital	Internal capital; External capital
		Value losses risk	Technical progress; Research and development
3.	Labor costs	Direct labor	Production labor
		Overhead	Auxiliary payment
		Salaries	Sales, General, and Administration (SGA)
4.	External service costs	Capital maintenance; Transportation; Licensing	
5.	Societal costs	Taxes; Fees; Contribution	

Table 3 Alternative Configuration of Types of Costs

No	Class	Sub-class	Practical Examples
1.	Direct costs	Direct material	Raw materials; Purchased parts
		Direct labor	Production labor
2.	Indirect costs	Factory overhead	• Variable overhead: Fuel • Fixed overhead: Machine depreciation
		Non-factory overhead	Sales, General, and Administration (SGA)
		Life-cycle overhead	Research and development; Customer service; Disposal

3.1.2. Cost Centres Perspective

In accordance with DIN 32 990, a cost centre is "an operational area of cost generation, demarcated by specific criteria." Cost centres in manufacturing enterprises are usually divided by production departments or business functions. Examples are given in these following lists (Ehrlenspiel, et al., 2007):

- General. These are cost centres which services are available for every other cost centres to use (plant wide). Examples: energy supply, facility management.
- Main productions i.e. assembly stations, machine shops.
- Auxiliary productions i.e. production planning, repair workshops.
- Materials i.e. warehouse, purchasing, testing,
- Supporting i.e. administration, sales, and distribution.

3.1.3. Cost Unit Accounting Perspective

Cost unit accounting discusses about cost assignment to an individual product or cost object (Ehrlenspiel, et al., 2007). The common states of an individual product in manufacturing context are part item, modular block, and fully assembled article. The measurement unit is "unit piece".

To perform cost unit accounting, all recorded costs must be distinguished based on their eligibility to be assigned to a unit piece of product. There are two generic paradigms according to DIN 32 990: direct costs and overhead costs. Direct costs refer to all cost that can be directly assigned to cost objects. The examples are direct material and direct labor costs. Meanwhile, overhead costs are all costs that cannot be directly assigned to cost objects i.e. office administrations, advertising, auxiliary materials, auxiliary wages, and capital maintenance.

Fisher & Krumwiede (2015) provides a framework which set the level of costs involvement in cost unit accounting. One of the frameworks which is deemed compatible with International Accounting Standard (IAS) is full absorption costing. This framework takes factory overhead into accounts (i.e. material costs, labour costs) and treats non-factory costs (i.e. administration, sales) as period costs, making them ineligible to be capitalized into inventory (cost object). Other framework satisfying IAS requirements is life-cycle costing, which capitalizes non-factory costs even though it requires more effort for the setup.

Ehrlenspiel, et al., (2007) demonstrates a method to determine overhead costs as the result of applying surcharge rate on direct costs. The method needs template of operation accounting sheet filled with historical data of manufacturing costs. The steps to set up the sheet are as follow:

1. Acquire the costs from bookkeeping records and grouped them as either direct costs or overhead costs.
2. Arrange the costs in accordance to their own cost centres. Distribute overhead costs from general cost centres and auxiliary cost centres.
3. Determine the overhead costs surcharge rate by division of direct costs by overhead costs.

This surcharge rate is useful in constructing cost unit estimate in the future development. This estimate is useful to find the real operational value of a company through comparison with the actual accrued costs from the operational accounting sheet. The example cost unit accounting is provided in this section Appendix B.

In other references, such as Fisher & Krumwiede (2015) and Öker & Adigüzel), product costs are classified as either direct or indirect based on their eligibility to be assigned directly to the cost objects. Direct costs are derived from department that directly influence the production volume i.e. manufacturing department. These costs are directly allocated to product lines that interact with manufacturing department. Meanwhile, indirect costs come from supporting department. These costs need to be allocated in advance to other departments, which is directly related to cost objects, according to their respective utilization of resource under supporting departments control (Öker & Adigüzel, 2010).

Fisher & Krumwiede (2015) presents a costing continuum based on the allocation method for the indirect costs, which closely tied with how overhead costs is organized into cost centres. Description of the continuum is given in Table 4.

Table 4 Continuum of Indirect Costs Allocation Method

No.	**Cost Centers Organization**	**Description**	**Allocation Method**
1.	Plantwide cost center	• Single cost center (plant). • The simplest method, yet the least accurate due to high risk of cost distortion from using single uniform driver only.	Volume-based
2.	Departmental cost centers	• Take differences of overhead costs among departments into account. Overhead costs are accumulated into separate departments. • More accurate than plantwide method in general.	Volume-based
3.	Activity-based costing (ABC)	• Activities are treated as cost centers. • Activity cost rates are determined by allocating overhead costs based on percent of time spent by a resource (i.e. employee, machinery) for the respective activity (Kaplan & Anderson, 2004). • Cost unit is assigned based on the consumption of activities by the respective cost object (Kaplan & Anderson, 2004). • More accurate than using volume-based allocation. • Require complex setup and maintenance in determining activity cost rates.	Activity based (Kaplan & Anderson, 2004): • process customer orders; • handle inquiries; • check credit; • etc.
4.	Time-driven activity-based costing (TDABC)	• Overhead costs are accumulated into separate departments. • Cost per time unit for consumption of resources (i.e. labor, machinery) is determined through division of overhead costs by cost centers capacity (Öker & Adigüzel, 2010). • Less complex to set and maintained compared to ABC. • Allow to compute the cost of unused capacity. • May not be as accurate when determining resource cost whose capacity is not measured by time.	Duration based: • setup time; • machining time; • design period; • etc.

Table 4 Continuum of Indirect Costs Allocation Method (continuation)

No.	Cost Centers Organization	Description	Allocation Method
5.	Detailed cost centres	• Overhead costs are tracked to individual work areas, more detailed than departments. • Strongly associated with resource consumption accounting (RCA) which distinguish fixed and variable costs, both allocated according to their dependence on the appearance of specific cost-controlling variable (Ehrlenspiel, et al., 2007). • Use operational quantities as models which represents causal relation between outputs (cost objects) and underlying costs. • Have the highest accuracy of cost unit accounting result, yet it is the most complex to be set and maintained.	Resource consumption intensity based (Balakrishnan, et al., 2012).

3.2. Production Systems

The term production and manufacturing are used interchangeably. However, in the context of hardware creation, these terms have similar definitions (Groover, 2011). Definition of manufacturing from technological point-of-view is the application of physical and chemical processes to transform the geometry, properties, and appearance of starting materials into more advanced states. Moreover, manufacturing also adds economic value upon the transformed materials.

Within discrete manufacturing context, production flows and layouts are dependent on both production volume and product variants (Bellgran & Säfsten, 2010). The classes of product flows are single unit process, intermittent process (batch), and continuous process. See Figure 2 for illustration.

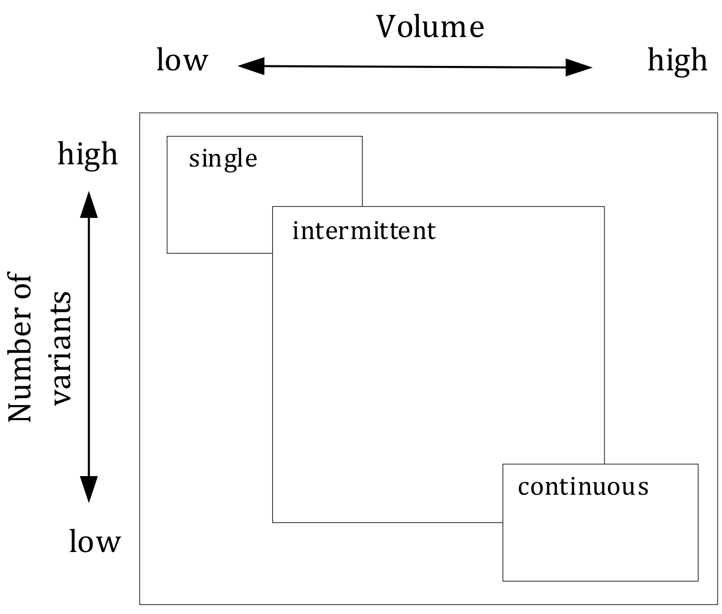


Figure 2 Type of Production Flows

In discrete manufacturing context, production flow is influential in determining production layout. Each flow is associated, or best fitted with, one or more layouts, as demonstrated by Table 5 below (Bellgran & Säfsten, 2010).

Table 5 Type of Production Layouts

No.	Layout	Flow
1.	Fixed position	Single unit (i.e. ship, aircraft building facility).
2.	Functional layout (process oriented)	Single unit or batch (i.e. ball-bearing).
3.	Cellular manufacturing	Batch (i.e. electronic goods manufacturing)
4.	Line-based flow (product oriented)	Continuous (i.e. automobile assembly line)

4. Case Study Results

In this chapter, results from data collections at The Electronic Enterprise will be presented.

4.1. Overviews

The Electronic Enterprise was founded in 1988 by two students from a local university in Sweden. One of the founders is still active in the central management of the company. Today, The Electronic Enterprise employs more than 500 people with each sales and research & development department holds more than 30 percent of human resource, respectively.

The Electronic Enterprise provides industrial communication devices and systems which have been evolving from the early centralized, wired system to the emerging smart-connected industries. The company portfolio comprises of:

- Brand-1 acts as enabler for communications between various standards of industrial networks and equipment. It is beneficial for peer-to-peer communication between industrial equipment. Brand-1 is available as standalone gateway or as embedded module.
- Brand-2 is used for communications between components within a system of machinery/equipment. Mostly used for safety measure in manufacturing operations of automotive industry.
- Brand-3 plays important role in making remote asset management controls via web possible. The product is mostly used in the monitoring and maintenance routines of remote radio communication infrastructure.

Production plants exist in twelve countries while distribution representatives are available in more than 50 countries. High-volume production is taken care by production plant in Lithuania and China. Meanwhile, plant in Sweden, Germany, Belgium, Spain, and The United States tackle demand with lower volume and higher flexibility characteristics.

Mainly, the target market covers business-to-business (B2B) sector, through direct sales or distribution centres. The customers of The Electronic Enterprise vary from manufacturing, transportation, life science, to energy business sectors. Many multinational companies are part of The Electronic Enterprise frequent customers i.e. automation equipment manufacturer, vehicle equipment manufacturer, automotive manufacturer, and electronics manufacturer.

4.2. Business Process at The Electronic Enterprise

The focal point of this section is the decomposition of DFD from enterprise level to operational level at manual assembly cells. See Figure 3 and Figure 4 for the context diagram and enterprise level DFD, respectively.

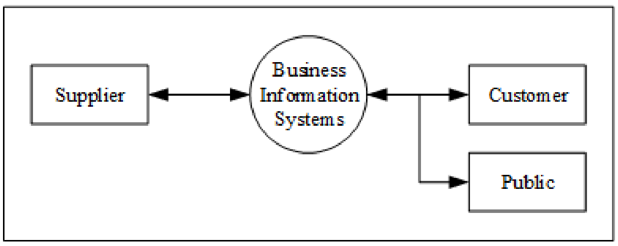


Figure 3 DFD - Context Diagram

The Electronic Enterprise utilizes an enterprise resource planning (ERP) system to manage its business processes. Both customers (with helps from sales representatives) and suppliers may place orders to and retrieve orders from The Electronic Enterprise, respectively, via electronic data interchange (EDI) mechanism.

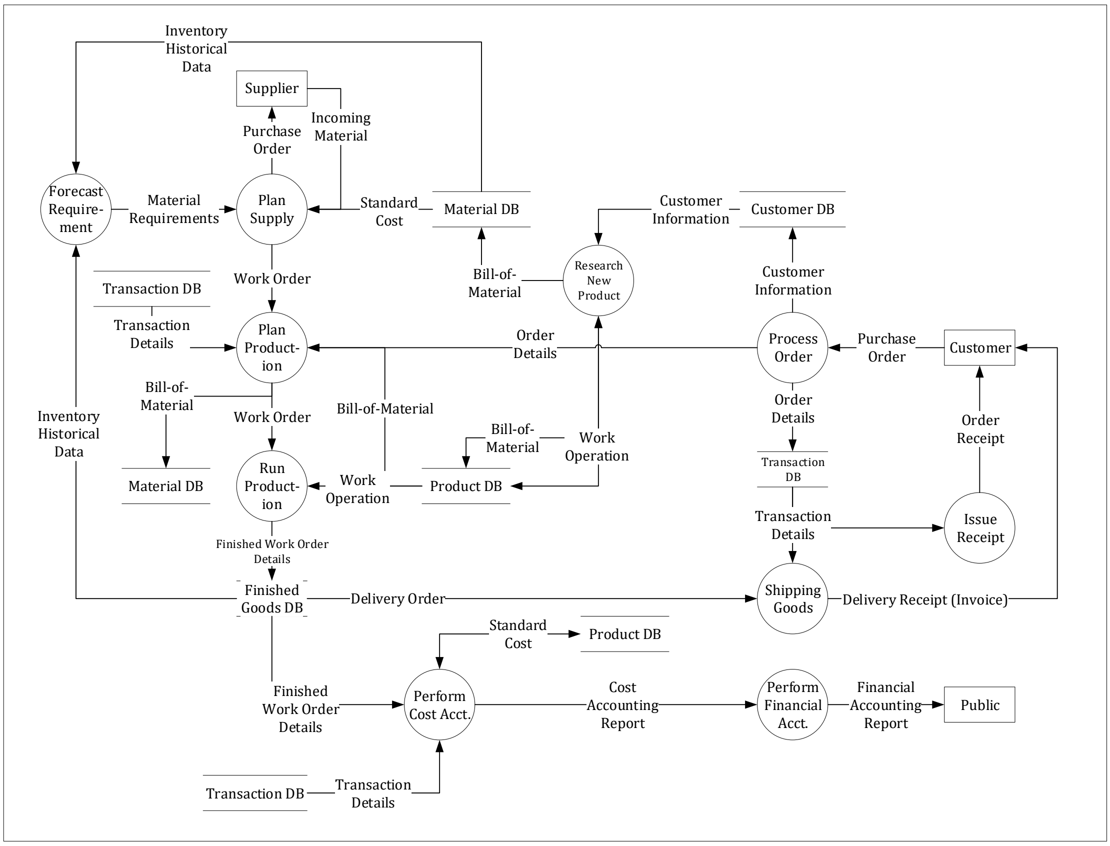


Figure 4 DFD - Enterprise Level

The processes in Figure 4 can be addressed to these departments of The Electronic Enterprise: supply planning, customer relations, economic, product development, and production.

4.2.1. Supply Planning

Supply planning department has two main responsibilities:

- send purchase orders to suppliers based on inventory status of raw material; and
- plan production run based on customer orders and inventory status of finished goods.

Supply planning department works closely with its sales and production counterparts. Business processes that lie under supply planning job descriptions are given in Table 6.

Table 6 Business Processes by Supply Planning Department

No.	Process Name	Description	Data Flows
1.	Forecast requirement	This process is usually done at the end of one calendar year that project the demand for the following year. It requires historical data of inventory status (material and finished goods) and provides material requirement for planning supply.	**Inventory historical data**: It comprises notion about inventory level status for raw materials and finished goods in every given point of time (discrete).
			Sales historical data: Annual sales summary.
			Material requirement: It gives information about the type of materials (or parts), the expected quantity, and the expected arrival date to raw material warehouse for supply planning department to release purchase order.
2.	Plan supply	Supply planning sends purchase order to supplier as well as work orders to production planner.	**Work order**: Work order applies for make-to-stock product that is forecasted and make-to-order or customized products that do not have any built-up inventories. It tells type of product, the quantity, completion date, and delivery due date to customers.
			Purchase order: It is basically material requirement documents that have been formalized into official documents. The data are sent to respective suppliers
			Incoming material: This data is sent by suppliers. It contains information about number of item, type of item, delivery date, technical standard, and price.
			Standard costs (described in Table 8)
3.	Plan production	There are two main situations to plan production run: • If work order is addressed to make-to-stock items, then regular production schedule can keep going as it is, mainly depending on raw material availability. • If work orders for customized products occur, then production schedule needs to be fine-tuned.	**Work order**
			Order details (described in Table 7)
			Transaction details (described in Table 7)
			Bill of materials: This data explains about how many parts required for one assembly item with its respective economic value. It also describes the source of the parts: either it is produced in-house or being outsourced.

4.2.2. Customer Relations

Customer relations works closely with sales representatives, whose main responsibilities are:

- to arrange purchase agreement with customers; and
- to put orders from their respective customers into the ERP system.

The first task depends highly on negotiation skill of the sales representatives. Meanwhile, the other task is critical for data distribution and processing within the ERP system. People at customer relations department have authorities to confirm the purchase orders from customers.

Table 7 covers the description of customer relations related business processes at The Electronic Enterprise.

Table 7 Business Processes by Customer Relations Department

No.	Process Name	Description	Data Flows
1.	Process order	This process includes taking customer orders into the ERP system. Then, the orders are decoded into customer information and technical details.	**(Customer) Purchase order**
			Customer information: This flow has general information about customers: name, address, and contact points.
			Order details: This explains the technical specifications of the orders sent by customers. It describes the functionality of the items, special features, order quantity, and delivery due date.
2.	Issue receipt	It sends notifications to customers as a proof that their orders are taken care of, given agreed terms and conditions have been completed by the customers.	**Transaction details:** Confirmed order details.
			Order receipt: It is similar with order details with additional information about order acceptance confirmation, confirmed delivery due date, and official total price.
3.	Shipping goods	This process represents the order delivery from The Electronic Enterprise's warehouse to the destined customers' locations.	**Delivery order:** Notification from production department that the specific order is ready to be delivered to its associated customer.
			Delivery receipt (invoice): Notification sent to customers informing that their orders are ready to be shipped. In addition, invoice for the specific orders is also included.
			Transaction details

4.2.3. Economy

The economic department holds responsibilities in producing cost accounting and financial accounting report. It produces economic report for both internal and external use. See Table 8 for demonstration.

Table 8 Business Processes by Economic Department

No.	Process Name	Description	Data Flows
1.	Perform cost accounting	Cost accounting is performed to examine the profitability of total company operations for internal evaluation. Accurate product costing is highly dependent on accuracy of production data (finished work order details).	**Finished work order details: It** is the combination of work orders and work operations. The unique elements of this data flow are the usage of actual run time and setup time based on the real operation that is carried out.
			Standard costs: This data flow contains crucial information about how much one unit of item costs. It is built up by data of material cost, hourly labor cost, and hourly machine cost. This data is generated initially by department of product development. But, it is might be updated based on findings during cost accounting process or changes in material price, labor wages, and machine depreciation policy.
			Cost accounting report: This is the formal document made based on latest cost accounting performed for internal use.
			Transaction details
2.	Perform financial accounting	Financial accounting is performed to produce an official annual financial report that has to be published to give insight to current shareholders, potential shareholders, and legal authorities (i.e. tax agency, venture capital etc.). In creating financial report, external auditors might present to oversee the whole entire or partial processes.	**Cost accounting report**
			Financial accounting report: This is the formal document made based on latest financial accounting performed for external reporting.

4.2.4. Product Development

Product development department is responsible in conducting research and development of new products and services. It takes input from customer orders and specification of current product portfolios. This process sends out bill-of-material and work instructions for new products.

The instructions communicate about the operations that must be performed to produce specific product types. It also shows production routing, planned run time per unit, and planned setup time per unit.

4.2.5. Production

Production department claims control over three main areas: surface mounting line, selective soldering, and assembly. The first two areas are highly automated with high capital expenditure from the purchase of equipment/machinery. On the other hand, assembly area uses less automation and have several sub-areas: laser marking, manual assembly, packaging, and final inspection (testing).

Special storage for material preparation exist at surface mounting and selective soldering areas. Meanwhile, assembling parts are stored in wagons placed within each workstation space. See Figure 5 for production flow illustration and Figure 6 for production layout illustration at The Electronic Enterprise's Sweden plant.

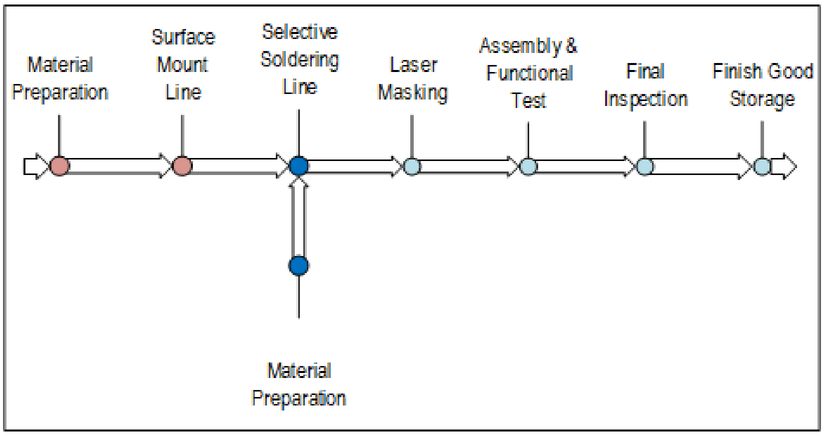


Figure 5 Illustration of Production Flow at The Electronic Enterprise

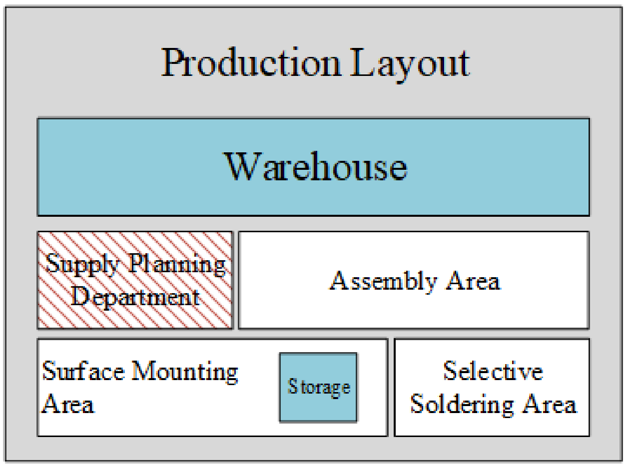


Figure 6 Illustration of Production Layout at The Electronic Enterprise

One critical note from the plant observation is that operators are capable to manually adjust the measurement results of actual setup and processing time before they get stored. This way, the measured time might have their authenticity put under serious doubt.

Other serious flaw from the current time recording practice is that the in-house production environment systems have bad sensitivity when determining the severity of actual time's deviation from the standard time. For example, there will always be alarm whenever deviation exists whether the magnitude is very small, ignorable (i.e. 0.01 percent deviation) or significantly severe (i.e. 200 percent). This situation goes to the extent that operators no longer being bothered at all by the deviation alarm.

Based on those two flaws in practice, the operation control officer suggests for the adjustment function to be removed, to be replaced by comment functions which determine whether normal situation or special condition occurred during the processing of the work orders. Furthermore, the sensitivity of deviation alarm needs to be fine-tuned. It is also necessary to have function which help directing operators to look for assistance whenever disturbance is assumed, in accordance with the severity of the deviation.

This set of description is formalized into use-case scenario for application development in Table 9. The visual representation of the scenario is also given in Figure 7 (Whitten & Bentley, 2007b).

Table 9 Use Case Scenario of Product Costing Application at The Electronic Enterprise

Use-case name	Assemble		
Short description	Operator performs manual assembly toward incoming batch of work-order.		
Precondition	Operator had logged in into the system and had received notification from supply planning department about work order identity, production schedule; and work instructions.		
Postcondition	Operator reports the following data into the business information system: finished work order identity, actual setup time; and actual operation time.		
Error situation	Time measurement apparatus do not function.	**System state in the event of error**	Actual time is not measured.
Actors	Manual assembly operator.	**Trigger**	Work order processing
Processes	**Actor actions**	**System responses**	**Alternative responses**
	• **Step 1**: Operator scans the barcode to enter work order identity into the system as work-in-progress (WIP). • **Step 3**: Operator starts performing setup right after activating stopwatch application to measure the setup time. • **Step 5**: Operator stops the stopwatch when setup is completed. • **Step 7**: Operator start performing manual assembly right after activating stopwatch application to measure the processing time. • **Step 9**: Operator stop the stopwatch when each assembly unit in the work order batch is completed. • **Step 12**: Operator submits the data, marking authenticity of the recorded time. • **Step 13**: Operator enters quantity of unit processed, number of rejected unit, and number of used assembly items. • **Step 14**: Operator scans the barcode, marking the completion of work-order processing.	• **Step 2**: System records work order as WIP. • **Step 4**: System start recording the setup time. • **Step 6**: System saves the recorded time as setup time. • **Step 8**: System start recording the processing time. • **Step 10**: System saves the recorded time as processing time. • **Step 11**: System displays the recorded time with option for operator to put notes before the time are stored to within the system. • **Step 15**: System registers the finished work-order. • **Step 16**: System removes work order from WIP list.	• **Alt. Step 6**: System sends signal to operators that the recorded setup time deviates beyond tolerance limit. • **Alt. Step 10**: System sends signal to operators that the recorded processing time deviates beyond tolerance limit. • **Alt. Step 12**: Operator puts notes commenting the cause of deviation before submitting the report.

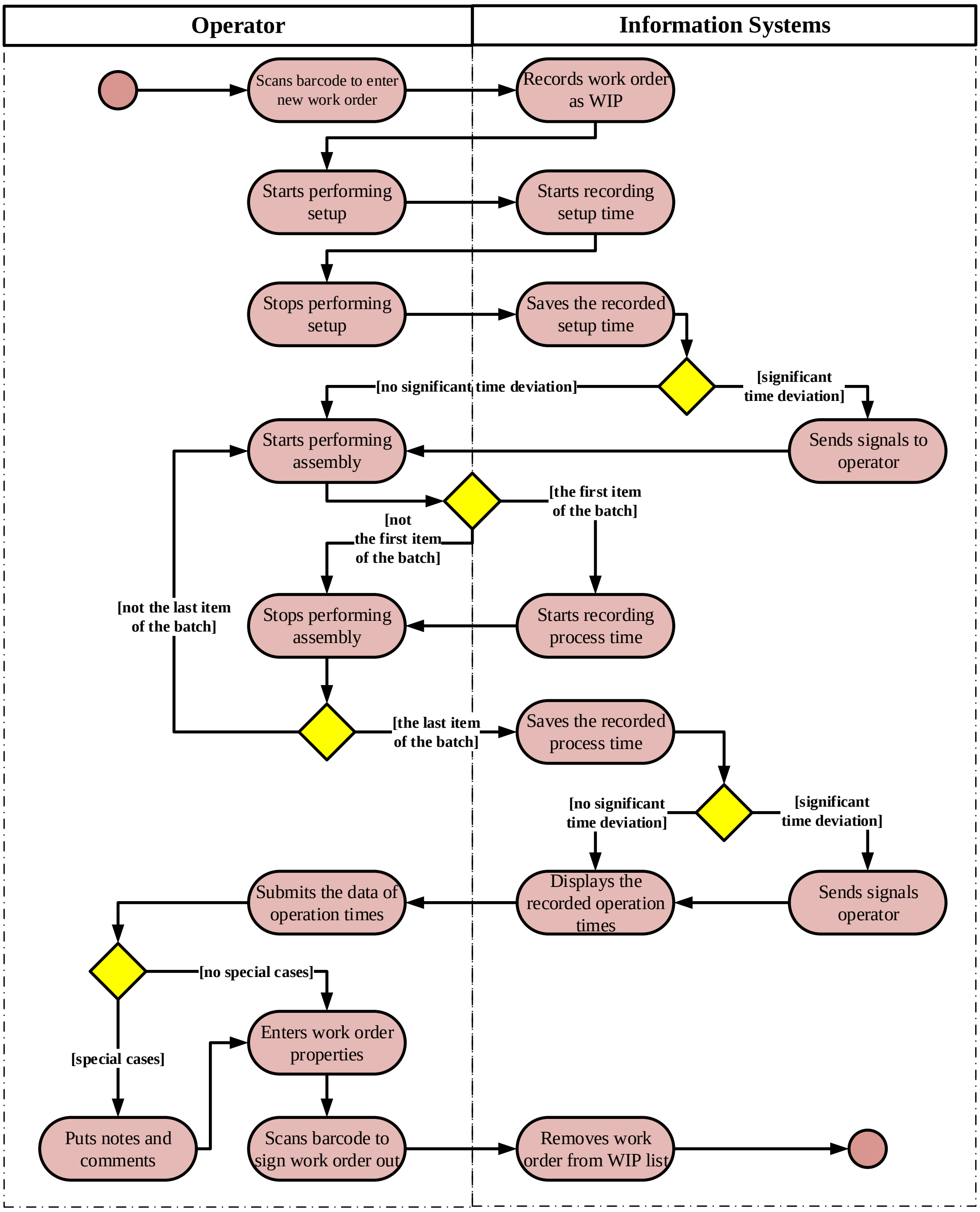


Figure 7 Activity Diagram of Product Costing Application at The Electronic Enterprise

4.3. Cost Unit Accounting at The Electronic Enterprise

As the operation control officer of The Electronic Enterprise holds position within economic department, the opportunity to observe the calculation process of cost unit accounting is imminent. In-depth demonstration is presented in this section.

4.3.1. Costs Structure

Product cost (per unit) is determined initially when product (article) is newly released after research and development stage. From the product design, cost of purchased materials or components can be determined. The capital investment estimation for required equipment is also roughly drawn based on product design. Then, pilot production run is carried out to examine the setup and run time for one unit of article.

The time will be standardized and be utilized to determine the throughput (production rate) of the system. Meanwhile, budget from capital and operational expenditures are used as the basis in determining standard capacity cost rate (cost per time unit) for both machines and labor, respectively.

The break-down of costs structure is given in the following Table 10:

Table 10 Costs Structure at The Electronic Enterprise

No.	Costing Parameters	Description
1.	Material cost per unit article	The role of bill-of-materials (BOM) is essential to describe the product structure including type of materials and the quantity required for each unit of product item. The basis for material cost per unit is the material purchase history record on database.
2.	Labor cost per hour	It is the result from the division of total labor cost per annum by the total labor capacity (in hour unit) per annum. In other words, labor capacity is the practical working time in one-year period. Meanwhile, total labor cost is obtained from the sum of direct labor costs and the overhead labor costs.
3.	Machine cost per hour	The calculation of machine cost per hour is quite similar with the calculation of labor cost per hour. It is obtained from the division of total machine cost per annum by the total machine capacity (in time unit) per annum. Total machine cost per annum is the depreciation value of the capital investment for the respective machine. The Electronic Enterprise uses 5 years of machine life as the basis to determine the depreciation value.
4.	Setup cost per hour	It is basically labor cost dedicated for setting up equipment. It is the result from multiplication of labor cost per hour by setup time and number of labor required to perform the setup.
5.	Labor cost per unit article	It is labor cost per hour multiplied with number of labors (required to perform specific operations), then divided by throughput per hour.
6.	Machine cost per unit article	It is total machine cost per hour divided by throughput per hour.
7.	Setup cost per unit article	It is obtained through the division of setup cost per hour by batch size. Bigger order size means smaller setup cost per unit.
8.	Markup rate (surcharge rate)	The categories of markup applied upon direct labor cost are as follow: • production overhead; • internal quality claim; • external quality claim; and • production management. Material surcharge rates are available for each specific article model.

Calculation example of cost unit accounting at The Electronic Enterprise is given in Appendix C.

4.3.2. Spreadsheets Structure

The operation control officer at The Electronic Enterprise frequently engages with spreadsheet application (Microsoft Excel) in doing his tasks. The application is integrated with the ERP system, which enable the officer to access operation data from other departments, especially from production floor. The structure of the spreadsheets being used is given Figure 8.

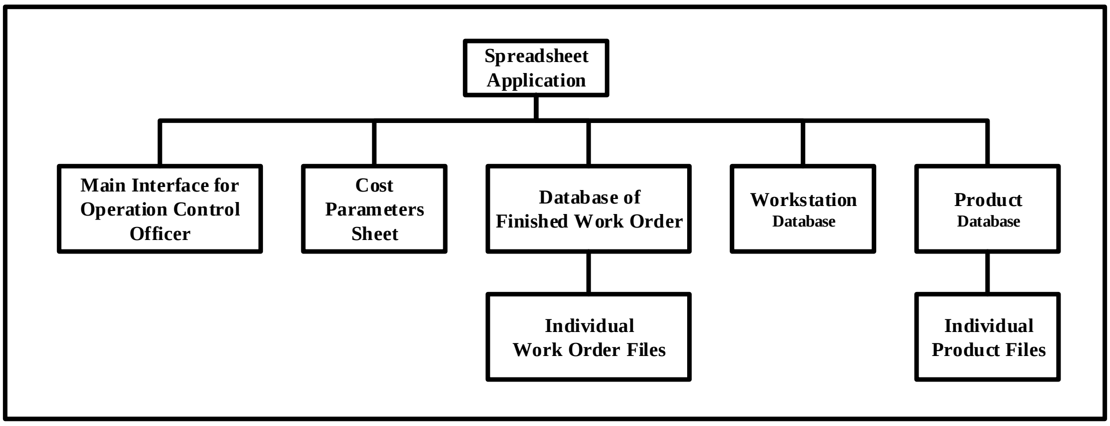


Figure 8 Spreadsheet Structure at The Electronic Enterprise

Through the interface, operation control officer is capable of tracking work order using its primary key identification. The list of work orders is stored in the work order database, which is connected to other databases (workstation and product).

5. Model of Product Costing System

This chapter presents the steps to create the model of product costing system based on the previous findings discovered from the case study at The Electronic Enterprise. The first section examines how production systems influence the choice of product costing methods. The next four sections demonstrate the identification of costing methods on separate continuums. Lastly, this chapter is closed by practical examples to determine where The Electronic Enterprise lies within these continuums.

5.1. Production Systems Domain

Knowing the configuration of production systems at a manufacturing company is critical in determining its product costing methods. For instance, a chemical company that sells its product in bulk measured in unit volume i.e. Dow Chemical (Anderson, 2009) will have different approach with an electronic company that vends in batches i.e. The Electronic Enterprise. The production flow continuum in Figure 2 is a good reference to determine the characteristic of a company under scrutiny.

A company which employs continuous flow most likely perform the traditional form of costing methods in each costing continuum. The low level of variations excludes the necessity to examine costs elements into further detail than the simple division of total costs recorded in general ledger by total volume of product produced during the respective period. On the other hand, it is hardly the case when examination is performed on company that offers variations of product portfolios and special customization.

5.2. Scope of Costs Involvement

This continuum identifies to what extent type of costs are included in calculating cost object value. Fisher & Krumwiede (2015) provides four options within the continuum (Figure 9).

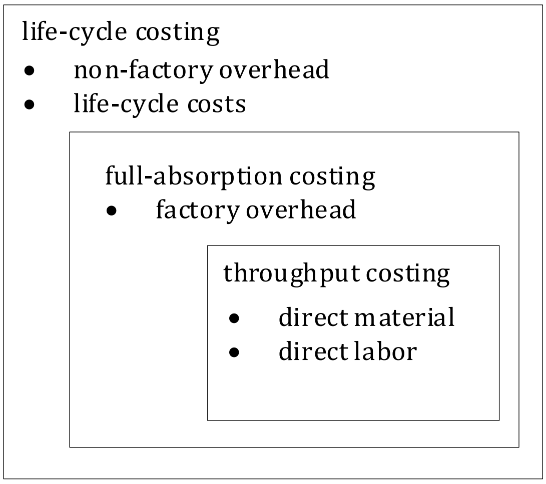


Figure 9 Scope of Costs Involvement

For this matter, the determinant factor is the size of the organizations. It is related with the sophistication level of information technology (IT) employed in the company. In practical sense, huge organizations operating in multiple regions are more likely to have IT systems which cover their business processes in more detailed fashion than small-medium enterprises (SMEs). Nevertheless, it does not exclude the possibility for SMEs to have extensive IT systems, even if it is in smaller scale than their counterparts.

5.3. Cost Centres

There are two approaches of cost centres identification within the scope of this thesis work. The first one is given in Section 3.1.2. (Ehrlenspiel, et al., 2007), which put emphasize on the business functions of separate department. In a more macro level, Fisher & Krumwiede (2015) gives distinctions of four options: plant-wide, departmental, work station, and activity. These four options are hierarchical to each other with activity as the indivisible cost centre. See Figure 10.

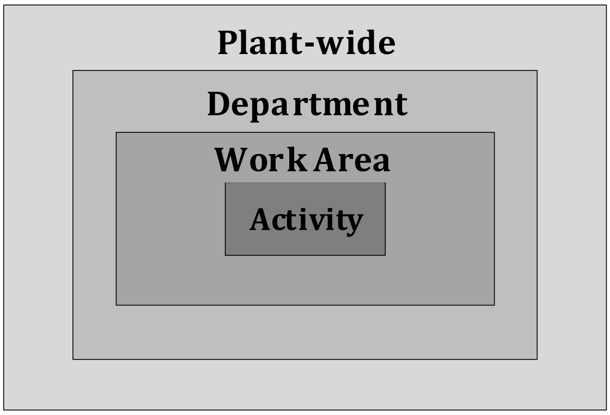


Figure 10 Hierarchy of Cost Centres

5.4. Allocation of Indirect Costs

Indirect costs are costs that cannot be allocated directly to cost object and exist in supporting cost centres (Öker & Adigüzel, 2010). They must be allocated to the cost object based on the consumption of resource they represented. Cost drivers are used to measure the consumption level. Every unit of consumption is monetized accordingly. It is possible for an enterprise to use more than one driver to allocate its indirect costs.

See Appendix C for numerical examples of overhead costs allocation using duration as cost driver. See Figure 11 for cost driver continuum.

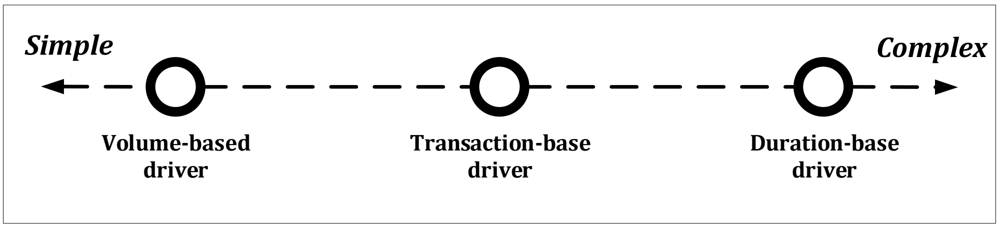


Figure 11 Cost Driver Continuum (Fisher & Krumwiede, 2015)

5.5. Degree of Traceability

This continuum simply identifies if a company trace their costs into work order batch, individual unit of complete assembly, or work-in-progress (WIP). Evidently, to trace the costs down to the state of work-in-progress needs more advanced IT systems in comparison with the tracing of costs of complete assembly and work order batch, respectively.

Company can attach unique identifier (ID) on each work order batch. If the individual unit in the batch does not have any unique identifier, individual unit traceability is achievable through the division of costs in producing the batch by the batch size. To perform tracking on WIP, unique ID for individual product being processed is mandatory, in addition to the monitoring systems to locate the specified product along the production route. See Figure 12 for illustration.

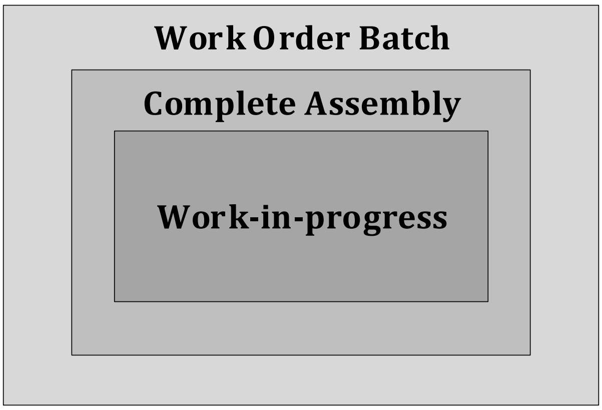


Figure 12 Traceability Continuum

5.6. Practical Example

The practical example of modelling the costing methods at The Electronic Enterprise is provided in Figure 13.

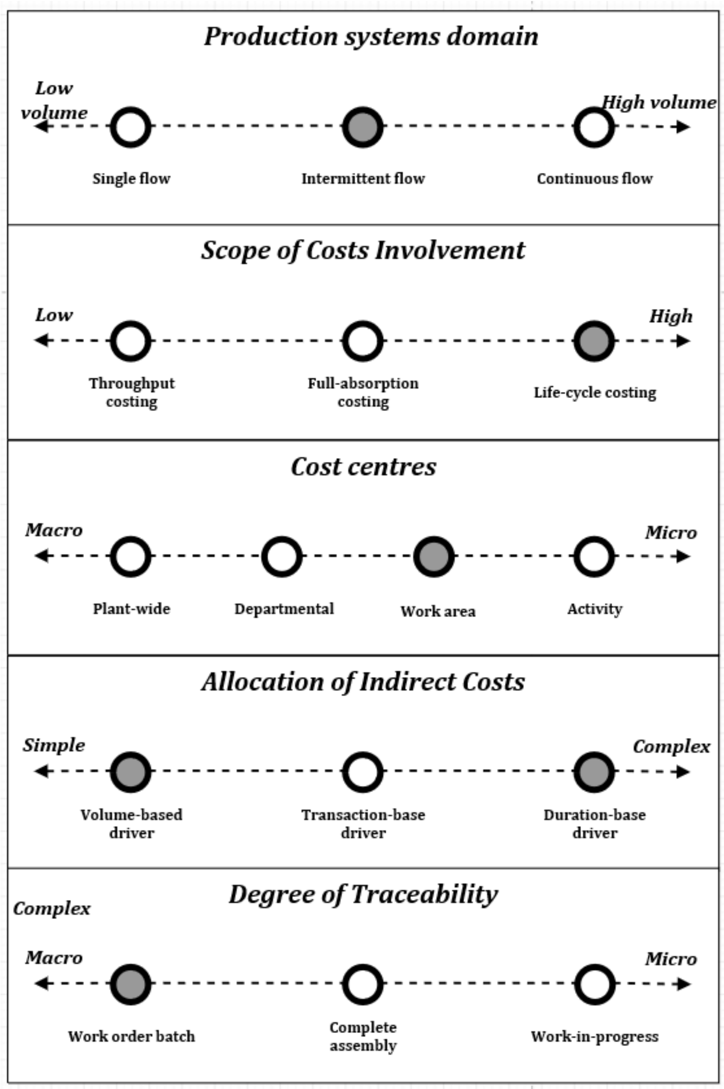


Figure 13 Costing Methods at The Electronic Enterprise

The Electronic Enterprise applied life-cycle costing that includes upstream and downstream costs as part of product costs. It was the most-detailed method in the scope of costs involvement continuum. Nevertheless, The Electronic Enterprise did not automatically use the most advanced methods in other categories. For instance, in regards with traceability, The Electronic Enterprise employed work order costing approach. It was the least-detailed method, yet it still had adequate costing accuracy level for batch manufacturing operations. Furthermore, The Electronic Enterprise used duration-based drivers to allocate almost all the involved costs to the individual cost object, except for material costs which has volume-based driver for allocation means. Surcharge rates were also used in accordance with the demonstration provided by Ehrlenspiel, et al., (2007) in Appendix B.

Based on the calculation examples of cost unit accounting at The Electronic Enterprise and the modelling of its costing methods, a generic product costing system for batch manufacturing operations can be generated. See Figure 14 for the illustration.

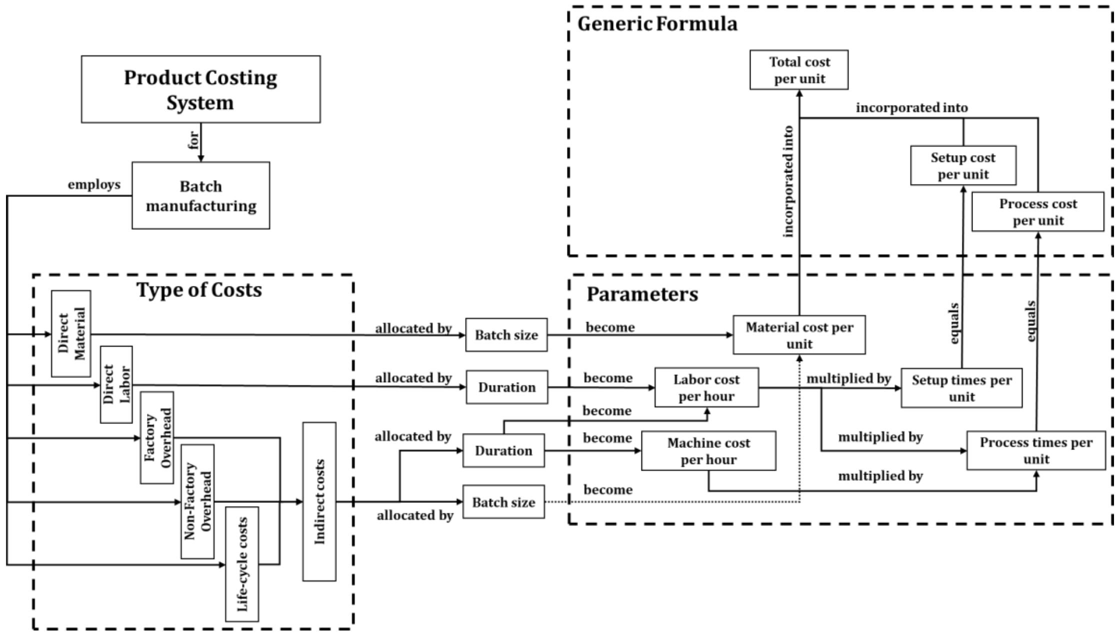


Figure 14 Generic Product Costing System for Batch Manufacturing

The generalizability of this product costing system will be evaluated using comparative analysis against the case study from Wouter & Stecher (2017).

6. Discussion

This chapter covers the discussion and analysis regarding the findings of this thesis work. The first part is addressed to discourse about verification of the case study results. Meanwhile, the second part explores the opportunities of future research based on the findings.

6.1. Verification of the Case Study Results

This thesis focused on discovering facts from the product costing practice at The Electronic Enterprise using case study approach. This choice allowed in-depth investigation on product costing processes at The Electronic Enterprise in the moment of data collections. The relationships between costing elements and parameters were identified through observations toward demonstrations of costing practices. More importantly, models of product costing systems were generated based on the findings at The Electronic Enterprise and SII Lab. Nevertheless, case study was part of qualitative research whose validity and reliability of its results received less confidence from its reviewer compared to quantitative research's (Morse, et al., 2002). To elevate their level of validity and reliability, rigorous verification toward the findings of case study was necessary.

The validity of the findings (accuracy and precision) was examined by the operation control officer at The Electronic Enterprise. Contextual explanation was given to the respondent especially in regard with the results of business process visualization using DFD. The validation happened in sequence with the interviews and observations. On the other hand, validation toward the results of cost parameters determination and calculation examples was performed simultaneously during the demonstrations given by the respondent, thanks to the usage of spreadsheet template. This validation by respondent was sufficient in accordance with the suggestion given by Denscombe (2010).

Meanwhile, the reliability of the data was represented by the neutrality and consistency of the methods used in this thesis work (Denscombe, 2010). The interview questions (Appendix A) were designed to be generic and neutral for business processes identification purpose at manufacturing companies (Fisher & Krumwiede, 2015). Then, DFD is a standardized process modelling technique (Whitten & Bentley, 2007a). At last, the modelling processes of product costing system cover holistic domains of production systems in discrete manufacturing context (Groover, 2011) and cost calculation methods (Fisher & Krumwiede, 2015).

One more important measure to grade the results of this thesis work is its generalizability. This criterion deals with the prospect in applying the findings within different settings (Denscombe, 2010). In this regard, comparative analysis between the findings from case study at The Electronic Enterprise and other findings from similar case studies is required.

The findings from the case study by Wouter & Stecher (2017), who designed product cost measurement for Stecher GmbH, a manufacturing company in Germany, is chosen as comparator. See Figure 15 for illustration of product costing methods at Stecher GmbH.

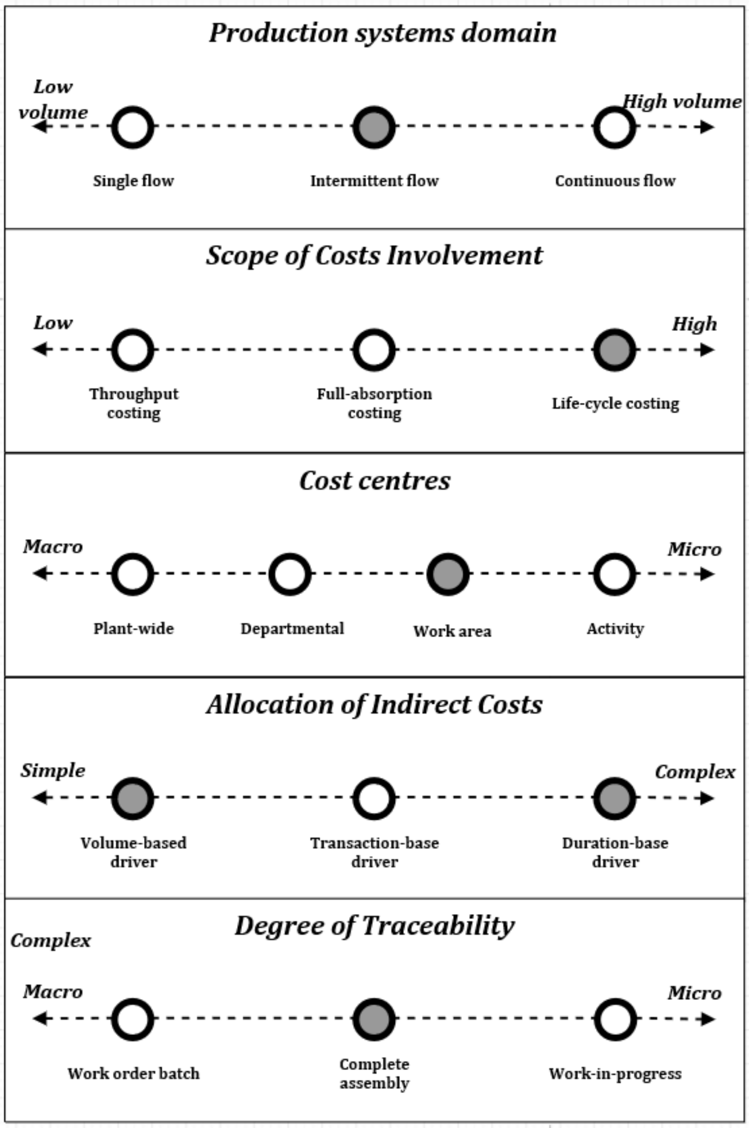


Figure 15 Costing Methods at Stecher GmbH

Both case studies have similarity in every continuum except for the degree of traceability. Furthermore, Stecher GmbH employs relatively similar practice with The Electronic Enterprise in determining the costing parameters for cost unit accounting purpose (see section D3 in Appendix D). Based on this comparative analysis, it is possible to regard the product costing system displayed in Figure 14 is generic even though it was obtained from case study toward only one case object (Denscombe, 2010).

6.2. Future Research Opportunities

There are two main opportunities to bring forward the result from this thesis work in the future. The first option is to perform modelling of product costing systems at other case objects. The scope of the study can be reduced specifically for the case objects with intermittent flow being employed. Thus, production systems domain becomes parameters instead of variables. From that point onward, only results from the costing method continuums which may vary. The data collected from the studies can be examined using quantitative analysis methods. For instance, statistical inference can be performed to determine the most generic configuration of costing methods for batch manufacturing operations.

The other future research opportunity is to complete the development of product costing application at SII Lab's demonstrator. Currently, the demonstrator is arranged to handle make-to-order type of work order with low production volume and high product variants. Sensors are useful to count the number of item processed from the production batch and to capture the actual time of the on-going operations toward an individual product. Figure 16 displays the top view of the demonstrator's working area.

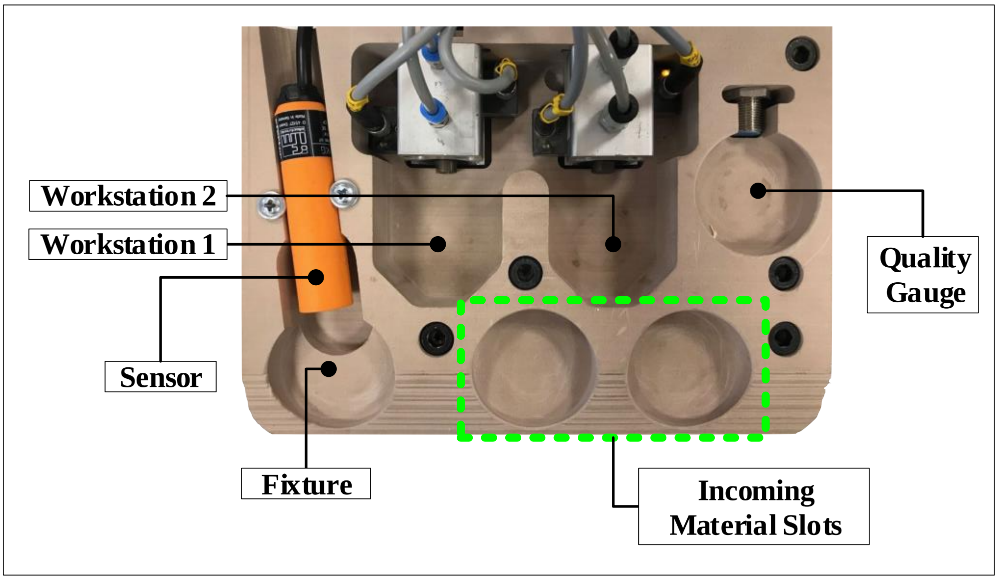


Figure 16 Demonstrator at SII Lab

The demonstrator can emulate intermittent flow and duration-based driver. It also has mechanism to trace individual unit going through its workstations and measure the operation times using sensors (time-stamp). Spreadsheet model for calculating the product costs was developed based on spreadsheet structure and the product costing system at The Electronic Enterprises (see Appendix E). The active costing parameters on the demonstrator were material cost per unit, labor cost per hour, machine cost per hour, batch size, standard times, and actual times (setup and processing). Meanwhile, the cost per unit product is the sum of setup cost per unit, process cost per unit, and material cost per unit.

7. Conclusion

This section provides the conclusions which answer the research questions of this thesis work. As it is stated, the aim of this thesis work is to develop a generic product costing system for batch manufacturing operations. Case study at The Electronic Enterprise, an electronic manufacturing company in Sweden, was performed to identify the practice of product costing in non-artificial settings. The findings from the case study were analysed to measure its generalizability.

Hereby the concrete answers to each of the research questions.

RQ1: How does The Electronic Enterprise perform product costing nowadays?

The Electronic Enterprise employs life-cycle costing method in scope of costs continuum, work area level of cost centres, work order level of traceability, and the combination of duration-based and volume-based drivers to allocate the indirect costs toward individual product unit.

RQ2: How should a generic product costing system for batch manufacturing operations be created based on case study at The Electronic Enterprise?

- Comparative analysis between model generated from case study at The Electronic Enterprise and models from various other case studies must be performed. Similarities between the models must become the point of attention. Duration-based and volume-based drivers are the key element that provide generic characteristic to the proposed product costing system.
- Generic product costing system for batch manufacturing operations employs costing parameters which consist of material cost per unit, labor cost per hour, machine cost per hour, batch size, standard times, and actual times. Actual times serve the purpose of performing cost unit accounting, in opposition with standard times whose purpose is to support cost unit estimation.
- Total cost per unit product is the sum of setup cost per unit, process cost per unit, and material cost per unit.

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Appendix A: Interview Questions

1. General questions about the company.
   - History
   - Organizations structure and size
   - Business portfolios
   - Major operations in manufacturing terms

2. Is there any gap between cost estimation and cost accounting results?
   - How severe?
   - Which costing elements have the most severe distortion?
   - Why could this possibly happen?

3. What is the role of IT department in product costing practice?
   - Are they directly involved in developing costing formula?
   - Are they only involved in providing data for cost calculation?
   - If there are other involvements, to what extent are those applied?

4. What is the role of operator/shop-floor employee in product costing practice?
   - Are they responsible in recording data?
   - Are they responsible in counting the number of item processed?
   - Are they responsible in reporting disruption in production process?

5. How does the product costing system at The Electronic Enterprise work?
   - Which type of costs that are included in product costing calculation?
   - What parameters does The Electronic Enterprise use for product costing calculation?
   - How many cost centres does The Electronic Enterprise have?
   - How does The Electronic Enterprise allocate indirect costs to its products?

6. Do you have any comments on the industrial digitalization initiatives in Sweden/Europe?

Appendix B: Cost Unit Accounting with Surcharge Rates for Overhead Costs

Material overhead costs surcharge rate (MtOCS) yields from the division of material overhead cost (MtOC) by material direct costs (MtDC).

$$MtOCS = \frac{MtOC}{MtDC}$$

Then, the actual material cost (MtC) is

$$MtC = MtDC + MtOC = (1 + MtOCS) \times MtDC = (\frac{MtOCS + 1}{MtOCS}) \times MtOC$$

In accordance with full absorption costing framework, total costs of operation (TC) is

$$TC = MtC + PC$$

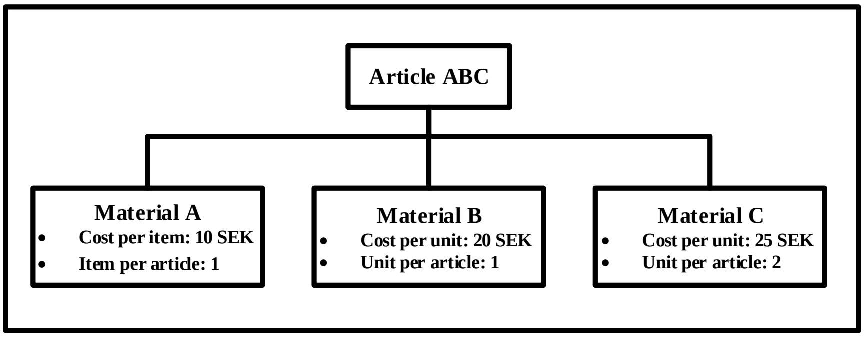
where PC is actual production costs, yielded from the sum of production labor costs (PLC) and production overhead costs (POC). Finally, cost unit is the result from division of TC by total unit pieces produced within the timespan stated in the operation accounting sheet.

Appendix Table 1 Operational Accounting Sheet Example

Types of costs			Cost centres		
			Auxiliary cost centres	Main cost centres	
				Production	Materials
Step 1 Costs acquired	Direct costs (SEK)	*MtDC*	-	-	250
		PLC	-	150	-
	Over head costs (SEK)	Bonus wage for labor	100	50	-
		Advertising	50	-	-
		Additional material	100	100	100
Step 2 Costs distribution		Sum of overhead costs	250	150	100
		Allocation of auxiliary cost centres	-	100	100
Step 3 Determine overhead costs surcharge rate		Sum of overhead costs of main cost centres	-	250	200
		Overhead costs surcharge rate	-	[250/150] = 1.67	[200/250] = 0.8

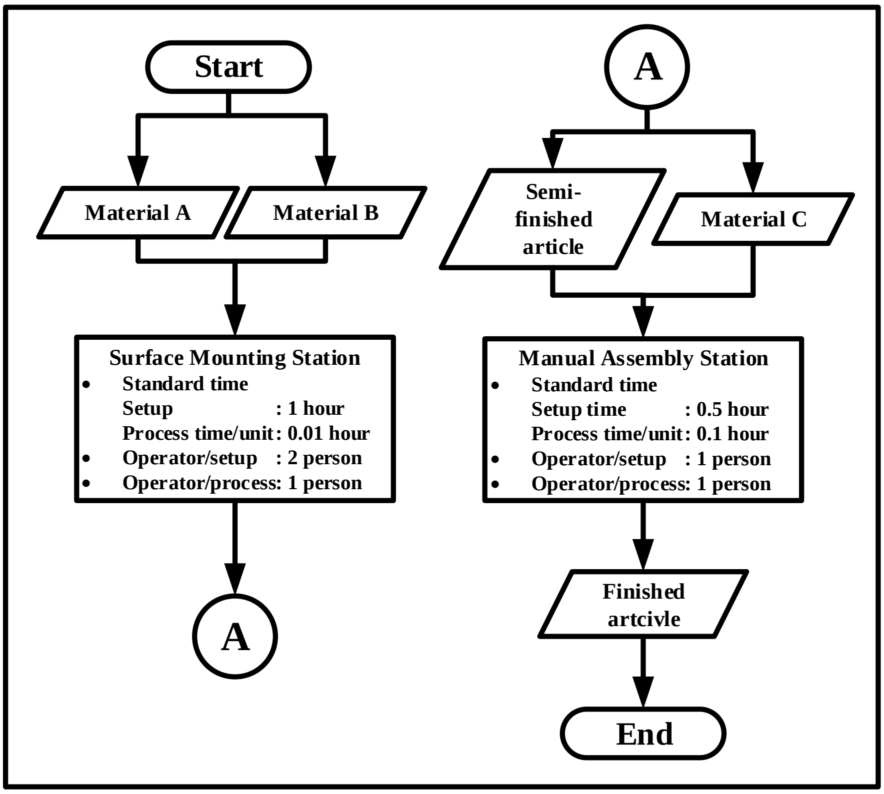
Appendix C: Numerical Example of Indirect Costs Allocation

As the previous section provides the overview of general structure of product costing practice at The Electronic Enterprise, this section will provide the numerical example of the cost unit accounting based on the demonstration given by the operation control officer. First thing first, consider this product structure given by the bill-of-material in Appendix Figure 1 below.



Appendix Figure 1 Multi-level Bill-of-Materials of Article ABC

Then, it is important to comprehend the production route of article ABC which is processed in surface mounting station and manual assembly station consecutively, one time each. See Appendix Figure 2 below for illustration.



Appendix Figure 2 Production Route of Article ABC

Appendix Table 2 Numerical Example of Costing Parameters at The Electronic Enterprise

No.	Parameter	Unit	Value	Description
[1]	Labor cost	SEK per year	5,000,000	10 labors with 500,000 SEK annual wage each.
[2]	Labor capacity	Hour per year	20,000	10 labors times 40 hour a week times 50 week a year.
[3]	Labor cost	SEK per hour	250	Division of [1] by [2].
[4]	Machine cost (surface mounting)	SEK per year	20,000,000	Annual depreciation of 100,000,000 SEK capital investment with 5-year machine lifespan.
[5]	Machine capacity (surface mounting)	Hour per year	4,000	1 machine times 80 hour a week times 50 week a year.
[6]	Machine cost (surface mounting)	SEK per hour	5,000	Division of [4] by [5].
[7]	Batch size	Unit article	100	Number of unit article per work order.

Appendix Table 3 Numerical Example of Cost Unit Estimation

No.	Parameter	Unit	Value	Description
[1]	Material cost	SEK per article	80	• 10 from Material A; • 20 from Material B; and • (2 x 25) from Material C.
[2]	Setup cost (surface mounting)	SEK per article	5	{(1 hour) x (2 person per setup) x (250 SEK per hour)} divided by (100 unit)
[3]	Labor cost (surface mounting)	SEK per article	2.5	(0.01 hour) x (1 person per setup) x (250 SEK per hour)
[4]	Machine cost (surface mounting)	SEK per article	50	(0.01 hour) x (5,000 SEK per hour)
[5]	Setup cost (manual assembly)	SEK per article	1.25	{(0.5 hour) x (1 person per setup) x (250 SEK per hour)} divided by (100 unit)
[6]	Labor cost (manual assembly)	SEK per article	25	(0.1 hour) x (1 person per setup) x (250 SEK per hour)
[7]	Total cost	SEK per article	163.75	Sum of [1] to [6]

Appendix Table 4 Numerical Example of Cost Unit Accounting

No.	Parameter	Unit	Value	Description
[1]	Actual setup time (surface mounting)	Hour	1.2	Slower than standard time.
[2]	Actual process time (surface mounting)	Hour	0.01	Same as standard time.
[3]	Actual setup time (surface mounting)	Hour	0.5	Same as standard time.
[4]	Actual process time (surface mounting)	Hour	0.08	Faster than standard time.
[5]	Material cost	SEK per article	80	• 10 from Material A; • 20 from Material B; and • (2 x 25) from Material C.
[6]	Setup cost (surface mounting)	SEK per article	6	{(1.2 hour) x (2 person per setup) x (250 SEK per hour)} divided by (100 unit)
[7]	Labor cost (surface mounting)	SEK per article	2.5	(0.01 hour) x (1 person per setup) x (250 SEK per hour)
[8]	Machine cost (surface mounting)	SEK per article	50	(0.01 hour) x (5,000 SEK per hour)
[9]	Setup cost (manual assembly)	SEK per article	1.25	{(0.5 hour) x (1 person per setup) x (250 SEK per hour)} divided by (100 unit)
[10]	Labor cost (manual assembly)	SEK per article	20	(0.08 hour) x (1 person per setup) x (250 SEK per hour)
[11]	Total cost	SEK per article	159.75	Sum of [5] to [10]

Once the product structure and production route are grasped, it is time to determine the costing parameters. Appendix Table 2 gives the numerical value of the parameters.

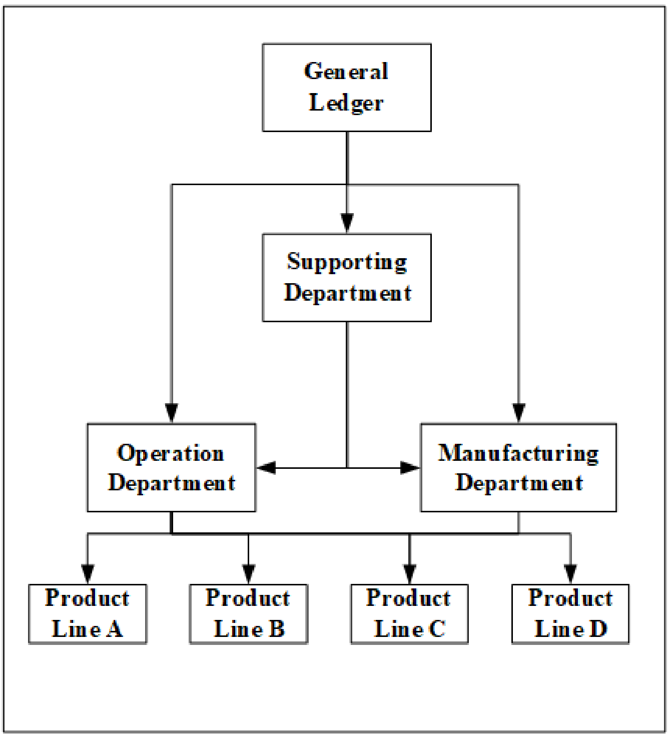
As all parameters are determined, both cost unit estimation (using standard time) and cost unit accounting (using actual time) can be demonstrated in full extent. See Appendix Table 3 and Appendix Table 4 for demonstration of cost unit estimation and cost unit accounting, respectively.

As it stands, the estimated cost per unit is 4 SEK higher than the accounted cost per unit. With batch size of 100 units of articles, The Electronic Enterprise saves 400 SEK of costs from the work order than it was initially estimated. This shows how critical it is for the actual time to be as close as possible to the standard time so that the distortion in creating reports of cost accounting as well as financial accounting can be minimized.

Appendix D: Numerical Example of Indirect Costs Allocation

D1. Overviews

Costs are allocated from general ledger down to individual unit of product in company's portfolio. Öker & Adigüzel (2010) provided reference for cost allocation scheme of time-driven activity-based costing (TDABC) practice in manufacturing company (Appendix Figure 3).

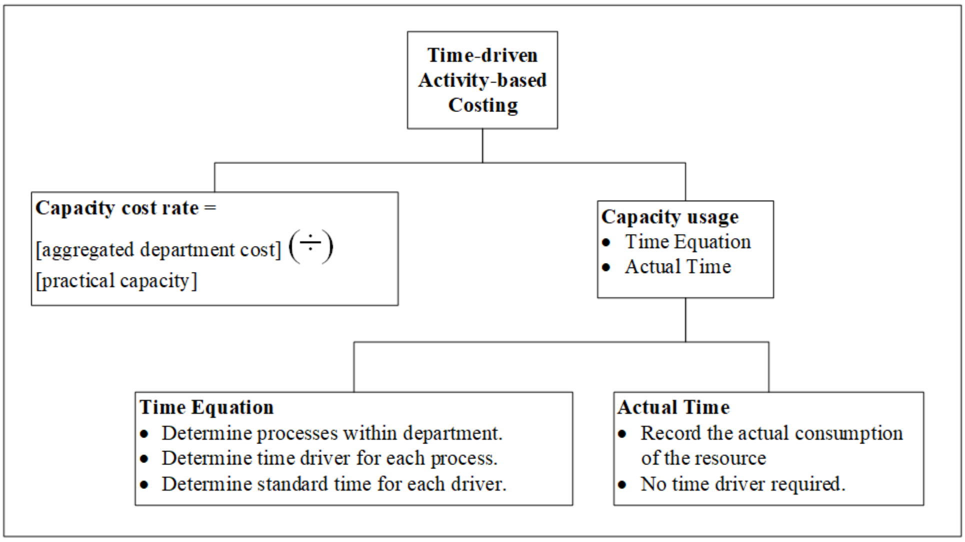


Appendix Figure 3 Cost Allocation Scheme of TDABC in Manufacture

TDABC only requires two estimates: capacity cost rate from each department and capacity usage by each transaction going through the departments (Öker & Adigüzel, 2010). Capacity cost rate is calculated from the division of aggregated departmental costs by practical capacity of the department. The practical capacity is usually measured in time unit (i.e. 8 hours/day, 40 hours/week etc.) with respect to theoretical capacity factored by performance efficiency (i.e. 85 percent efficiency of theoretical capacity).

Supporting departments gets their departmental costs from general ledger only, unless, they consume resources from other supporting departments. On the other hand, operation and manufacturing departments are almost apparent to get some costs allocated to them from the supporting departments. Thus, the allocated costs (i.e. cost of consuming supporting department's resources) need to be aggregated with the cost assigned directly from the general ledger (i.e. labor costs). In this sense, supporting departments must be prioritized when determining the two estimates for further allocation purpose down the allocation scheme.

Once the capacity cost rate is determined, it is time to measure the capacity usage to get the exact number of allocated cost by multiplication. See Appendix Figure 4 for demonstration.



Appendix Figure 4 TDABC Estimates of Cost Rate and Capacity Usage

The capacity usage can be determined in two ways: time equation and actual time. The time equation approach is more common since it is part of the original form of TDABC (Kaplan & Anderson, 2004). The actual time approach itself is proposed by Wouters & Stechter (2017) and is uniquely used in manufacturing department circumstance which blend the consumption of labou hour and machine hour simultaneously. Let us see the demonstration of these two approaches.

D2. Time Equation

This section will demonstrate the steps in constructing time equation as measure of capacity usage for TDABC calculation.

D2.1. Human Resource Department (Supporting)

First step in developing time equation is to create list of processes within department. This step will be followed by describing key activities along with the time drivers which act as variables within the time equation. Meanwhile, standard times for these time drivers must be determined and be set as coefficient within the equation.

Öker & Adigüzel (2010) gave example of human resource department's elaboration (Appendix Table 5).

Appendix Table 5 Human Resource Department List of Processes

Processes	Key Activities	Time Driver	Time per Step (minutes)
Determining workforce requirement	Incoming demands from department.	Number of new personnel demanded.	100
	Demands evaluated.		50
Recruitment	Interview with candidates.	Number of position.	2,400

A process can have more than one key activities while still maintain one time-driver. It is an apparent rule of thumb that number of time driver cannot be larger than number of key activities in a process. Meanwhile, the level of granularity of time driver can vary with respect to the accuracy of standard times measurement. For example, time driver for recruitment can be "number of candidates" instead of "number of position". This will automatically affect the coefficient number (time per step).

The resulting equation for human resource department is:

$$150[X1] + 2{,}400[X2]$$

where X1 and X2 is "number of personnel demanded" and "number of position", respectively.

D2.2. Pressing Department

Pressing department is a part of manufacturing department group which has special case in determining time equation due to heavy involvement of processing time using machineries. The labor element can also be decomposed into experienced labor or inexperienced one (not demonstrated in this occasion). See Appendix Table 6 for demonstration (Öker & Adigüzel, 2010).

Appendix Table 6 Pressing Department List of Processes

Processes	Resource Consumed	Time Driver	Time per Step (minutes)
Mold preparation	Labor hour	Number of production run including pressing department.	20
Pressing material according to technical drawing	Labor hour Machine hour	Number of product processed in pressing department.	2

The resulting time equations are:

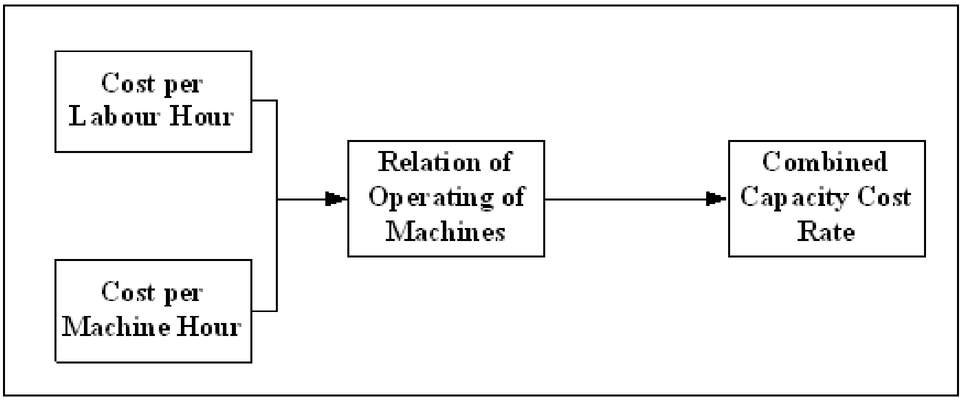
- For labor : 20[X1] + 2[X2]
- For machine : 2[X2]

where X1 and X2 is "number of production run" and "number of product", respectively.

For this setup, the capacity cost rate is different between labor and machine. The former is derived from payroll account of direct labor in the department and total labor working hour in the department. Meanwhile, the later comes from aggregated cost allocation to the pressing department and total machine working hour in the department.

D3. Actual Time

Wouters & Stechter (2017) proposed this approach to overcome the difficulties in determining time equations for their case study in small-medium manufacturing enterprise. The enormous variants on the company's product portfolio list make it infeasible to include every machining parameters (i.e. forward speed, tools material, cutting angles etc.) into the equation. This method utilizes the recorded actual machining time from the system for both labour and machine capacity usage. To do this, the capacity cost rate between cost per labour hour and cost per machine hour are combined. See Appendix Figure 5.



Appendix Figure 5 Combined Capacity Cost Rate Scheme

The relation of operating machines (in German: *Bedienungsrelationen* or 'B') is the ratio between total labour hour in a machining department and total machine hour in the same department. The combined capacity cost rate is calculated as follow (Wouters & Stecher, 2017):

$$\left([labor\ cost\ per\ hour] \times \left[\frac{1}{B}\right]\right) + [machine\ cost\ per\ hour]$$

Here are examples of the capacity cost rate calculation (Appendix Table 7).

Appendix Table 7 Combined Capacity Cost Rate Tabulation

Activity	Department	Labor Cost per Hour (SEK)	Machine Cost per Hour (SEK)	*B*	Combined Capacity Cost Rate (EUR))
Setup	Turning	300	40	1	340
	Drilling	290	140	1	430
Machining	Turning	55	140	5	151
	Drilling	80	290	4	310

Appendix E: Spreadsheets Model

WorkOrder_ID	WO_00103
Product_ID	SII_002
Batch size (units)	200.00
Actual setup time per unit (hour)	0.02
Actual process time per unit (hour)	0.24
Standard setup time per unit (hour)	1.67
Standard process time per unit (hour)	0.13
Material cost per unit (SEK)	150.00
Actual cost per unit (SEK)	399.65
Standard cost per unit (SEK)	352.00
Revenue Margin per unit (SEK)	-47.65
Due Date	10/5/2018
Completion Date	8/5/2018

Appendix Figure 6 Operation Control Officer User Interface

WorkOrder_ID	WO_00101	WO_00102	WO_00103
Product_ID	SII_001	SII_001	SII_002
Batch size (units)	50	100	200
Actual setup time per unit (hour)	0.083642362	0.045131721	0.020894995
Actual process time per unit (hour)	0.118276851	0.120129561	0.239201005
Standard setup time per unit (hour)	0.573308228	0.132827614	1.668086693
Standard process time per unit (hour)	0.14	0.14	0.13
Material cost per unit (SEK)	100	100	150
Actual cost per unit (SEK)	294.7594415	256.0735845	399.6485022
Standard cost per unit (SEK)	321	321	352
Revenue Margin per unit (SEK)	26.24055847	64.92641549	-47.64850221
Due Date	6/5/2018	6/5/2018	10/5/2018
Completion Date	5/5/2018	5/5/2018	8/5/2018

Appendix Figure 7 Work Order Database

WorkOrder_ID	WO_00101
Product_ID	SII_001
Batch size (units)	50.00
Actual setup time per unit (hour)	0.08
Actual process time per unit (hour)	0.12
Standard setup time per unit (hour)	0.57
Standard process time per unit (hour)	0.14
Material cost per unit (SEK)	100.00
Actual cost per unit (SEK)	294.76
Standard cost per unit (SEK)	321.00
Revenue Margin per unit (SEK)	26.24
Due Date	6/5/2018
Completion Date	5/5/2018

WorkStation_ID	Description	Operator_ID	Actual Setup Time per batch (hour)	Actual Setup Time per unit (hour)	Actual Process Time per unit (hour)	Standard setup time per unit (hour)	Standard process time per unit (hour)	Actual setup cost per unit (SEK)	Actual labor cost per unit (SEK)	Actual machine cost per unit (SEK)	Actual cost per unit (SEK)	Standard cost per unit (SEK)
WS_001	Surface Mounting	Op_0028	3.47	0.07	0.02	0.004	0.010	69.32	8.31	8.31	85.94	19.00
WS_002	Selective Soldering	Op_0029	0.14	0.00	0.02	0.004	0.030	1.43	9.77	9.77	20.97	47.00
WS_003	Manual Assembly	Op_0030	0.57	0.01	0.08	0.010	0.100	5.73	41.06	41.06	87.86	155.00

Appendix Figure 8 Individual Work Order File

WorkStation_ID	Description	Person per Setup	Person per Process Run	Standard throughput (unit/hour)
WS_001	Surface Mounting	2	1	500
WS_002	Selective Soldering	1	1	250
WS_003	Manual Assembly	1	1	50

Appendix Figure 9 Workstation Database

Product_ID	Material cost per unit (SEK)	Standard setup time per unit (hour)	Standard process time per unit (hour)	Standard cost per unit (SEK)
SII_001	100.00	0.018	0.14	321.00
SII_002	150.00	0.0168	0.185	435.90

Appendix Figure 10 Product Database

Product_ID	SII_001
Material cost per unit (SEK)	100.00
Standard setup time per unit (hour)	0.018
Standard process time per unit (hour)	0.140
Standard cost per unit (SEK)	321.00

WorkStation_ID	Description	Standard Setup Time (hour)	Standard Setup Time per Unit (hour)	Standard Process Time per Unit (hour)	Standard Setup Cost per Unit (SEK)	Standard Labor Cost per Unit (SEK)	Standard Machine Cost per Unit (SEK)	Standard cost per unit (SEK)
WS_001	Surface Mounting	2.00	0.004	0.01	4.00	5.00	10.00	19.00
WS_002	Selective Soldering	1.00	0.004	0.03	2.00	15.00	30.00	47.00
WS_003	Manual Assembly	0.50	0.010	0.10	5.00	50.00	100.00	155.00

Appendix Figure 11 Individual Product File