THESIS – BACHELOR'S DEGREE PROGRAMME

TECHNOLOGY, COMMUNICATION AND TRANSPORT

UPDATING UNIT COSTING METHOD FOR INJECTION MOLDED PRODUCT X

A case study of UK-Muovi Oy

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Abstract

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Abstract

The thesis project was offered by the case company UK-Muovi Oy, a plastic product manufacturer located in Iisalmi, Finland. Difficulties were found in the product costing phase. The current costing system became obsolete and left unchecked for a long period. The calculation methods fell behind and were no longer precise in cost estimation. As a result, the measured product unit costs were not reliable, and many recalculations had to be made to ensure the product's profitability. This correction project was necessary due to fast and constant inventory flow, where product prices were required to be informed to customers as soon as demanded. Risks of losses in sales might arise when products were not priced in time and properly to generate profit.

The main objective of the study was to investigate the current costing system to understand how it measured the product costs, especially the product unit cost. Later, with the data collected from the study, an improvement roadmap for the cost estimator was suggested. The study covered three major determinants of product costing. These were labor, raw material and energy cost allocations.

As a result, key improvements were identified in the production cost determinants, mostly in the cost calculation formulas, providing more accurate cost information to support production and sales department in manufacturing cost controlling. The implementation of updated formulas was suggested to the cost estimator. The new cost tracking methods were integrated into the current Excel cost simulator instead of the company's ERP system due to its instability. Further development work was discussed to implement new changes to correct the ERP system's cost calculation.

Keywords
Product costing, Unit cost, Calculation method, Cost model

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1 INTRODUCTION

1.1 Topic background

The role of a manufacturing company is to provide its customers values through its goods and services. At the same time, it must be able to generate sustainable income and profit to sustain the business activities. Therefore, it is important for a manufacturer to have a reliable management and cost accounting system, keeping track of expenses and income. At management level, a good management accounting system provides reliable information for internal control and production performance evaluation. At product level, accurate manufacturing cost calculations provide accurate data for profitability analysis and decision making. From there, a product can be priced competitively, and generate sustainable profit for the company.

UKM is a plastic manufacturer located in Iisalmi city, Finland. Briefly, the production sector was having difficulties in measuring the unit cost of injection molding products. The calculation methods were obsolete and no longer accurate. The manager of the production line mentioned that incorrect calculations have been causing difficulties in pricing the products and controlling the production runs. Multiple attempts were made to recalculate unit cost of produced goods, and they were time consuming.

Potential losses in sales could be generated due to the wrong cost information from product costing systems. Inaccurate costing results in costly mistakes, like setting prices lower than manufacturing cost, which results in zero profit or losses. A business could be sued by competitors for artificially lowering the price to disturb the market. (Chan, 2017)

The topic of the thesis was important to the company since the cost calculation methods must be studied, checked, and compared to other reports to produce reliable information for production managers to evaluate the performance of production lines. They could decide whether to proceed the production of a certain product or stop it, based on the data gathered from the cost calculation methods. With a bad product costing method, risk of ending a profitable product was high and this could put the company's profitability in danger. Since the study case was unique and based on the company's need, very few previous similar cases were found for references. Furthermore, the concepts, and terms in the practical work of the project were agreed to be discussed in a basic manner, for the sake of accessibility for employees of different skill levels.

1.2 Case company UK-Muovi Oy

UKM is a plastic fabrication company, located in Iisalmi, Finland. The company is currently employing 50 employees and generated €15.4 million in 2017. UKM was founded in 1963, originated in Hollola. Later in 1975, the operations expanded to Iisalmi, Finland. UK-Muovi's main production methods are: EPS block molding and shape molding, rotational molding, and injection molding.

Figure 1. UK-Muovi Oy logo

The main product line was EPS (Expandable Polystyrene) building insulation materials. In 1995, a new production method was added, the rotational molding method. This method molding produces waste containers, composters, sandboxes, and floating equipment in marine environment. One of the UKM famous rotational molded products is the Greeny composters with. Shortly after, the company acquired injection molding operation from Elplast Oy and transferred it to the Iisalmi production site. The injection molding products are supporting accessories for concrete work in construction. UK-Muovi Oy offers a wide range of product designs based on customer demands. Customers can choose from the existing production designs, or require customized products based on their preferences and special specifications. The following section explains further the production methods with visual examples of the products.

1.2.1 Product groups

UKM currently has three main manufacturing processes: EPS (expandable polystyrene) block molding and shape molding, rotational molding, and injection molding. The company supplies insulation materials for clients in construction industry. EPS can be molded into blocks or desired shapes using molds. Under the temperature of 200 Celsius of hot steam, the EPS pellets with a diameter of 1 mm expand and are compressed into shapes by molds. The blocks can either be cut into sheets or any shape demanded by clients. Apart from insulation materials for building, UKM also produces EPS fish and vegetable boxes for hygienic and safe transportation.

Figure 2. Molded EPS block

Waste, gravel containers, floating buoys, pontoons, composters, and other products with hollow structures are produced using the rotational molding process. Rotational molding refers to the process of creating plastic walled products using the method of melting powered plastic in a 2 axis-rotating mold. The mold halves containing the powdered plastic rotate in 2 axes inside an oven. After reaching its melting point, the material forms around the mold's inner walls, creating a layer with desired thickness. After cooling, the finished product is removed from the mold, trimmed to remove any excessive material, and installed with accessories such as wheels, air plugs, thermometers, screws, and bolts. Locking equipment can be installed on waste containers to protect the contents inside it.

Figure 3. Rotational molding products

UKM also provides construction supplies and accessories for concrete work such as adhesive spreaders and reinforcement spacers with various sizes and shapes, shown in Figure 4. The plastic spacers are used to hold the reinforcement steel mesh net at the wanted height above the ground surface before concrete casting. Adhesives are evenly spread on surfaces using spreaders before laying the tiles. These products are manufactured using injection molding process. Customers can choose from a wide selection of sizes and geometries. Injection molding is the process of pressing molten plastic into mold tools. After cooling the plastic solidifies into desired shapes and is ejected from the mold.

Figure 4. Injection molding products

UKM ensures that the EPS fish and vegetable container products are stored indoor with care, protected from moist and dust. The quality of plastic products is regarded with high commitment, for UKM's quality checking procedures follow and comply the quality assurance standard ISO 9001:2015 and the environmental management standard ISO 14001: 2015.

1.2.2 The production technology

As the study mainly focuses on injection molding products, it is necessary to understand the production process. From there, it can be identified from where in the process the manufacturing costs arise. This section introduces the basic information about injection molding manufacturing process. There are three main steps, which are getting raw materials from inventory, converting raw materials into finished goods, packaging the products on pallets and moving them back into inventory.

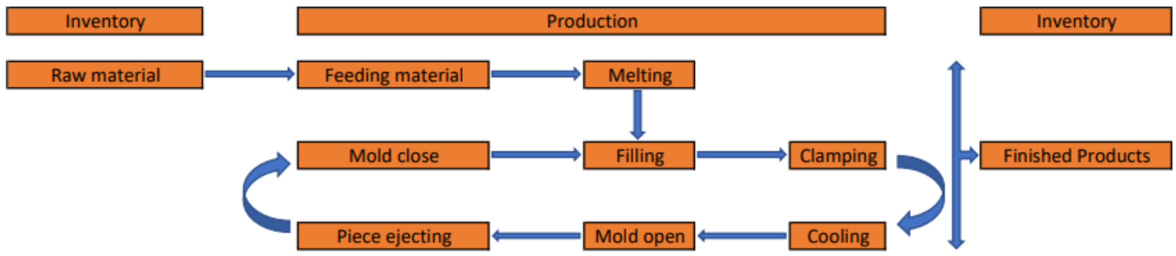

Figure 5. Injection Molding Process

Raw material comes in from small pellets with a diameter of 2 mm. Theses plastic pellets are fed into the molding machine's hopper. This hopper then drops the pellets into the injection unit. The pellets are melted inside the barrel, under temperature of 200-250 Celsius degrees. The reciprocating screw inside the barrel heats up the pellets and moves them forward by rotating. The molten plastic is pushed forward by the screw and into the mold. Molten plastic flows into the mold through the main channel called the sprue. The sprue directly connects the injection unit and the mold. From the sprue, the molten plastic then spreads out through multiple channels called runners, leading to mold cavities where the product takes shape. Sprues and runners can be automatically removed from the piece when ejected thanks to mold designing. Otherwise, they are removed manually or by a robot. Either way would leave scars called runner marks. This can be avoided by using hot runner. The hot runner installed in the sprue bush of the mold keeps the plastic in the sprue channel from cooling and solidifying. This reduces scars on product surfaces. Hot runners are used in molds that has complex designs and produce pieces with high surface quality.

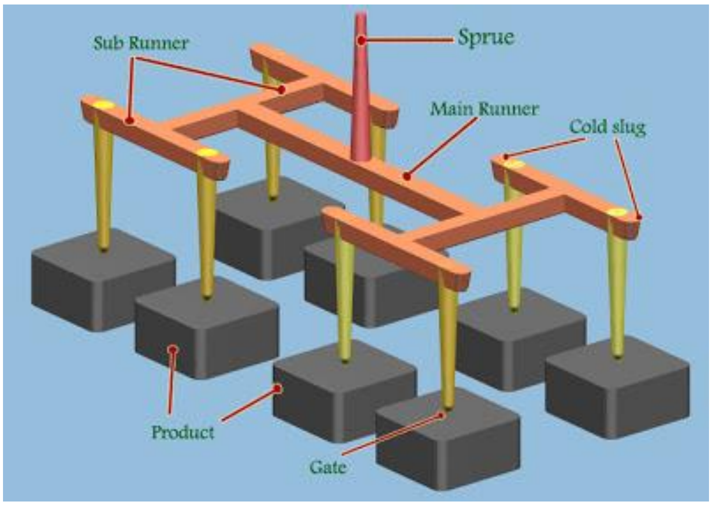

Figure 6. Demonstration of product formation inside molds (powerjet-machinery.com, 2021)

1.3 Objectives

Currently the company is using Lemonsoft as an ERP (Enterprise Resource Planning) system for tracking resource consumption, and Excel is used for cost summary and assessment. The program works for company needs for now, however only at an average extent since its calculation methods are not accurate. This leads to difficulties in cost tracking and controlling. In other words, the numbers given by the system are not reliable for price setting and decision making. The project investigates the management accounting area, and the current ERP system, where the production costs are tracked for inventory valuation and product pricing. Mainly, the study focuses on how costs are tracked and allocated into the products. From the investigation, the causes of incorrect calculations can be identified. Finally, a roadmap of key improvements and corrective actions needed for the current calculation method of production costs will be developed. The objective of this thesis is not to directly implement a new costing system into the product costing system but to highlight shortcomings in allocations and calculations at product cost level. Later, it will be attempted to integrate these key improvements to the ERP system in further development future projects. At product level, the study subject is the unit cost of the products, which is also called the breakeven point. Breakeven point is the lowest price the company could sell the product for to avoid losses. Also, the project work might require using Excel program in calculation. Excel works as a testing environment to practice the cost calculation before officially implementing it into Lemonsoft ERP system. During the practical work of the project, the actual costs of production are compared against the reported costs to highlight the differences, and an updated calculation method to produce more accurate calculation outputs is developed. There are some main research questions that the investigation looks to answer. Answers to these questions are the guidelines of development of the update product cost calculation method.

The main research questions are:

- What differences are there between the Lemonsoft data and the data from the updated method?
- What are the potential reasons for these variances between the old and new calculation?
- Which development actions are needed in product cost calculation for the product?

The expected result of the study is a better understanding of product costing and cost allocations, a new calculation method that will track the unit costs with better accuracy. The new calculation method is developed to meet the following qualifications:

- Understandable: The new calculation method must be comprehensible for managers and operators since everyone has different skill level.
- Accessible: It is easy to access, and variables are easy to control.
- Accuracy: Deviances in calculations are reduced to minimum.
- Economical: It is not expensive to implement.
- Adaptive: The updated version of product cost calculation method, with additional adjustments, is applicable for tracking the unit costs of other products.

1.4 Limitations

Since time and resources for the thesis project is limited, the study focuses on one individual product first before examining the entire product range. It was suggested to start with the product X, produced by the machine A. As there is an agreement on the company's confidential information, data such as product name, machine name and photos are kept from publicity. It is started with product X since its production remains isolated from other product groups. This means that the product is manufactured in a separate production cell, using unique raw material. This makes the manufacturing costs of this product X less challenging to track and allocate.

1.5 Research method

The research methodology includes both practical work and theoretical reviews. Data such as machine specifications, labor hours, manufacturing costs, materials prices are collected from the production site and the logistics department. This data will later serve as parameters for the new unit cost estimation tool. The old costing system is studied through observation and interviewing, and results are compared to the actual manufacturing cost to test the reliability. The theoretical review involves gathering information about cost accounting and costing systems for academic books, research, and articles from various web servers. The study also comprises scheduled discussions with the current production manager for progress reporting, communication channels are often Zoom meetings, direct meetings, emails, and text messages.

1.6 Structure of the study

The first section of the report introduces the project background and basic information about the case company, its products and production methods. The second and the third chapter discuss the basic cost concepts and commonly used costing systems used by manufacturers. Chapter four explains how product X's unit cost is calculated under the current method and the updated one. Comparisons between two methods, and improvement suggestions are introduced. Chapter five summarizes the results and improvements implemented into the calculation method.

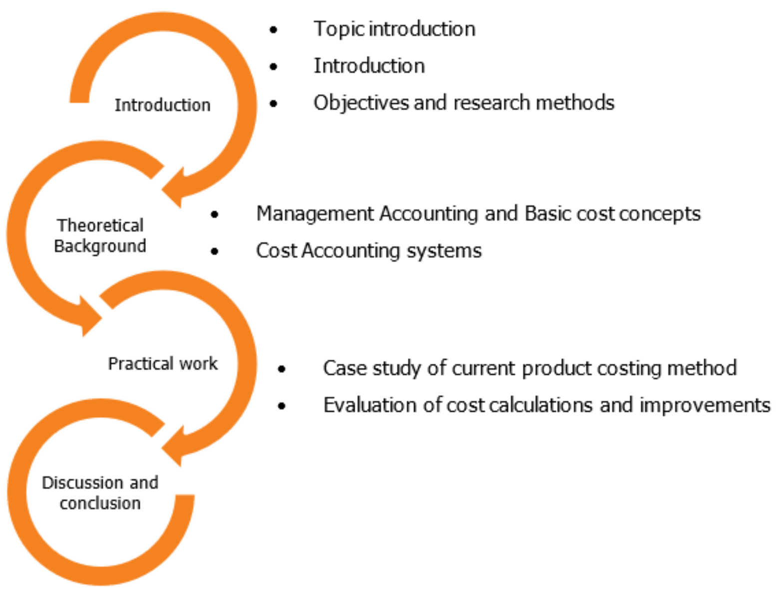

Figure 7. Study structure

2 MANAGEMENT ACCOUNTING AND BASIC COST TERMS

Management accounting means identifying, analyzing, and communicating a business's internal economic information. This information is then used by managers for planning, controlling, and evaluating the performance of the targeted operations to achieve the company's goals. Inventory valuation and profit evaluation are the processes that mostly require the work of a management accounting system. The objective of inventory valuation is to trace costs to finished and work-in-progress products, and unused raw materials. These costs are then reflected against revenue generated to calculate the profit. In some cases, accounting system is used for setting the selling prices + calculating the inventory value. This is a crucial role of the management accounting system since it affects the company's profitability. This is emphasized for the manufacturers with a wide range of product to be tracked and priced. The planning process involves translating goals and objectives into actions and resources to accomplish them. Planning comes in two forms: long-term and short-term. Short-term planning includes the budgeting and controlling processes and evaluating performance. The control process compares collected information with preset targets and standards, mostly from the budgeting phase for evaluation. Therefore, short-term planning often requires more data and is prepared more detailed than long-term planning. A standard management accounting system is required have these three functions: (1) allocate costs of goods sold for internal and external report, (2) provide enough data for good decision making, (3) provide information for planning, control, performance evaluation, and continuous improvements. (Drury, 2018 p. 16)

2.1 Cost terms

The managers, employees, and accountants involved in the management accounting system and decision-making team should be able to understand the fundamental cost terms and concepts used in management accounting reports and financial statements to communicate and cooperate effectively. Cost refers to an amount of monetary resource given up for an exchange of a physical product or a service. (Drury, 2018 p. 22) defines a cost object as an activity for which an individual measurement of costs is desired. To simplify, a cost object is an item that the organization is assigning resources to. Cost object could be an output like a product, a service, an operation, like the production process, or a business relationship.

Costs are classified based on their treatment and behavior to the activity level. Four mainly used cost terms are variable costs, fixed costs, direct costs, and indirect costs, which are explained in the following section. The cost terms product costs and period costs are used in inventory valuation and profit measurement. The product costs or manufacturing costs refer to the costs of producing a group of products. These costs are associated with purchased goods, work-in-progress, or finished products for resale. They are listed as expenses (Cost of Goods Sold) when the products are sold. Profit of selling the products is the revenue less the product costs. Period costs, also called non-manufacturing costs, are costs expensed.to support the production or selling of the product, like sales commissions or administrative costs. (Drury, 2018 pp. 26-27)

2.2 Variable costs and fixed costs

Variable costs and fixed costs are two main type of costs incurred when manufacturing products. **Variable costs** increase and decrease along with the activity level. If the number of produced units rises, the variable costs increase. When manufactured units goes down, so do the variable costs. It is necessary to distinguish between total variable costs and unit variable costs. While **total variable costs** changes with the production level, the **unit variable** remains constant in regard production level. For example, when a product that has a variable cost of 1€ increases from producing 100 pieces to producing 200 pieces, the total variable cost has an increase amount of 100€ as well. However, the unit variable cost remains as 1€, no matter how many more pieces are produced. Some typical examples of variable costs are direct material, direct labor, and variable overheads.

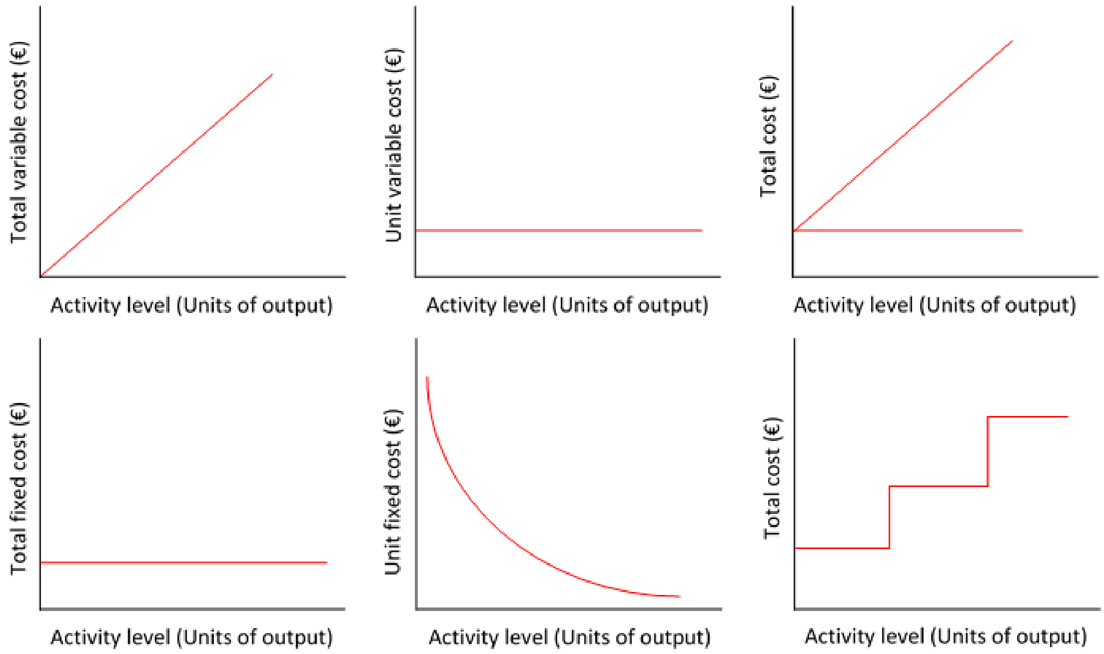

Figure 8. The effect of production level on variable and fixed costs

Fixed costs are costs that remain the same when production level changes. Though total fixed costs are constant regardless of whether goods are produced or not. The **unit fixed cost** has a distinctive reaction to production level. The reaction is mathematically explained by dividing the total fixed cost by the total manufactured units. When units of output increase, the unit fixed cost decreases since the total fixed cost is constant and vice versa. There are also other cost terms like semi-variable costs (mixed cost) and semi-fixed cost (step fixed cost). **Step fixed costs** are expenses that are constant through a level of activity but changes when passing that level. **Semi variable** costs contain both fixed and variable elements. One common example is the taxi fare. The trip starts with a fixed base fare, then the following fare increases proportionally with distance traveled. (Drury, 2018 p. 30; Hayes, 2021)

2.3 Direct and indirect costs

Direct costs are costs that can be directly traced to a cost object, which could be a product, operation, or department. Direct costs are often variable costs since they increase as the production level rises. Direct costs can also be fixed in some cases. Rent is typically considered as an overhead. However, some companies might choose to allocate rent costs into units produced. Some common direct costs are direct material costs and direct labor costs, fuel, and power consumption. In manufacturing company, direct material costs are directly charged to the products, meaning the materials become part of the final products. For example, a car manufacturer ties steel and plastics material costs straight into the manufactured cars. Direct labor costs refer to the labor involved directly in the manufacturing process. The quantity of labor used to manufacture a product or provide a service is often measured by physical observation. If a car requires about 17-18 hours to be manufactured and assembled, then the labor costs of that 18 hours are directly traced into the car's cost. (Drury, 2018 p. 24; Klenton, 2020)

Indirect costs or overheads, however, are more challenging to allocate to a cost object since they are not directly contained in the manufacturing process. Indirect costs are assigned to products using allocation methods, which are explained in later chapters. Overheads are often seen as expenses to support the production and selling of the products. Some typical indirect costs are, indirect materials, rent of building, machineries, equipment, administrative overheads. Machine maintenance labor wages, and costs of materials used in repair cannot be identified to a specific product. Same goes with taxes, lighting, heating, gas, and other utilities. (Drury, 2018 p. 24)

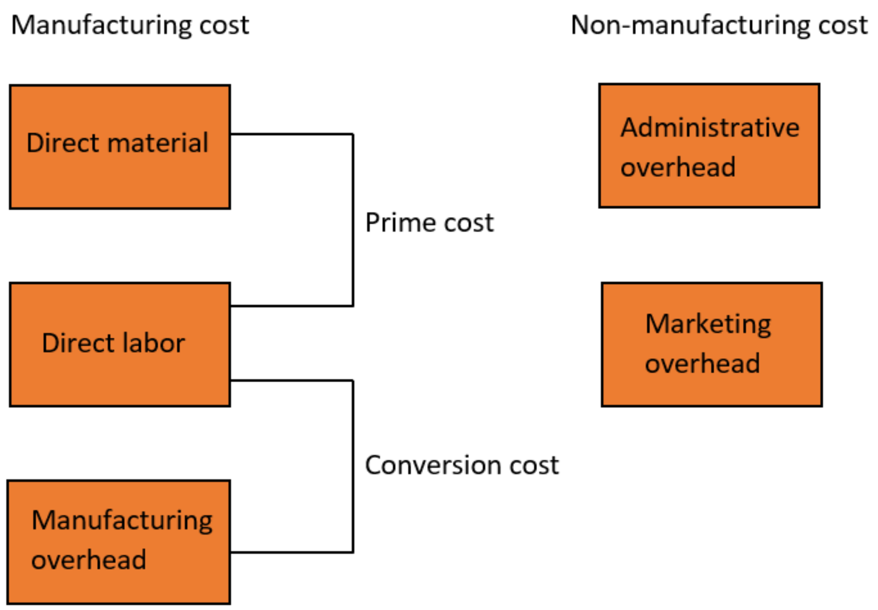

Figure 9. Manufacturing costs and non-manufacturing cost by (Drury, 2018 p. 25)

Figure 9 illustrates the definition of direct and indirect costs. Here are two more cost terms: prime cost and conversion cost. **Prime cost** is the sum of manufacturing costs which are direct labor costs and direct material. **Conversion cost** is the total direct labor and manufacturing overhead. In other words, it represents the costs of turning raw materials into final products. (Drury, 2018 p. 25)

3 COSTING

Costing is the practice of assigning expenditures to specific phases of production or other operations of the business. A costing system is designed to evaluate and control the costs incurred by operations and processes of a company. The system includes selections of input bases, inventory valuation and cost accumulation methods, cost flow assumptions, and recording intervals. The design of the costing system is dependent on the purpose of the business. Costing reports often convey information about revenues, costs, and profitability. Costing systems are used in various areas such as products and services, customer relationship, department control, research and development, operation control. Data provided by costing systems serves many purposes, including: (1) monitoring operations effectively, (2) planning for future operations, (3) measuring actual costs against planned budget for performance evaluation and profit calculation, (4) identifying cost reduction opportunities. Accounting systems and product costing for the injection molding production sector is explained in the following sections of the report.

3.1 Accounting systems with various purposes

All accounting systems are built based on flexibility and adaptability. An accounting system must be flexible to fit the business's nature, requirements, and purposes. It must be adaptive when there is a change in plans, operations, and processes. The accounting system should provide profound information to support leaders, managers, and accountants in the decision-making process. In the end, what everybody really wants is to drive the organization to its achievements, and a reliable accounting system is the key. Without precise calculations, and accurate information, all data-driven judgements are jeopardized. Not knowing where the money is spent is dangerous for a company's profitability and sustainability.

How costs are assigned to products depends on the purpose of the system. Normally, there are two main purposes of assigning costs: for internal profit measurement and external financial accounting requirements to identify production costs expensed during a period between inventories and costs of goods sold; for informed decision-making requirements. The purpose of the accounting system affects its level sophistication. For instance, **external financial reporting** does not require the figures to be exactly precise, but with an accepted deviancy in results. In most countries and, financial accounting requirements stated that only the total manufacturing costs are emphasized in the financial statements. In contrast, accounting systems used for **internal control and decision-making** are required to be more precise and specific. All costs including manufacturing costs and overheads or non-manufacturing costs, must be assigned to products. This information is needed for managers to determine the profitability of the products. This leads to discontinuation for the non-profitable goods to reduce costs and save resources. Though such important decisions require as much information as possible, some costs called irrelevant costs can be excluded, like depreciations of machinery and production plant since they are not affected by the judgements. (Drury, 2018 pp. 46-47)

3.2 Structure of an accounting system

Accounting systems are often mistaken as being one complete body. In fact, they are combinations of different processes and each process has multiple methods of cost treatments. As mentioned, each company has its own style of assigning costs, using a unique accounting system. The system's individuality comes from its diverse combinations of methods and processes based on its user's needs and purposes. An accounting system's five elements and cost treatment methods are demonstrated in Figure 10 below, provided by Martin (no date).

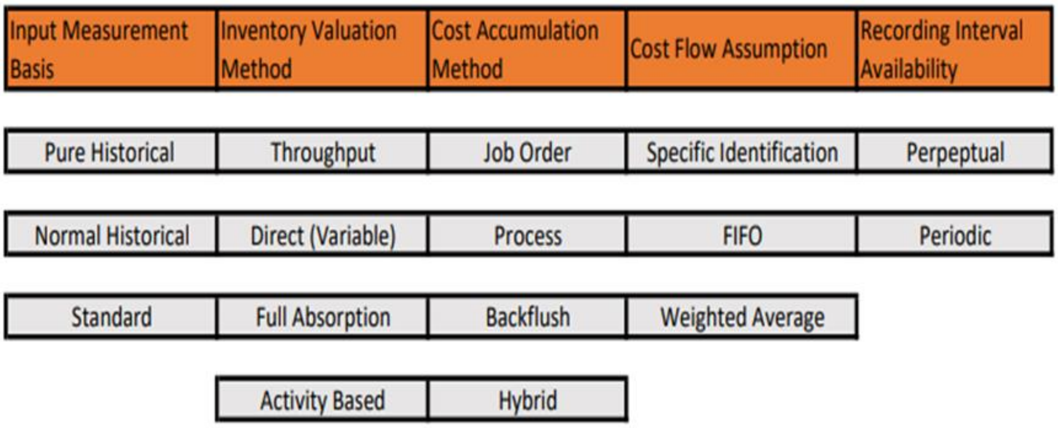

Figure 10. Five parts of a cost accounting system (Martin)

Each part of the cost accounting system represents an accounting phase and methods used in it. There are input measurement basis, inventory valuation method, cost accumulation method, cost flow assumption and recording interval availability. The costing phases and their cost treatment methods are explained in the following sections.

3.2.1 Input measurement basis

The input measurement basis is the basis for the whole system. It determines which costs are recorded in inventory. The input measurement basis can either be pure historical, normal historical or standard. In a **pure historical**, or actual costing system, only historical or actual costs flow into inventory, meaning costs re only listed when incurred. Direct labor, direct material and factory overhead costs are recorded, and listed as expensed at the end of the period. **Normal historical costing** records only the actual costs of direct material and direct labor. Factory overhead costs are charged under a predetermined overhead rate per activity measure, like machine hours or labor hours. The variance between the applied and actual factory overhead costs is listed as expenses at the end of the period. In a **standard costing system**, direct material, direct labor, and factory overhead costs are charged to the inventory using standard or predetermined prices or quantities. The differences between the charged costs and actual costs are listed as expenses or cost of goods sold. (Martin, no date)

3.2.2 Inventory valuation method

Inventory valuation determines which part of the costs is charged to inventory and which is period costs. This part of the cost accounting system is often used for product costing. Product costing is the process of assigning costs to the process of converting raw material to finished goods. Commonly used methods are throughput costing, direct costing (variable costing), full absorption costing, and activity-based costing. **Throughput costing** is mostly used in JIT (Just in Time) oriented organization. The Just in Time philosophy refers to the practice of keeping minimum to no inventory, meaning operations only start when customer demands arise. In a throughput costing system, only direct material costs are capitalized in inventory. All the remaining costs like variable and fixed factory overheads, variable and fixed administrative costs are listed as expenses in the balance sheet. **Direct or variable costing** chargers only variable costs to the inventory, which are direct material, direct labor, and variable factory overhead costs. Fixed manufacturing costs like fixed factory overhead, fixed, and variable administrative are charged into expense accounts when incurred**. Full absorption costing** capitalizes direct material, direct labor, factory overhead both fixed and variable in inventory. These costs become assets and become expenses only when products are sold. While selling costs and administrative costs are listed as expended during the period. **The activity-based costing** or so called the ABC system assigns all manufacturing costs into activity cost pools and charges no costs to expense accounts. The costs are traced to products through activities used by those products. Comparing to other valuation methods, activity based has improved accuracy with activity costing. However, this method requires more resources, data acquirements, and efforts to implement. (Martin, no date)

3.2.3 Cost accumulation method

The next part of the cost accounting system is the cost accumulation method. Cost accumulation refers to how costs are collected for calculation. The methods are defined based on orders, jobs, batches, and department. The four main accumulation methods are job costing, process costing, backflush costing and hybrid costing. In a **job-costing system**, costs are assigned to a unit or a batch of a product or service. Products are services in this costing system are often unique and customized according to customer demands. **Process-costing** is used in allocating costs to a large quantity of similar products. There is no pure job- or pure process-costing since these two accumulation methods are often combined. In this case, the term **hybrid costing** is used. Hybrid costing is applied when customer demands unique products in large quantities. Most manufacturers are using hybrid costing system since most of their mass-produced products are customized and standardized based on customers' preference. In a **Backflush costing system**, the total manufacturing costs are recorded at the end of the production run. This leads to fewer allocations needed since detail tracking expenses like material, and labor costs are removed throughout the manufacturing process. However, information relating to production and sales can be limited. (Liberto, 2020; Martin, no date)

3.2.4 Cost flow assumption

Cost flow assumption refers to how costs are dispatched from the inventory and become expenses or cost of goods sold. Common cost flow assumptions are FIFO (First in First Out), LIFO (Last in First Out), and weighted average. Assumed that similar items were purchased and kept in inventory at different price points. Under FIFO rules, the item's oldest cost is listed as cost of goods sold. In contrast the latest cost of the item is listed as costs of goods sold. Finally, with weighted average, the average value of the oldest cost and the newest cost is removed from inventory and charged into COGS (Costs of Goods Sold). Specific identification is used when rare operations or products are required. In this situation, no cost flow assumption is needed sine the costs are charged straight into COGS when these specific products are removed from inventory. (Martin, no date; Averkamp, 2021)

3.2.5 Recording interval availability

Recording interval refers to the methods used to record inventory valuation information. It could either be perpetual or periodic. A perpetual inventory updates expenses instantly as items leaves and enter the production facility. This method or recording provides up to date and accurate information for cost measurements, and reporting. However, it might require high investments and sophisticated ERP (Enterprise Resources Planning) software development. Therefore, it is more suitable for larger business with complex inventory. Periodic inventory on the other hand, is more manually operated. Inventory valuation data is recorded manually at the end of a set period, like once a month, a quarter, or a year. (Martin, no date)

3.3 Designing and implementation of a cost accounting system

As there are countless combinations of methods and processes than construct a cos accounting system that serves various purpose, it is challenging to select a perfect system. In fact, there is no such perfect system since each has its own pros and cons. However, an organization can select and design its cost accounting system by answering the following key questions: What function does this system serve? What costs should be included in the product cost calculation? How indirect costs are allocated to products? How do we track direct products? The answers to these questions are the foundation on which the updated product costing system is built.

3.4 The development process of a product costing system

This section describes shortly the overall process of developing a new product costing system. There is yet to be a standardized costing system solely for management decisions. Therefore, it is challenging to define one. We can only determine the system that best serves our purpose. In other words, the calculation should reflect the actual production cost most accurately.

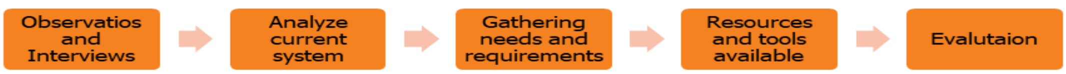

Figure 11. Process of costing development

The study comprises of interviews and observation is conducted to capture the current cost determinants, and how they are allocated. The next step is to analyze the company's ERP system and cost structure to find potential flaws that cause inaccuracies in cost calculations. Later comes the evaluation of existing requirements and needs from the company, the improvements are made based on these factors. This information can be collected through interviews and discussions with production managers, operators, and sales staff. Each costing system is examined against the requirements to determine the most suitable for the company's purpose of use.

4 CASE STUDY OF CURRENT COSTING SYSTEM

4.1 Overview of function needs

It is essential that the ERP system matches with the company's nature and needs. Correct cost calculation is needed in many departments of the business. However, in the end, we all desire a reliable costing system that produces actual cost calculations as precise as possible. In other words, a correct product costing system is beneficial for almost every department from production planning, production, operation, finance, research, and development (R&D). Interviews with employees on different level of operations were conducted to collect opinions and ideas on how to improve the current costing system. The needs and requirements of different department are present below.

Product portfolio management needs a reliable product costing system in order to be able to decide whether to continue producing a product or not based on its collected profitability data. If the calculation is not precise and generates faulty results, managers might end up cancelling a profitable product and manufacture another one with less return. This could heavily impact the sustainability of the company. It is recommended to perform a rearrangement on product portfolio to identify and eliminate non-profitable products. Molds used to produce those products are gathered and handled to the recycling service to free up some inventory and warehouse space. After reorganizing the product list, we can move on to measure how must cost a product costs to produce.

A more reliable product costing system helps the sales department to determine the break-even point for the product and tailor its price accordingly. The company must sell the product above the break-even point price to generate profit. It would be a fatal mistake if the costing system gives the wrong value which is less than the break-even point (unit cost), which will end up in losses in sales. In some cases, if the price is lower than the agreed market price, the market and competition could be badly affected. Consequently, there is a high chance of this resulting in a legal allegation. (Chan, 2017)

The product costing system has a major impact on the finance and book-keeping sector. Inventory valuation depends greatly on product calculations. Mistaken calculations lead to bad decision making and wrongly valued inventory. Taxation, custom taxes require attention if the company expands its operations to foreign countries. In several countries, customs taxes are based on the item's initial value. Though this amount might not be significant, it increases when shipment volume is larger. In other words, custom taxes could be affected by imprecise product costing.

Though production department is not directly involved in with cost controlling. A more precise product costing system offers opportunities for operators and employees to see their impact on the manufacturing cost by reducing wasted materials during production processes. In other words, the actual costs reflected in the updated costing system help raise cost awareness among operators and motivates saving and reusing recyclable material for production. This need should be regarded since raw materials take up almost 60% of total manufacturing cost.

4.2 Explanation of the input interface

The case company is currently relying on the Lemonsoft ERP system to record keep track of material consumptions, production output and machine hours in manufacturing. The cost accounting system uses direct or variable costing method as a basis. Manufacturing variable costs include raw material consumption, labor costs and energy consumption. These three are the main cost drivers of the cost calculation. They are explained in more detail in the following sections.

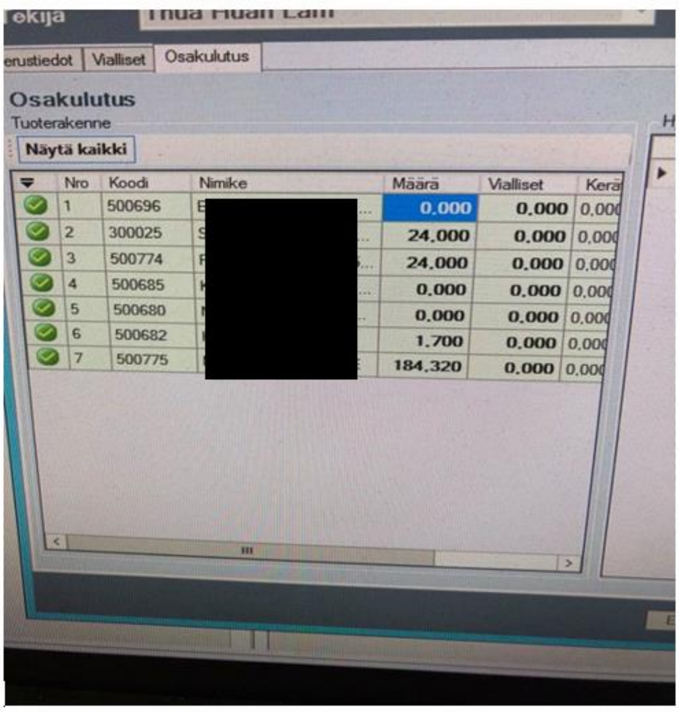

Figure 12. Input interface

Material consumption is measured, and the data is uploaded to the ERP system as a daily routine. This provides a realistic view of material withdrawal and keeps the stock level in check. Each product carries a product code, and the required materials and supplies are attached to it. The operator counts the number of packages produced by the end of the shift and the system automatically calculates the consumed raw material and other production supplies. The values are checked thoroughly before being uploaded.

4.3 Cost accounting system in use

This section describes the current cost accounting system, currently applied by the case company. The structure of the system is demonstrated in Figure 13 below and it is based on the five-part cost model introduced in the previous chapters.

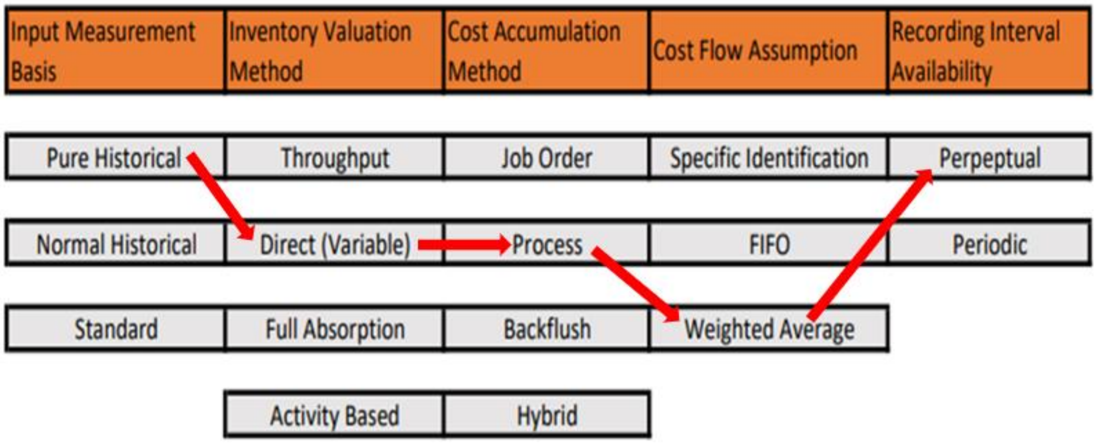

Figure 13. UKM's current cost accounting model

The existing cost accounting method uses pure historical costing as an input measurement basis. Where actual costs of direct labor, direct material and factory overheads are tracked, measured, are reviewed monthly. By doing this, managers can perform benchmarking and variance analysis on costs to identify significant variances. This method of costing gives better visibility and opportunities to improve the performance. As mentioned, the inventory valuation uses the direct costing method, which records manufacturing variable costs such as direct labor, direct material, and variable manufacturing overheads. While other fixed costs and overheads are listed as expenses in the balance sheet. Process costing is used in cost accumulation method production runs are in large volumes. Though rarely, job costing is also used when customized products are ordered by other manufacturers and clients. The weighted average methodology applied when assuming cost flows. It offers consistency in product cost and simple calculation. In case there is any change in raw material prices, the product costs change accordingly. This provides manager a more up to date picture of the current cost situation. Furthermore, weighted average product costs fit well with the perpetual recording interval as the latest cost of goods sold is recorded and updated instantly to the system as soon as the products dispatch. Lastly, perpetual inventory valuation is applied as a recording interval. Item entries and withdrawals are monitored by the ERP system, and such information are updated as soon as there are fluctuations in stock level. Even though, periodic inventory valuation is performed to identify and repair any systematic flaws in the system due to incorrect data input. The accounting system is depicted in Figure 13, but alternative methods and processes are also considered when there are abnormalities occur in production conditions.

4.4 Review of product costing calculation

The first step was to perform an analysis on the existing costing methods for Product X. First, the costs are calculated under the current parameters. Then, the costs were measured using the update methods and parameters. Both methods were simulated by Microsoft Excel. Next, a comparison and evaluation between the old and updated calculation was constructed. It was mainly focused on the variable costs' calculation since these costs were affected by the production volume. Through observation, major variances in the variable cost tracking were found. The study discovered that the existing product cost calculation method has the following issues:

- Missing information in production tools and equipment requirements
- Missing information and variables in material consumption calculation
- Unrealistic workforce distribution among machines

The following charts demonstrate the differences between simulated variable production cost calculations from the current ERP system (left chart) and the actual cost calculations by the updated methods (right chart).

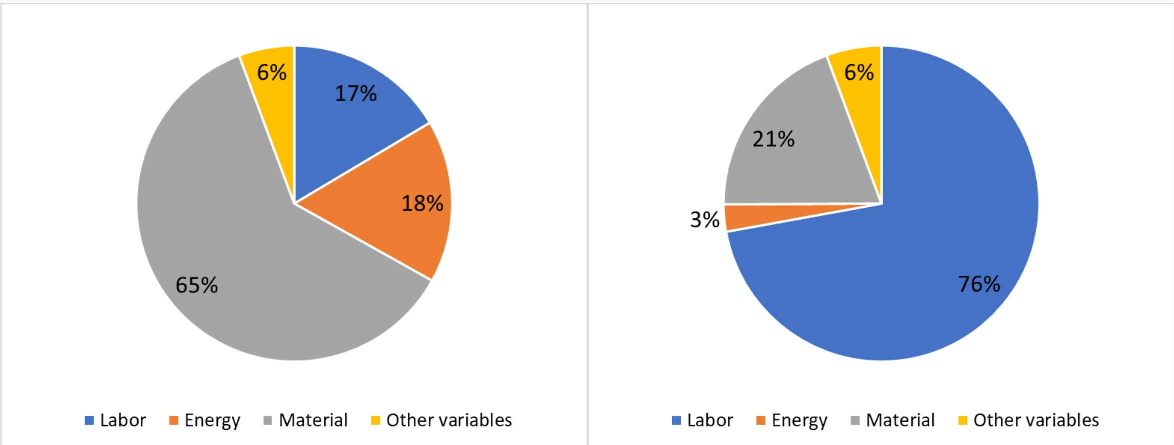

Figure 14. Production cost structure in actual calculation and financial reports

As seen in Figure 14, the product X's unit variable cost structures calculated by two methods differ significantly. The labor cost and material cost are the two costs that vary the most based on our findings. Since the Lemonsoft ERP system has just been applied into the company's resource tracking process recently incorrect values are expected while the ERP software was still in configuration phase. The investigation aimed at identifying the ERP's system calculation flaws and locating their origins. From there, updates and improvements to its cost measuring methods were developed, creating a more realistic approach when allocating costs to the product. This benefited the pricing process, by giving more accurate information than the previous version.

4.4.1 Raw material and scrap cost allocation

As mentioned, raw material consumption was the biggest manufacturing cost on product level. It consisted about 60% of total cost. In day-to-day production, the amount of material consumed for production was measured and uploaded regularly. However, a large amount of material was left unreported during production, which is the scrap and pre-cycle material. The molding process creates both the product and the runner. Sprues and runners were granulated and recycled into production. Another type of scrap material is the setup or pre-cycle material. Prior to the production run, the residual resin inside the injection unit needs to be extruded. This type of scrap could be ground and reused like the sprues and runners. Its quality was affected due to excessive exposure to high heat and other unknown contamination. However, this amount of pre-cycle waste was insignificant compared to the total amount of processed material. Therefore, it was accepted to be excluded from the material cost calculation.

Equation 1. Current raw material cost calculation method

$$\frac{\text{Raw material [kg]} \times \text{€/kg} + \text{Colorant [kg]} \times \text{€/kg} + \text{Indirect material [pcs]} \times \text{€/pcs}}{\text{Total output [units]}}$$

The old method only considered the amount of converted material and ignored the ground material. In result, this rendered miscalculations in material consumption rate, and total cost. Product X's molding cycle converted 338 grams of resin into finished pieces and runners. Total weight of the runner was 18 grams, which was about 5.2% of the total shot weight. The machine completed approximately 550 cycles per shift. By calculation, about 187 kilograms of resin material were molded. Unfortunately, only 95% of this amount was reported. The manufacturing process of product X consumed 44 tons of HDPE material, under normal conditions. With the condition of the currently used calculation, about 2,4 tons of material cost was left unreported annually. And this amount is only for product X alone, as there were more unreported material coming from other molding machines. In other words, the amount of unreported scrap material from the remaining product lines is much larger. In general, thousands of euros' worth of raw material was not assigned to products, causing major inaccuracy in product costing and pricing. An updated formula was proposed as below for more accurate calculation regarding raw material consumption.

Equation 2. Suggested raw material calculation method

$$\frac{\text{Raw material + scrap [kg]} \times \text{€/kg} + \text{Colorant [kg]} \times \text{€/kg} + \text{Indirect material [pcs]} \times \text{€/pcs}}{\text{Total output [units]}}$$

The measuring gap was patched by accounting the runner weight as scrap material into the calculation method. Including both the plastic piece and the runner into material cost tracking helped managers estimate raw material withdrawal and track the stock level with more precision.

Table 1. Unit material cost summary

Direct and Indirect material consumption		
Mold cavities	2	cavities
Cycle time	46	secs
Cycles per day	547	cycles
Pieces per day	1094	pieces
Pieces per package	48	pieces
Packages per day	22	packages
Shot weight per cycle (runner included)	338	gr
Shot weight per cycle (runner excluded)	320	gr
Total processed raw material	184.886	kg
Total processed raw material (runner excluded)	175.0	kg
Total processes colorant	1.85	kg
Total processes colorant	1.7504	kg
Colorant price	4.15	€/kg
Plastic bag price	0.22	€/piece
Material price	0.78	€/kg
Total material cost	144.21	€
Total colorant cost	7.67	€
Indirect material cost	4.84	€
Total material cost	156.72	€
Total material cost (runner excluded)	148.64	€
Difference	5.16	%

The difference between the two cases was about 5%, for product X and other products as well, with little deviation. It was recommended that all traceable costs are included in the products, even the indirect material such as containers or packaging material. This not only saved the effort of recalculating the indirect material expenses at the end of the year and increased the accuracy of the cost tracking product costing phase. In conclusion, along with the new calculation method, operators needed to establish the routine of uploading scrap material along with the processed material amount to the product costing system as well. Since the scrap material was the biggest difference on raw material cost calculations by far.

Regarding the raw material price, the material costs were measured based on the amount of material used to produce a specific product and the unit price of that material. The price of raw material was kept by the procurement department and updated monthly. When a new batch of raw material arrived, its costs were weighted to the in-stock value. As soon as the update was done, the product costs also adapted under the rules of weighted average cost flow. FIFO was suggested as an alternative method for product costing system. The oldest price of material was used after the inventory update, and the finished goods would be priced based on it. Though this method reflected the actual cost of production precisely and easily fluctuated based on products' market value, it could complicate things by creating different prices for the same products through updates. This required more effort and resources to keep costs in check. Therefore, the weight average costing method was kept. As plastic raw material price fluctuated widely in the recent years, it was challenging to forecast when it increased or decreased. However, it was ensured that a specific budget was reserved for purchasing in bulk as price is forecasted to rise and look to keep minimum inventory as the price drops to prevent value drops in capitalized raw material, and in results our products.

4.4.2 Energy cost allocation

Energy consumption was as well a major variable cost in the product costing system. Energy costs accumulated from the power consumption rates of machines, other auxiliary tools and equipment used in manufacturing process of the product. As shown by the chart in Figure 17, the reported energy cost of product X had a difference of 50% when compared to the actual production energy cost.

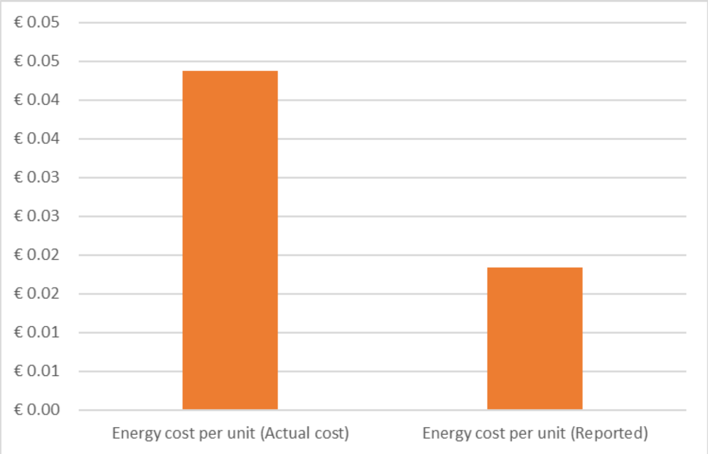

Figure 15. Comparison of unit energy cost

One obvious reason for this variance were the unregistered specifications of equipment and tools involved in the manufacturing process. Apart from the injection molding machine, other supporting equipment such as hot runner controller, water temperature controller, handling robot, and conveyor belts were participating in the production process at once. This equipment must be accounted, for more complete and accurate manufacturing energy cost. The key improvement would be adding the tools and equipment power rate when estimating energy required for manufacturing a product. Such information would be attached to each product code as its required manufacturing tools and equipment. The tools and equipment specifications are different from product to product. Therefore, a thorough analysis on the product groups' technical requirements was recommended. The power consumption rate of each equipment should be recorded and applied to measure the energy used in the production run.

Table 2. List of tools and equipment

Equipment requirements and specifications	
Injection Molding Machine	16.9 kW/h
Handling Robot	0.5 kW/h
Hot Runner Controller	7 kW/h
Water Temperature Controller	7.2 kW/h
Water Pump	2.2 kW/h
Conveyor Belt	0.5 kW/h
Robot Controller	3 kW/h
Total	37.3 kW/h

The cost calculation of the remaining products could also follow the same framework when listing equipment and controllers needed for production. The more detailed the specifications were, the better the energy cost could be captured. When all the total energy rates were achieved, production power cost for product X, or any other product could be calculated precisely.

Table 3. Unit energy cost summary

Unit energy cost - Machine hour allocation basis		
Injection Molding Machine	16.9	kW/h
Handling Robot	0.5	kW/h
Hot Runner Controller	7	kW/h
Water Temperature Controller	7.2	kW/h
Water Pump	2.2	kW/h
Conveyor Belt	0.5	kW/h
Grinder	3	kW/h
Robot Controller	3	kW/h
Total	40.3	kW/h
Energy unit price	€ 0.17	/kWh/h
Total energy cost	€ 6.85	/machine hour
Units produced per hour	157	units/machine hour
Energy cost per unit (Actual cost)	€ 0.04	/unit
Energy cost per unit (Reported)	€ 0.02	/unit

Machine hours were used as the allocation basis for energy costs as electricity cost accumulate from working shifts and machine hours required for production. Total energy cost per machine hour was calculated by the total power rate of machines and equipment multiplied by the unit price of electricity per hour. The result was then divided by the total output in units molded in a machine hour for the unit energy cost. The original calculation by the ERP system follows quite the similar principle. However, it included only the machine’s specification into calculations, and this leads to the showed difference between the actual and reported cost calculation.

4.4.3 Labor cost allocation

Labor cost allocation in product costing was the major challenge. As injection molding remained an automatic production process, it allowed the operator to work with multiple machines at once. This indeed was an advantage since the productivity can be maximized with several production lines running at once. However, assigning labor costs to products was a hard task for the same reason. Each product required a different packaging material and process, raw material refilling and beyond. Some products were packed continuously as the machine is running, and constant supervision was required. Other products were collected into containers, labeled, and packed afterwards, requiring less "babysitting" from the operator during the production run. Therefore, it was important that the operator organized his time on duty reasonably to process and package required products. A standard shift lasted 7.5 hours and an operator could effectively manage three to four machines during one shift. Which means 2-2,5 hours were spent on each machine to process its products. Unfortunately, the present system did not consider the variety between required labor hours for the product and the machine hours recorded. Meaning, the Lemonsoft ERP system considered product processing time and machine running time as one element. The measuring method was simplified with the following equation.

Equation 3. Current unit labor cost calculation method

$$\frac{\text{Machine effective hours or labor hours x €/hr}}{\text{Total output [units]}}$$

The ERP's system assumption was imprecise because product processing time was independent from the machine hours. If every machine required the same labor hours as their operating time, the calculated unit labor cost would be unrealistically high, as shown in the figure below.

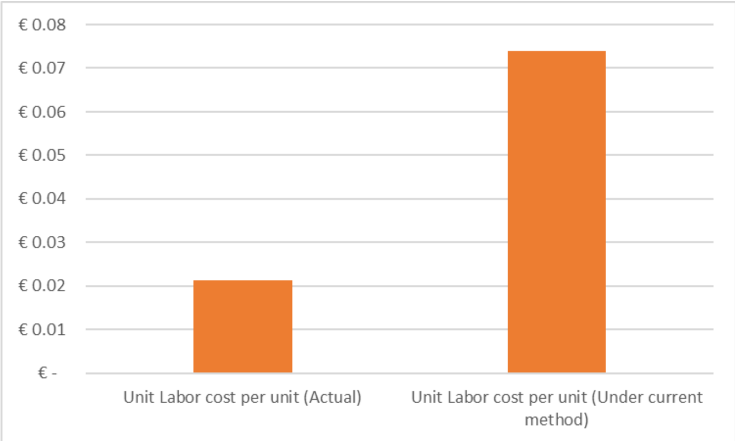

Figure 16. Comparison of unit labor cost

As presented in the charts, the unit labor cost of product X calculated by the current product costing system was 248% incorrect in comparison with the actual labor cost. An analysis was performed on product X's manufacturing process to identify where direct labor resource was assigned. Operator's time during the production run was often spent on various tasks: product processing and packaging, machine troubleshooting, palletizing, raw material refilling, moving material and products between production site and warehouse and back. First step was to gather the production variables for the investigation.

Table 4. Calculated unit labor cost summary

Labor allocation	
Total effective machine hours	7 hours
Pieces per hour	157 pieces
Pieces per package	48 pieces
Packages per hour	3 packages
Time spent each package	2 minutes
Total packaging time per shift	46 minutes
Wrapping and moving the pallet	15 minutes
Unexpected troubleshooting	30 minutes
Mold adjustment for product size change	30 minutes
Total Labor Involved per Shift	2 hours
Direct Hourly Wage	11.63 €/hr
Labor cost per unit	0.02 €/pc
Labor cost per unit (Under current method)	0.07 €/pc

For every shift, an estimated total of 46 minutes of labor time is required for packaging. Based on the given data of the molding cycle, we can estimate that 26 kilograms of raw material was processed in one machine hour. 25 kilograms was the standard net weight of one HDPE raw material package, and it took about 30 seconds to empty the bag into the raw material container. Next, the product packages were stacked on a pallet to be wrapped and removed to the warehouse. This often takes about 10-15 minutes per shift since only the machine produces one pallet a day. A total amount of 30 minutes was spent per shift for realignment, and adjustment in case of unexpected technical errors. Another 30 minutes was added for events such as mold adjustments for a different product size. Finally, the labor resources spent during each working shift to manufacture and process product X was approximately 2 hours. The unit cost was identified by dividing the labor cost per shift by the unit produced per shift.

Equation 4. Suggested unit labor cost calculation method

$$\boxed{\frac{(\text{Packaging [min]} + \text{Wrapping and moving [min]} + \text{Troubleshooting [min]} + \text{Adjustment [min]})/60 \times \text{€/hr}}{\text{Total Output [units]}}}$$

Investigating the labor resources assigned to manufacture the product down to the minute would be time consuming, but the cause was just. Especially, the time spent on a particular machine and its product is not constant. And there was no such method as a perfect one to reflect exactly how long the processing time was, since there were so many variables that could happen during production, like machine malfunctions or unplanned mold changing. However, this can benefit the cost tracking work by identifying from where in the production process direct labor work was needed. Operators and managers could identify the unnecessary and time-consuming process during the production and attempt to eliminate it.

5 PRODUCT UNIT COST ESTIMATION TOOL

Based on the developed methods, a cost estimation tool was constructed using Microsoft Excel. The purpose of this tool was to simulate the reaction of unit cost of the product would according to the inserted production variables. Also, due to the limited access to the Lemonsoft costing system and its current instability, Excel was a useful testing environment for the suggested key improvements. Meaning the production variables in the Excel simulator could be changed as desired without the risk of disrupting the real costing system. The calculation tool accepted inputs such as piece weight, mold technical specification and material categories and gave the correspondent products unit cost as an output. The Excel tool focused on the product X as planned, then it was further modified to calculate the unit cost of other products. This chapter explains in detail how the simulator converted product variables into product unit cost.

5.1 Material and molded product inputs

This first section of the simulator contains the key information about the injection molded product. Information such as assigned machine, material type, product name, product code, piece weight and colorant needed are updated here. The step is demonstrated in the following table.

Table 5. Molded part and material inputs

MATERIAL/PART INPUTS		
Key info		
Product name	[redacted]	
Product code	[redacted]	
Machine number	[redacted]	
Machine name	[redacted]	
Material	[redacted]	
Material code	[redacted]	
Colorant	[redacted]	
Colorant code	[redacted]	
Sprue/Runner weight per cycle	[redacted]	grams
Piece weight	[redacted]	grams
Hot runner controller	1	(1=yes, 0=no)
Handling robot	1	(1=yes, 0=no)
Conveyor belt	1	(1=yes, 0=no)
Water temperature controller	1	(1=yes, 0=no)
Packaging supplies		
[redacted]		

Regarding the auxiliary tool needed for production, the selection could either be 1 or 0, for the equipment required differed from product to product. Due to the confidential agreement, the product name and other classified information cells were colored black.

Table 6. Machine specification

Machine Number	Installed	Machine name	Machine tonnage		Energy consumption	
2	1980	Klöckner F85t	850	KN	19.17	kW
4	1979	Engel 60t	600	KN	7.9	kW
5	1989	Knöckler FX100t	1000	KN	17.23	kW
6	1991	Battenfeld 85t	850	KN	15.45	kW
7	2010	Haitian 120t	1200	KN	7.61	kW
8	2009	Haitian 250t	2500	KN	3.64	kW

By selecting the injection molding machine number from the material input step, the machine's name, technical specification such as tonnage, and energy consumption rate were automatically retrieved from this table.

5.2 Labor information inputs

The next step was to upload the labor input, information such as the operator's hourly wage, the benefit rate, yearly working days, and the direct labor resources required to process the product from raw material to finished goods in inventory. Benefit amount included sick leaves, vacation. HEKO referred to the additional amount added to original hourly wage, maximum €2.6 yearly. Pre-cycle time and unplanned downtime of machine were also included in the list.

Table 7. Labor input

LABOR INPUTS		
Hourly wage	11.63	€/hour
Benefit rate	65%	
Average HEKO (shift bonus and age allowances)	2.1	€
Working days/year	240	days
Production direct labor	2	hrs/day
Shift duration	8	hrs/day
Coffee break duration	0.5	hrs/day
Paid labor	7.5	hrs/day
Production setup time	0.5	hrs/day
Unexpected downtime (troubleshooting)	0.5	hrs/day

As can be seen, though the normal shift duration was 7,5 hours, only two hours traveled to the direct labor work required account to the conversion phase of the product. Since there were multiple machines running at the same time, the work shift was suggested to be assigned to machines based on their outputs, meaning total units produced and packaged. This differed among machines, because some products required continuous supervision and packaging, while others can be stored and packaged after the production run as stated in the previous chapters. The unit labor cost gap discussed in chapter 4 is demonstrated in the following sections using the Excel simulator.

5.3 Equipment and tools requirements for production

The following step was to list all equipment and tools needed for production. The sum of energy consumption provided the total energy cost of manufacturing the product, the equipment list is presented in the table below.

EQUIPMENT REQUIRED FOR PRODUCTION	
Injection Molding Machine	3.64 kW/h
Handling Robot	0.5 kW/h
Hot Runner Controller	7 kW/h
Water Temperature Controller	7.2 kW/h
Water Pump	2.2 kW/h
Conveyor Belt	0.5 kW/h
Robot Controller	3 kW/h
Total	**24.04 kW/h**

The equipment list varied depending on the product's size and surface finished requirements. If the product was used for concrete pouring, produced in small sizes, and required no special handling process, or high-quality surface finishing, there is no need for hot runner, water temperature controller and handling robot. In results, it had lower energy cost of production. In contrast, if the product had a complex geometry, and is relatively large, or requires a smooth surface finish, more supporting tools and equipment must be involved in production, rising the energy cost. The logical value of 1 and 0 in the previous table of material part input determined the output of this list, in terms of total power consumption rate. In case the value in the item's logical cell is as 0, meaning it was not required in the production process, its energy consumption is set as 0 in result.

5.4 Process inputs

This section presents the required inputs for molding process of the product. Machine life, shot weight, and mold life were provided from the machinery and mold tool suppliers. Production data such as cycles counted per shift, defective and scrap rate were measured from weighting the molded piece, runners and timing the production cycles.

Table 8. Manufacturing process inputs

PROCESS INPUTS		
Machine life	20	years
Mold life	1,000,000	cycles
Mold change date	10.12.2021	
Mold change hours	4.5	hours
Total cycle time	46	secs/cycle
Estimated cycles per day	547	cycles
Estimated cycles per hour	78	cycles
Total cycles per year	131,280	cycles/year
Gross weight per cycle	338.4	grams
Scrap rate (% total processed material)	5%	
Defective rate	0.5%	
Colorant ratio(% total processed material)	1%	
Operator on duty for machine	1	worker
Numberof mold cavities	2	cavities

The provided production variables like counted daily cycles, injection shot weight, and scrap rate per cycle, colorant consumption rate supported precise estimation of raw material and colorant intake for the manufacturing process, and from there captured the approximate direct material cost of the product. Mold changing was often scheduled once a year and required 4.5 hours of machine downtime and operation time. This labor cost was added to the yearly labor cost and assigned to total molded units. It was ideal to apply large volume production to compensate the lost amount during mold change and reduce the unit labor cost of mold changing.

5.5 Other calculation key variables

The estimator also accounted other key variables to support the detailed production cost calculation for the product. Equipment cost included the cost of main machine, mold tool cost and the closed production cell. Following the equipment cost register was the cost ratios. These cost ratios were estimated based on the machine, equipment, and mold cost.

Table 9. Other key calculation variables

EQUIPMENT COST			
Machine	€	80,000	2009
Mold Cost	€	40,000	
Production Cell	€	15,000	
COST RATIO			
Overhead budget (%fixed cost)		35%	
Installation cost (%machine and equipment total cost)		20%	
Maintenance spare part cost (%machine and equipment total cost)		2%	
MATERIAL, HOULY RATE AND POWER COSTS			
Raw Material		0.78	€/kg
Colorant		4.15	€/kg
Säkinsuljentlanka (Bag Sealers)		55	€/10.000pcs
Pussi (Plastic Bags)		0.22	€/pcs
Press cost per hour (hourly machine rate)		64.74	€/hour
Electricity		0.17	€/kWh
ANNUAL INPUTS			
Effective annual output production volume (with defective rate)		261,247	/year
Maximum production capacity		262,560	/year
Annual material input		44,425	kg/year
Annual colorant input		444	kg/year
Annual average effective machine hours, (no overtime included, mold change excluded)		1,673	hrs/year
Annual energey consumption		39,168	kWh/year
Annual technician salary allocated to machine		6691.5	€/year
Annual direct labor allocated to machine		480	hrs/year

The unit price for electricity raw material, colorant, and packaging supplies were registered to the simulator to measure the direct and indirect material cost of the product. The price data are retrieved from the purchasing department. As stated, the values were updated, provided monthly by the servicers and suppliers. Therefore, the data inserted here was only for demonstration and would become outdated as time passes.

Finally, the annual inputs showed the annual consumption of energy, raw material, and colorant. As required by the production manager, I estimated the effective annual molded units, including the defective rate. That was the ideal scenario where we run the machine on a standard full-time basis, 7 hours a day and five days a week, with no overtime operations. However, the true number of yearly molded units is much less based on data from the cycle counter installed on the mold tool.

Figure 17. Cycle counter on mold tool, taken 03.29.2021

As shown in the figure above, the mold has only completed 396,962 cycles, with no resetting of the counter. The mold was installed in 2010, meaning about 40,000 cycles completed yearly. When converting this value into units produced, the result was approximately 80,000 molded pieces per year, since the mold had two cavities. Switching between ideal and actual outcome significantly affects the depreciation cost of the mold tool, and unit cost of product.

5.6 The product unit cost summary

Based on the production variables and mentioned in the previous sections, I constructed a basic unit cost summary. The cost summary, known as the key element of the product cost model, is comprised of three main cost components, the variable cost and fixed cost, and total cost. These costs were segmented into further categories such yearly, per unit, and percentage rate against total unit cost. The arrangement of the cost terms and methods of product unit cost calculation are discussed in the following section.

Table 10. Product unit cost summary

VARIABLE COSTS	per piece	per year	percent
Direct material			
Material cost	€ 0.13	[redacted]	31.99%
Colorant cost	€ 0.01	[redacted]	1.70%
Packaging supplies		[redacted]	
Plastic bags 400x1500x0.075mm	€ 0.005	[redacted]	1.11%
Bag closing yarn (Säkinsuljentalanka)	€ 0.0001	[redacted]	0.03%
Engergy cost (machine only)	€ 0.03	[redacted]	6.15%
Labor cost + mold change hours	€ 0.04	[redacted]	9.52%
Total Variable Cost	**€ 0.21**	[redacted]	**50.50%**

FIXED COSTS	per piece	per year	percent	investment
Machine and equipment cost				[redacted]
Machine depreciciation cost	€ 0.01	[redacted]	3.40%	
Mold depreciation cost	€ 0.02	[redacted]	4.46%	
Production cell and equipment depreciation cost	€ 0.003	[redacted]	0.64%	
Installation cost		[redacted]		[redacted]
Allocated maitenance, technician salary + spare parts	€ 0.04	[redacted]	8.67%	
Allocated supervision cost, manager salary	€ 0.06	[redacted]	13.87%	
Allocated building and facility rental cost (utilities and services included)	€ 0.08	[redacted]	18.47%	
Total Fixed Cost	**€ 0.21**	[redacted]	**49.50%**	

Total Cost	**€ 0.41**	[redacted]	**100.00%**	[redacted]
Cost per bag	**€ 19.90**			
Cost per pallet	**€ 477.58**			

Based on the table of unit cost summary of product X, the variable cost was composed of the direct material such as resin raw material and colorant, packaging supplies, and electricity consumed. The raw material and colorant costs were calculated using updated formulas presented in chapter 4. The machine, mold and production cell depreciation were calculated using the straight-line depreciation method. First, we subtracted the estimated salvage value (often 8-10% of purchase value) from the asset's original cost, next we divided the result by the asset's useful life. This depreciation calculation method was recommended since there was no clear pattern in which the assets are used, since the production level fluctuated based on customer demands, either seasonal or impulsive. As explained, first installation and annual maintenance costs were extracted from the total machine and equipment cost, under predetermined ratios. Finally, the production facility rental cost was registered to the calculation. It was a fixed cost since the production level does not have any effect on this cost. The product's unit cost was achieved by dividing the total annual expense by the annual total number of manufactured units. Though unit cost referred to cost per piece, it was also essential to calculate the production cost of one bag or one complete pallet. This benefited not only the production managers in performance tracking, but also the sales staff and accountants in price setting and quoting.

As stated, the main purpose of this thesis project was to identify the causes of imprecise product cost calculations and make suggestions of improvements. The Excel product cost model was a suitable simulating tool for the proposed calculation methods. The simulator succeeded in redesigning the calculation methods and providing more accurate unit cost information. Which was important for price setting, and stock valuating for our plastic products. However, the simulator was specialized for a single product, and was far from applicable for actual product cost measuring, and integration into the Lemonsoft cost calculation formulas. Further analysis and development were required to translate these new cost measuring methods from the Excel simulator to the case company's ERP system, in order to construct a digitalized and automatic, and accessible product costing system.

6 DISCUSSION AND CONCLUSION

The study introduced the background of the thesis topic and objectives. Next, fundamental cost concepts and cost accounting theoretical background was discussed in further detail. The following step was to perform an investigation on the case company's current product costing method, focusing on its components, and costing activities. This section of the report explained the results and limitations of the study. Finally, conclusions and further development were discussed based on the findings.

6.1 Summary of results and suggestions of future development

The study focused on three following variable costs of production: raw material, labor, and energy cost. When compared to reported values, these costs posed major differences. Therefore, an analysis of their allocation method on products was performed.

Regarding the raw material and waste measurement, the input of material cost to the ERP system should also consider the agreed percentage rate of waste material in injection molding production. The event triggered waste such as changeover material waste, which is only 0.5 to 1 kg each changeover, is insignificant in comparison to the total amount used. However, it was recommended that attention should be paid to this type of waste as well for more accurate tracking on raw material consumption rate. Furthermore, consistency in material consumption checking is necessary. In other words, recording both the converted material and waste must be defined in the operator's daily work routine. This required more time and awareness from the operator, but its benefits outweighed the resource sacrificed as it was possible to capture a more realistic material consumption information. As a result, the desired reliability of a product's material cost was achieved.

Labor cost was the most challenging cost to allocate to products since every product and machine had distinctive requirements on labor resources. A large amount of work and time must be invested to study all the current product's requirements of processing and packaging methods. From there it could be tracked how much workforce went into the product itself. The old calculation method was oversimplified, affecting the product labor cost's accuracy. The system misunderstood labor work as machines hours. Meaning the operator takes as long as the machine's running time to process and package the molded pieces. Which was far from the actual amount since the shift last only 7.5 hours and must be effectively distributed to all running machines at once. The labor resource allocated to each machine must be broken down into more details such as collecting and labeling, repairing unexpected errors, wrapping, mold changing and transporting, material mixing and refilling. From the structure breakdown, the amount of work needed to product a specific product could be estimated. As a result, more accurate labor cost allocations to molded products could be achieved.

The miscalculation of energy cost rooted from the missing information of machine and equipment specification. The injection molding machine was not the only equipment used in the production process. There are many other tools and equipment to be included in the calculation. This equipment could be robots, conveyor belts, water, and runner temperature controllers. The production process of product X was an example of equipment requirements and specifications in manufacturing a product. Every machine had a unique power consumption rate, based on their functionality, operational age. The production site currently had several machines that are over 30 years of age, which made them consume more power than the more advanced models. It was suggested that all tools and equipment needed for the manufacturing process of a product should be examined, to measure and assign the energy cost more accurately. Additionally, major overheads such as utilities (heating, services, lighting), manager salary, technical support and maintenance staff salary costs were suggested by our production director (Minna Aronen) to be distributed to the number of machines in production based on their average outputs, like machine hours or product units. This amount could be added to the machine hourly rate in the Excel cost estimator.

To summarize, material consumption, labor allocation, and energy consumption were the three decisive concerns that need reworking for better costing information. Remodeling the calculation method was beneficial to many departments, as mentioned in chapter 4. Additionally, the study served as a jumping off point of the project as it starts only from identifying the systematic and calculation flaws in product costing. The ERP system implementation requires more experiences and resources to perform. More importantly, the employees' work routines and responsibility must be highlighted with these suggested changes. Managers and employees need to ensure that the updated data was correct to create reliable information to promote precise performance evaluation, smart decision making and competitive product pricing.

6.2 Limitations

The investigation was performed with several analyzes and observations at the production site of the injection molding sector. The main difficulties in product cost calculation were found and many corrective actions were consulted to managers. Even though, there remained some challenges and limitations that needed to be investigated. First, the product range of the injection molding process was wide, with over 50 products. Therefore, only the costing method of one single product as a starting study object could be used, and it was attempted to apply the improved version of costing method to the rest with additional adjustment when needed. Also, the updated product costing calculation methods were used for commercial products only. Further study was required for costing process of internal use molded components for rotational products.

Additionally, the study was only focusing on correcting the variable manufacturing cost and not the fixed cost. Excluding the fixed cost from the equation could lead to the risk of not measuring the complete actual production cost. The case company mentioned that the project was required for investigating purpose, and corrective actions are consulted from the gathered information from the observations and experiments. The project was not focusing on putting the updated methods directly into use, but on updating the current calculation methods.

Next, the methods were yet to be tested since the Lemonsoft ERP system is still in the integrating phase. Also, there were several personnel changeovers in the technical support team, which makes it difficult for the latter staff to catch up with his predecessor work, in operating the program. This makes it hard to put everyone on the same page, since multiple time-consuming retraining has happened. Furthermore, the authority to modify the calculation methods and variables of the Lemonsoft system is only available for engineers and managers.

6.3 Conclusion

Based on the updated product cost calculation methods, there were many changes in the costing structure to be expected. First, some products would have higher costs, and some would have lower costs. Second, there would be a significant shift in operators' work routines and responsibility. Other departments would experience changes as well.

According to the data collected from the investigation, labor cost allocation will be significantly different from the past because workforce is now precisely distributed based on the product model and its packaging requirements instead of following the total machine hours. The nature of packaging can either be continuous or multi staged packaging. Also, the energy cost allocation is changed due to the inclusion of auxiliary tools and equipment in production. This means that complex products with high surface finish requirements might experience rising costs of production. Furthermore, additional work is suggested for also measuring the air pressure and water used in production, to fully capture the utility cost of production. Finally, the raw material cost of the product is expected to rise since the updated version of calculation method is now considering also the waste created in the manufacturing process and changeovers.

A noticeable improvement is a reliable product cost with more informed and realistic approach. Measuring the resources used during day-to-day production is the efficiency method to identify the costs incurred during manufacturing process. Correct data from the calculation helps facilitate faster and more precise decision making, which is crucial to all businesses. Reliable product cost also supports product range management by spotting out products that are underperformed in profit return. Thanks to this feature, management decisions can be made to stop the production run for these products or commence a pause in manufacturing to identify the cost wise problems. As a result, there will be a more available inventory, some capital will be released, and cost of production will be lowered. The sales department can also benefit from the updated costing method by being able to perform better gross margin analysis, setting up the most suitable sales plan for the product.

Furthermore, a more adaptive costing method allows us to simulate the production batch level of the products to see its potentially incurred cost. This helps price quoting to be more precise. An accurate product costing system enables testing of many outcomes of different scenarios, to select and follow the best roadmap of production possible. In conclusion, the updated version of calculation method has met the following requirements of the production manager and the case company:

- Being adaptive and can be modified according to different injection molding products.
- Having a more realistic approach to material, labor, and energy cost allocation.
- Evaluating the performance of product in terms of costs and revenue comparisons.
- Serving as a solid foundation for product pricing.
- Precise gross profit margin analysis.

With all the promising benefits, the costing system is still far from complete and needs a lot more resources and time before being fully functional and put into action. There are still the fixed cost and other overheads to consider and measured to reflect the actual production cost of the product. In order to accomplish that, we need to account as mush details in terms of expenses during production as possible.

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