Faculty of Manufacturing Engineering

A FINANCIAL ANALYSIS TO IDENTIFY CONSTRAINT TOOLS AND ITS OPERATIONAL IMPACTS

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A FINANCIAL ANALYSIS TO IDENTIFY CONSTRAINT TOOLS AND ITS OPERATIONAL IMPACTS

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DECLARATION

I declare that this thesis entitled "A Financial Analysis to Identify Constraint Tools and Its Operational Impacts" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature   : ....

Name   : ....

Date   : ....

APPROVAL

I hereby declare that I have read this thesis and it is sufficient in terms of the scope and quality to gain the award of Master of Science in Manufacturing Engineering.

Signature   : ....

Supervisor Name   : ....

Date   : ....

DEDICATION

To my beloved father, mother wife and son

ABSTRACT

Basic downtime analysis refers to the effort of understanding overall downtime rates which is related to production issues leading to the efficiency improvement of the whole production. However, in a large production system, there are a lot of different types of machines and processes with their individual capacities despite being linear in manner. The specification is referred as the parameters of the downtime cost related factors which have different impact on the downtime analysis. As a result, common study is unable to justify which process or machine requires focus and priority in any downtime improvement program. The justification needs to be supported with a financial analysis which requires the costing method on the downtime issues since the improvement program requires possible financial budget and the potential cost saving activities should be well planned and managed.

The main objectives of this project are to link up actual downtime issues to the cost followed by a further analysis on the impact of the downtime cost. The project will be a future tool for the top management to make decision and changes in their operations to move their companies towards better practices and most importantly reducing the operational costs. A period of ten consecutive weeks of downtime monitoring has been conducted in a chosen company by selecting two of its bottleneck processes. During this study, two major downtime cost categories from each process is calculated by using the introduced costing method and an overall potential cost saving improvement program is established. Findings from this study will provide linkages of downtime to financial losses followed by a detailed Pareto breakdown of key drivers. Therefore, this clear determination enables necessary recommendations of downtime improvement effort to be provided within the factory.

ABSTRAK

Asas analisis downtime *merujuk kepada usaha dalam memahami kadar* downtime *secara menyeluruh yang berkait dengan isu pengeluaran yang membawa kepada penambahbaikan kecekapan dalam seluruh pengeluaran. Walaubagaimanapun, dalam satu sistem pengeluaran yang besar, terdapat banyak jenis mesin dan proses yang berbeza dengan kebolehan mereka yang tersendiri selain mengikut turutan. Spesifikasi merujuk kepada faktor parameter yang berkaitan dengan kos* downtime *yang memberi kesan keatas analisis* downtime. *Hasilnya, kajian biasa tidak boleh mengenalpasti proses atau mesin yang manakah yang memerlukan fokus dan keutamaan dalam mana-mana program penambaikan* downtime. *Pengenalpastian ini perlu disokong dengan analisis kewangan yang memerlukan kaedah pengiraan kos keatas isu* downtime *memadangkan penambahbaikan program memerlukan bajet kewangan yang mencukupi dan kegiatan-kegiatan yang berpotensi untuk menjimatkan kos harus dirancang dan diuruskan dengan baik.*

Objektif-objektif utama projek ini adalah untuk mengaitkan permasalahan downtime *yang sebenar dengan kos seterusnya diikuti dengan analisis terhadap kesan kos* downtime. *Projek ini akan menjadi satu alat kepada pihak pengurusan atasan untuk membuat keputusan dan perubahan dalam operasi mereka untuk menggerakkan syarikat mereka kepada praktis yang lebih baik dan paling penting mengurangkan kos operasi Pemerhatian* downtime *selama satu tempoh masa selama sepuluh minggu berturut-turut telah dilaksanakan di satu syarikat yang terpilih dengan memilih dua daripada proses-prosesnya yang bermasalah. Dalam kajian ini, dua kategori utama kos* downtime *daripada setiap proses dikira dengan menggunakan kaedah pengiraan yang diperkenalkan dan satu program penambahbaikan penjimatan kos yang berpotensi telah dibangunkan secara menyeluruh. Hasil penemuan daripada kajian ini akan mengaitkan* downtime *dengan kerugian kewangan diikuti dengan pembahagian Pareto yang menyeluruh sebagai pemain utama. Oleh itu, keazaman yang jelas ini membolehkan usul-usul dalam usaha penambahbaikan* downtime *yang diperlukan dapat disediakan dalam kilang tersebut.*

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CHAPTER 1

INTRODUCTION

1.1   Introduction

A factory or manufacturing plant is an industrial site, usually consisting of buildings and machinery where workers manufacture goods or operate machines processing raw materials into Finished Goods or any other products. Most modern factories have large warehouses or warehouse-like facilities that contain heavy equipment used for assembly line production. Factories arose with the introduction of machinery during the Industrial Revolution when the capital and space requirements became too great for common cottage industry or workshops to sustain the market needs of produce. Entrepreneurs such as Henry Ford further revolutionized the factory concept in the early 20th century, with the innovation of the mass production system. Highly specialized labourers situated alongside a series of rolling ramps (today's conveyors) would build up a product process by process. This concept dramatically decreased production costs for virtually all manufactured goods and led to a blooming industrial age.

In the mid to late 20th century, the industrialized countries introduced next-generation factories with key improvements that included advanced statistical methods of quality control, pioneered by the American mathematician William Edwards Deming. Quality control helped turn Japanese factories into cost-effective and production quality leaders. The other was Industrial automation on the factory floor, introduced in the late 1970s. These computer-controlled arms and grippers performed simple tasks quickly and with high precision that cut manufacturing costs and improved cycle time. Decisions made

during the engineering design phase of a product and subsequent process development determined the majority of the costs in manufacturing the product. Engineers use known physical properties such as engineering design correlations and practicality judgments to arrive at a workable and optimal design. If this is sound, and we remove potential technological advances in the future from the equation, the design is intended to be time invariant. In other words, if the engineering design to meet a particular need is fulfilled today - the final design in decades to come will not need to be changed significantly. However, conclusions reached through economic evaluation are not necessarily time invariant. Economic decisions have to be based on the best information available at the time of the decision and a thorough understanding of the uncertainties in the forecasted data. Any changes along the way to the process and product will lead to today's variation that is proposed from time to time.

The rise and sustainability of factories can be a result of economies of scale. In microeconomics, economies of scale are the cost advantages that enterprises obtained due to size, output or scale of operation, with cost per unit of output generally decreasing with increasing scale as fixed costs are spread out over the units of output. The operational efficiency becomes greater with increasing scale, leading to lower variable cost (Sullivan and Sheffrin, 2003).

Economies of scale is applied to a variety of organizational and business entities and at various levels, such as a business or manufacturing unit, plant or an entire enterprise. For example, a large manufacturing facility is expected to have a lower cost per unit of output than a smaller facility and all other factors to be equal. While a company with many facilities should possess more benefits in the cost advantage than a competitor with less facilities. Some economies of scale such as the capital cost of manufacturing facilities and friction loss of scraps and industrial equipment limitations have an

engineering basis that can be changed. In this paper, the intent of the study is to understand the actual run rates versus tool capability and identify the figures of losses from operational idling as well as the constraints in the pipeline.

1.2   Benefits and Significance

True Downtime Cost is a method of recording and analysing all costs associated with the equipment downtime in a production, processing or manufacturing facility. It provides the way to assign a monetary value to the stoppages that reflects the direct, indirect and opportunity costs which are lost because of the plant and equipment outages. It includes the downtime factors that are commonly overlooked, or previously considered "non-tangible" to achieve a more accurate value for the real cost of downtime (Fitchett and Sondalini, 2006). Downtime Costs Analysis focuses on the costing methods and costing techniques that quantify activities that fall under the indirect cost definition such as the hidden cost of machine downtime and no available manpower for continuously running the production (Fitchett, 2003).

Calculating potential downtime costs allows an organization to make rational decisions on the appropriate level of investment that should be made in enhancing business continuity. Estimating downtime costs can be of much benefit to the maintenance decision-making for several reasons including a measure of impact of equipment on system efficiency, an assessment of the effectiveness of maintenance policies as well as decision-making contexts, such as replacement policies, preventive and condition-centred maintenance strategies and spares stock levels (Pascuala, Meruane and Rey, 2008).

1.3   Problem Statement

Typical industry practices in the improvement of the project ideas are identified based on the following basis including but not limited to:

1. New Product Introduction (NPI) or existing product line expansion

2. Equipment and process selection

3. Manufacturing cost reduction

4. Equipment replacement (End of Life)

5. Service level or quality improvement initiatives

In standard operations, most improvements are launched on the basis of cost reduction and quality improvements. However, effective improvement programs need thorough and conclusive cost justifications during the planning stages. While in many aspects, downtime may not be the key factor for the cause of sustained investments but maybe due to the lack of understanding of subsequent losses associated to the idling (tool down). Therefore, the right formulae are needed to link up the period of unplanned downtime to the loss of opportunity cost in the production line. This cost analysis is required to influence the decision making by prioritising the improvement plan of the company by analysing the impact of the downtime cost and the potential benefit that can be achieved by the downtime improvement project to the company.

Future downtime predictions, preferably for projected duration in each category of equipment will be useful for the reasonable assessment of the relative impacts of Downtime (Nepal and Park, 2004).

1.4 Objectives

The objectives of this project are to provide an overview and understanding of the downtime cost calculation and the related theory of it. The linked aspects on the shop floor which are inherently related are also covered. The main objectives of this paper are:

1. Identification of marginal or constraints tools in each operation.

2. Draw susceptible linkage between equipment downtime and idling periods with financial impacts.

3. Analyse the major causes that contribute to the highest downtime related costs in the factory.

Meeting this objective requires a clear understanding of the downtime issues, causes and costs so that the factory management is able to achieve an acceptable informed levels to initiate investments that meets the organization's business continuity and profitability goals. At the end of this project, the outcome of the derived Opportunity Revenue Loss and the Labour Loss Cost, which are the two major downtime cost categories will be evaluated and discussed based on the investigated production line.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

In manufacturing plants, engineering is involved in every detail of goods production starts from conceptual design to shipping of the products. In fact, engineering decisions are accounted for the majority of the product costs. Engineers must consider the effectiveness or fixed capital assets such as buildings and machinery. One of the primary tasks of an engineer is to plan the acquisition of equipment (capital Expenditure) that will enable the firm to design and manufacture products economically.

With the purchase of any fixed asset-equipment, the profit estimation is crucial to be done so that the asset is capable to generate it during its service period. The figure below shows the relationship between the design aspects and eventual impacts during the evaluation and monitoring stages.
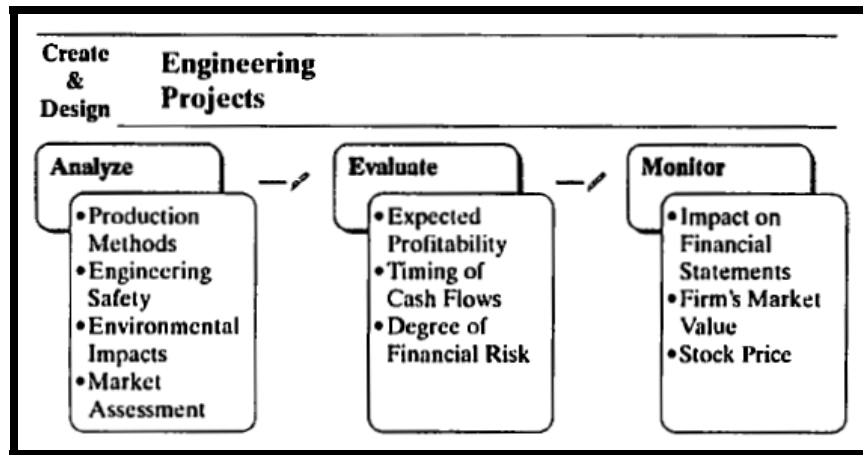
Figure 2.1: How a Successful Engineering Project Affects the Market Value of a Firm

Tooling needs analysis that typically starts off with the cycle time and output needed by any organization to fulfil the needs of a customer. Takt time is calculated virtually on every task in a business environment. It is used in manufacturing builds, control tasks and even in simple administration (Laraia, Anthony C.; Patricia E. Moody; Robert W. Hall, 1999). It is, however, the most common in the production lines that moves a product along a line of stations in which each of them perform a set of predefined tasks.

Implementation of a Takt system has a number of benefits including:

1. The product moves along a line, so bottlenecks (stations that need more time than the planned ones) are easily identified when the product does not move in time. Correspondingly, the stations that do not operate reliably (suffer frequent breakdown, etc.) can be easily identified.

2. The takt leaves only a certain amount of time to perform the actual value added work. Therefore, there is a strong motivation to get rid of all non-value-adding tasks (like machine set-up, gathering of tools, transporting products, etc.)

3. Workers and machines perform sets of similar tasks so that they do not have to adapt to new processes every day thus increasing their productivity.

Based on the information stated above, capacity planning of the line is able to be set up. Capacity planning is the process of determining the production capacity needed by an organization to meet the changing demands for its products (Gunther, Neil, 2007). In the context of capacity planning, design capacity is the maximum amount of work that an organization is capable to complete in a given period. Effective capacity is the maximum amount of work that an organization is able to finish in a given period due to the presence of constraints such as quality problems, delays and material handling.

A discrepancy between the capacity of an organization and the demands of its customers results in inefficiency either in under-utilized resources or unfulfilled customers. The goal of capacity planning is to minimize this discrepancy. Demand for the capacity of an organization varies based on the changes in the production output, such as increasing or decreasing the production quantity of an existing product, or producing new products. Better utilization of existing capacity can be accomplished through the improvements in overall equipment effectiveness (OEE). Capacity can be increased by introducing new techniques, equipment and materials, increasing the number of workers or machines, adding more shifts and acquiring additional production facilities.

Capacity is calculated as

Capacity = (no. of machines or workers) × (no. of shifts) × (utilisation) × (efficiency).

$$(2.1)$$

The equation (2.1) above draws linkage to the key component ideology of the project on the utilization (from tool uptime) as well as the number of workers which forming the backbone of the study for the running of the manufacturing facilities.

Downtime cost analysis considers the study of whole manufacturing policies focusing on the downtime towards the objectives of the company. In this chapter, three

primary topics which are the downtime issues, examining the cost of downtime and cost elements of downtime are discussed in order to clarify the basic foundation of the downtime knowledge. They will enable good justification based on fact and figures made by the plant management to seek for potential investment. For this reason, the downtime cost analysis will definitely improve the information of the financial costing input in order to determine the true cost related to the downtime in a production line.

2.2   Downtime

Downtime is a term referring to a time span that a machine is in an offline mode caused by planned or unplanned events. The term is also commonly applied in industrial environments in relation to failures in industrial production equipment. Some facilities measure the downtime incurred during a work shift, or during a 12 or 24-hour period. Another common practice is to identify each downtime event as having an operational, electrical or mechanical origin.

Industry standards for the term "Outage Duration" can have different point of initiation and completion thus the following clarification should be used to avoid any conflicts presence during the contract execution:

1. "Turnkey" is the most engrossing of all outage types. Outage or Maintenance starts with an operator of the plant or equipment pressing the shutdown or stop button to initiate a halt in an operation. Unless otherwise noted, Outage or Maintenance is considered to be completed when the plant or equipment is back in its normal operation ready to begin the manufacturing or ready to be synchronized with the system or grid or ready to perform duties as a pump or compressor.

2. "Breaker to Breaker". This Outage or Maintenance starts by having operators of the plant begin the operation or equipment removing the power circuit (main power breaker is in "off" or "disengaged" or "On-Cooldown" condition) but it does start not start with the control circuit of the operation. This condition still allow the equipment to be cooled down or brought to ambient such that the outage/maintenance work can be prepared or initiated. Depending on the equipment type, "Breaker to Breaker" outage can be an advantage if contracting out controls related maintenance is done as this type of maintenance work can only be performed while the main equipment is still in the cool-down or stand-by mode. Unless otherwise noted, this type of outage is considered complete when the power circuit is re-energized by engaging the power breaker.

3. "Completion of Lock-out/Tag-out". This Outage or Maintenance starts by having operators of the plant begin the operation or equipment removing the power circuit, disengaging the control circuit and performing other neutralization of potential power and hazard sources (typically called Lock-Out, Tag-Out "LOTO"). This point of maintenance period is typically the last phase of the outage initiation stage before an actual work starts on the facility, plant or equipment.

It is important to understand the types of the downtime before defining the downtime cost. In general, the downtime is divided into planned downtime and unplanned downtime. In the scope of the cabling of the production line, both downtimes are referred to the production stoppages and they should be managed effectively in order to get the best maximum output. The great majority of clocked downtime on the shop floor are the results of planned downtime that occur due to required maintenance (Mirghani, 2001). Unexpected or unpredictable nature of the unplanned downtime means that any single

downtime incident may be more damaging to the whole production process line than any other occurrences of planned downtime. Calculating the costs associated with the downtime is often more difficult than it appears as both preventive and corrective maintenance activities cost money and the providers must strive hard to strike a right balance between the costs related to these activities (Hamoud, Toneguzzo and Yung, 2002). Standard tangible costs of the downtime, such as the salaries paid to idled employees, penalties incurred if service agreements are breeched and so on can be derived from standard matrix. However, the less easily quantifiable costs such as the cost of lost customer loyalty or the cost of prospects that cannot be converted into real customers because the company has gone out of business can be much higher than the tangible costs. In this context of study, an examination on the tangible costs of downtime is executed with assignable numerical involved in the production line.

2.2.1 Planned Downtime

Planned downtime describes the time when the machine is offline, or in a restricted state while technicians perform maintenance or other required tasks. Planned downtime is usually scheduled and the duration is typically estimated at the outset (White Seymour, 2007). The primary objective of planned maintenance is the minimization of total cost of inspection and repair and equipment downtime that are measured in the lost production capacity or reduced product quality (Mirghani, 2001). Planned downtime typically accounts for at least 80% of all downtime in a given automated production line (Eti, Ogaji and Probert, 2006).

Planned downtime is mainly broken down into four primary areas:

1. Preventive Maintenance - maintenance machine program that needs to be conducted base on the planned schedule.

2. Daily production meeting - activities performed on a regular basis in order to brief the operators about the production schedule before starting the production.

3. Production preparation and 5S - normal production preparation before starting up the production process.

4. No Scheduled Runs – the period when there is no schedule to run production due to no planned order is given out for the machine to function.

The correct planned downtime figures are essential to be determined because it will be deducted from the total available production hour in order to find out the total plan of production hours.

2.2.2   Unplanned Downtime

The major downtime cost is always referring to the unplanned downtime. This always refers to machine breakdown or process stoppages. For machine breakdown it required maintenance personal to repair the machine and to start up back the production line. By "troubleshooting" is meant the urgent interventions carried out because of the risk of serious accident or stoppage of production as well as those necessary to restart a machine under satisfactory conditions. Troubleshooting always causes an immediate malfunctioning in the production programme and maintenance personnel (De Groote, 1995). Other than machine failures, human error also contributes the largest reason for unplanned downtime, which relates to the process downtime such as no manpower, wrong setting during machine start up or no materials available to run production. In these