QUANTITATIVE MODELLING OF OEE USE WITH SPREADSHEET FOR MACHINE CAPACITY PLANNING

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QUANTITATIVE MODELLING OF OEE USE WITH SPREADSHEET FOR MACHINE CAPACITY PLANNING

by

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LIST OF ABBREVIATIONS

A	Availability
CAPS	Capacity Optimisation Planning System
CC	Clearing & Cleaning
C_D	Design Capacity
C_E	Effective Capacity
C_{LL}	Lower-Limit Capacity
CM	Constraints Management
CRP	Capacity Requirements Planning
C_S	Safety Capacity
CSU	Consumables Item Setup
C_{UL}	Upper-Limit Capacity
DOE	Design of Experiment
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
FO	Facilities Outages
JF	Jig & Fixture Setup
JIT	Just-In-Time
L	Lot Size
LMS	Lean Manufacturing System
LSS	Lean Six Sigma
MPS	Master Production Schedule
MRP II	Manufacturing Resource Planning
MRP	Material Requirements Planning

MTBA	Mean Time between Assist
MTBF	Mean Time between Failures
MTTA	Mean Time to Assist
MTTR	Mean Time to Repair
NW	Not Work Schedule
OEE	Overall Equipment Effectiveness
P	Performance Efficiency
PDT	Planned Downtime
PES	Process Engineering Setup
PM	Preventive Maintenance
PPC	Production Planning and Control
Q	Quality Rate
QES	Quality Engineering Setup
RDS	R&D setup
R_t	Machine Throughput rate
SA	Specification Adjustment
SCAPS	Stochastic Capacity Optimisation System
SCM	Supply Chain Management
SEMI	Semiconductor Equipment and Materials International
SPC	Statistical Process Control
T_a	Available Time
T_{asu}	Short Stoppage Time to do Minor Adjustment on the Machine
T_{bf}	Buffer Time
T_{bd}	Time Loss Due to Machine Breakdown / Failure
T_{cc}	Stoppage Time to Do Cleaning & Clearing

T_{co}	Changeover Time
T_{csu}	Time to Top up Consumable Items / Parts
T_{dt}	Downtime Losses
T_{jf}	Time to Do Jig & Fixture Setup
T_{lsu}	Lot Setup Time
T_{max}	Maximum Number of Manufacturing Hour
T_{mhr}	Manufacturing Hour Reduction
T_{mtbf}	Average Time between Machines Failed
T_{mttr}	Time to Repair Machine
T_{NW}	Time Loss Due to the System Not Worked
TOC	Theory of Constraints
T_p	Processing Time
TP	Trial Run Process
T_{pes}	Process Engineering Activities Time
TPM	Total Productive Maintenance
TPS	Toyota Production System
T_{qes}	Quality Engineering Activities Time
T_{ql}	Quality Losses
TQM	Total Quality Management
T_{rds}	R&D Setup Activities Time
T_{sa}	Specification Adjustment Time
T_{SC}	Set up and Changeover Time
T_{sl}	Speed Losses
T_{tp}	Trial Run Time
T_{wt}	Time to Replace Wear & Tear of Items / Parts

Tη	Net Operating Time
Tι	Loading Time
To	Total Operating Time
Tυ	Valuable Operating Time
UPDT	Unplanned Downtime
UPH	Units per Hour
WIP	Work-in Process
WW	Work Week

PERMODELAN KUANTITATIF OEE DENGAN MENGGUNAKAN ‘SPREADSHEET’ UNTUK PERANCANGAN KAPASITI MESIN

ABSTRAK

Mengurus kelakuan asas lantai pegeluaran seperti permintaan pelbagai produk yang tidak tetap, pengurangan masa pengeluaran, mesin melahu, variasi mesin dan kehilangan penghasilan adalah asas perancangan dan kawalan pengeluaran yang berkesan. . Kajian-kajian lepas dalam mengurus kelakuan asas lantai pegeluaran memberi tumpuan kepada pengukuran produktiviti, celusan pengeluaran dan penggunaan tidak dapat mengenalpasti masalah-masalah secara keseluruhan. Maka, adalah amat penting untuk membina suatu model yang boleh mengintegrasikan kerawakan kelakuan asas lantai pegeluaran dengan komponen OEE. Ia boleh digunakan untuk pengiraan bagi tujuan memastikan kapasiti mesin yang optimal dan memberi justifikasi terhadap prestasi mesin. Oleh itu, kajian ini akan membentangkan permodelan kuantitatif OEE dengan menggunakan ‘spreadsheet’ untuk perancangan kapasiti mesin. Model yang dibangunkan ini terdiri daripada dua bahagian, iaitu modul pengiraan kapasiti mesin dan modul pengiraan prestasi mesin. Faktor-faktor penting yang mempengaruhi kelakuan asas lantai pegeluaran akan dikenalpasti, dikasifikasi dan difomulasi ke dalam bentuk parameter model. Pengubah model and pengubah keputusan model pula dibentuk secara berperingkat berdasarkan kaedah matematik. Kesemua persamaan matematik yang telah dibentuk akan diterjemahkan ke dalam ‘spreadsheet’ bagi tujuan kemasukan data dan pengiraan hasil. Seksyen verifikasi model memastikan integrasi dinamik yang tepat dan tanpa ralat antara persamaan-persamaan matematik dalam model itu. Manakala seksyen validasi model pula menunjukkan kemantapan model dalam mengesahkan kes kajian industri. Model ini digunakan dalam (i) menilai kapasiti mesin dan prestasi mesin bagi tiga jenis permintaan produk yang tercampur dan (ii) untuk mengira jumlah mesin yang diperlukan bagi memperuntukkan kekangan proses pembuatan. Keputusan kajian menunjukkan suatu kaedah bagi merancang peruntukkan jumlah mesin dan bilangan minggu kerja pengeluaran yang diperlukan untuk menghasilkan pelbagai permintaan campuran produk. Kekuatan model ini ialah sebarang perubahan boleh dibuat untuk mensimulasi pelbagai scenario pengeluaran tanpa risiko kos gangguan terhadap sistem pengeluaran yang sebenar.

QUANTITATIVE MODELLING OF OEE USE WITH SPREADSHEET FOR MACHINE CAPACITY PLANNING

ABSTRACT

Managing shop floor basic behaviours such as product mix demand fluctuate, manufacturing hour reduction, machine idling, machine variation, and yield loss are fundamental for the effective production planning and control. Previous works in managing shop floor behaviours focused on measuring productivity, throughput, and utilization are insufficient for identifying the problem. Therefore, the concerns are to develop model that can integrate stochastic characters of shop floor basic behaviours with OEE components. It is used for calculation to ensure an optimal machine capacity and machine performance justification. Therefore, this research will present quantitative modelling of OEE use with spreadsheet for machine capacity planning. The developed model consists of machine capacity computation module and machine performance computation module. All influencing factors of shop floor basic behaviour are being identified, categorized and formulated into model parameters. Model variables and decision variables are built in incremental steps based on the mathematical approaches. All mathematical equations derived are then translated and resided into a common computation spreadsheet for data input and output computation. Model verification section ensures dynamic integration between numerous mathematical equations in the model is error free and accurate. Model validation section demonstrates the robustness of the model in validating industrial case study. The model is employed in (i) assessing machine capacity and machine performance under three different types of product mix demand and (ii) to compute total numbers units of machine needed to allocate to the constraint manufacturing process. The study demonstrated a methodology to allocate or plan total number of machine and number of work week needed in completing various product mix demands. The strength of the model is that any changes made to simulate various manufacturing scenarios are possible without the risk of costly disruptions to the real manufacturing system.

CHAPTER 1

INTRODUCTION

1.0 Background

Production system is fundamentally concern with managing production resources to meet customer's demand. Gershwin (1994) described that a production system consists of machines, people, computers, transportation elements, storage buffers and other items that are used together for manufacturing. Cells, work centers or work stations can be used interchangeably and are subsets of production systems. Production system involves the basic task of managing the processes which transform a set of inputs (raw material, labour, energy, technology, capital and information) to outputs (functionally desirable, reliable and quality products). Companies must plan and control their production in such a way that the disruptions in performance of their production systems are minimised in order to remain competitive and able to adapt to today's fast changing business environment.

Slack et al. (2004) defined planning as formalisation of what is intended to happen in the future. Rather it is a statement of intention. However, the stochastic nature of the manufacturing environment does not guarantee that the plan always followed as expected. It is frequently evidenced by supplier's late delivery, price fluctuation of raw material, defective parts, machine breakdown, workers absence and / or uncertainty in customer demand.

Control is the process of coping with changes and makes the adjustment to reset the plan and bring the operations back to its original objectives. The examples are: sourcing for alternative supplier, repairing the machine, swapping workers to cover absentees and etc.

Production Planning & Control (PPC) is concerned with planning and controlling all aspects of manufacturing, including demand management, detailed material planning, capacity planning, quality control, scheduling machines and people, maintenance management, coordinating suppliers and respond to key customers requirements. Many important decisions in manufacturing organisations are made in regards of these activities. The purpose of planning and control is to ensure all activities are well organized and well integrated for highly effective and efficient production system.

1.1 PPC Overview

PPC change over time and differ greatly with regard to the length of time. In managing the system, various decisions have to be made continuously, from a simple choice, which job to be processed next on a certain machine, to the serious consideration, whether to build a new factory or to shut down an existing one. It is therefore essential to categorize the decision making process into system-wide planning horizon. Different planning horizons will imply different PPC scope, with plans becoming more specific and detailed as the planning horizon becomes shorter. Virtually, every manufacturing organization in the world divided it into long term, medium term and short term horizons.

In the long term, company establishes the overall company direction concerning business activities that place demands on the manufacturing capacity. Planning horizon can range from 2 to 5 years, with normal emphasis in product options and volumes to produce in the future and in determining the manufacturing capacity, human resource capabilities technology, and geographical locations to meet the firm's future needs. Nahmias (2004) predicted patterns of demand, costs of constructing and operating new facilities, new technologies and competitors' strategies as an important capacity strategy in this planning horizon. Financial targets and budgets will be set to identify the costs and revenue targets which are intended to achieve.

The medium term encompasses activities focus on providing the exact material and production capacity needed to meet customer needs. This means detailed material planning for the right quantities of raw material, part and components to arrive at the right time and place to support product production. The manufacturing capacity requirement for typically a month to 1 year planning horizon needs to be checked against the production plan in order to ensure an achievable plan. Stephen et al. (2007) pointed on type of products, quantity, delivery date and location preference are among basic information that needs to be match with manufacturing capacity, workforce level, inventory level, quota availability and other factors in order to fulfill the demand within a specific time frame. Contingencies production plan will have been put in place to allow for slight deviations when it is not followed as intended.

Short term activities as described by Vollman et al. (2005) mainly on assessing demand in totally disaggregate basis. This involves detailed scheduling of material, machine, labour and delivery lead time to meet customer requirements. The shop floor system will properly schedule customer orders into daily or weekly production plan. All important manufacturing performance such as material consumption, labour utilisation, machine utilisation, on time delivery and etc are systematically tracked, measured and reported for day to day activities monitoring.

Thus, Hopp et al. (2008) mentioned the logical function of PPC consists of strategy (long term), tactics (medium term) and control (short term) which forms a hierarchical framework. Each planning horizon represents different production function activities and decision problems in separate planning and control module. Followed Vollman et al. (2005), Figure 1.0 relates the vertical integration of these PPC modules in the production system.

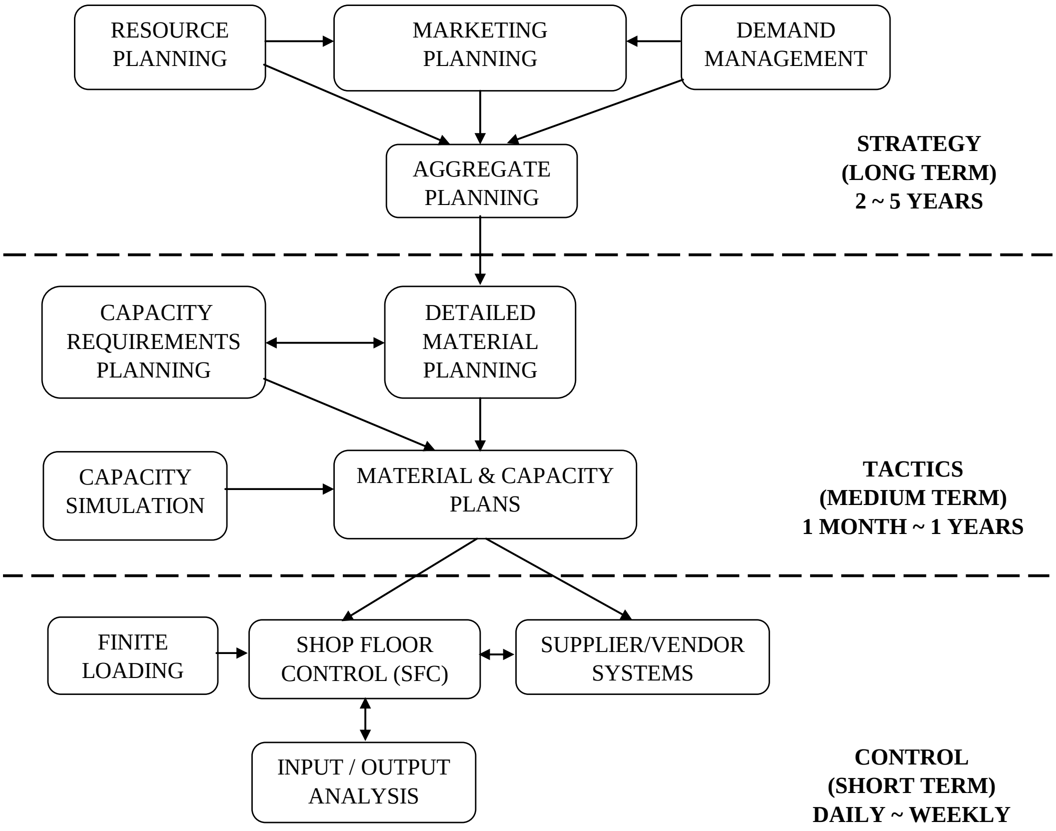

Figure 1.1 Hierarchical PPC Framework (Vollman et al., 2005)

As depicts in hierarchical PPC system, the output from each planning module in long term and medium term are considered in short term control module. Over the past decades, many principles and methods of planning and control (e.g. MRP, MRP II, ERP, SCM and etc) and also wide range of PPC improvement methodologies such as TQM, JIT or range of lean manufacturing tools had been proposed, developed, evolved and widely implemented in various industries. These developed principles and methods of planning and control are presented in Section 2.2 of Chapter 2.

However, most of these approaches which is commonly supported by software packages do not necessary worked all right in all manufacturing company.

According to Hopp et al. (2008) a survey by the Standish Group in 1995, showed that over 31 percent of all IT projects are cancelled before they get completed and that almost 53 percent of the projects would cost 189 percent of their original estimates. Moreover, only 16 percent of the software projects were completed on time and on budget.

The following sections will describe inherent complexity of the shop floor basic behaviour and discussed on the needs for quantitative metrics in PPC.

1.2 Shop Floor Basic Behaviour

The nature of shop floor activities is concerned with ensuring high-level planning module in the long term and medium term that is consistent with low-level control module in the short term PPC hierarchy. Shop floor is the workplace consisting of the part of a factory housing the materials, machines and man power directly involved in the productive work to produce parts or final products. The essential task of the shop floor system is to manage and to control the flow of material, the capacity of the machine and people, and to respond to a given production plan over a planning horizon to meet customer’s demand.

The specific requirements to accomplish these tasks must take into account inherent complexity of shop floor basic behaviour such as product mix demand fluctuate, manufacturing hour reduction, machine idling, machine variation, and yield loss that are fundamental for the effective PPC.

1.2.1 Product Mix Demand Fluctuate

Based on actual shop floor requirements, there exist several different products (or termed as product mix) using the same or similar machine. Given that the demands vary not only over time but also by the product type, shop floor loading plan has to periodically revise and subject to changes. Customers will feedback a certain product mix ratio, e.g., the product mix ratio for three types of products may be (A : B : C) = (1 : 2 : 3) and later revised to (A : B : C) = (3 : 1 : 2). It is obvious that demands are lumpy and time varying. Due to the fluctuation of' product mix demand pattern, machine in shop floor are faced with irregular utilization fluctuation between over and under-loading. Shop floor's ability to response to the dynamic demand and product mix changes has become a key competitive advantage in PPC.

1.2.2 Manufacturing Hour Reduction

The shop floor activities have an explicit reference of time. Manufacturing hour of a production system is the total time allocated for manufacturing activities on a daily, weekly or monthly basis. In a typical 7-day period, the planning department programmed shop floor operated on 24-hour day basis as weekly maximum manufacturing hours (T_{max}).

Most shop floor operates on shift basis. In practice, there are some periods the shop floor can not operate continuously at all time. Public holidays, unworked shift, shutdown of any reasons such as weekend, plant maintenance, stock take and etc. are all so called as Not Worked Time Loss (T_{nw}).

Downtime is unpredictable and can not be ignored in PPC. Time losses take place when the production is interrupted by a temporarily malfunction. For instance, short idle periods or minor stoppages between consecutive machines runs, malfunctioning of conveyors, blockages of raw material in the nozzle, air pressure adjustment, major machine breakdown or aborts and so on. Based on a machine's history of interrupted breaks down, unplanned stoppage and failure, they are considered as unscheduled downtime (T_{usdt}).

Another downtime related to machine is scheduled preventive maintenance, e.g. routine inspections, servicing, maintenance or calibration on the machine and keeping facilities in good repair to prevent failure. It is a weekly, bi-weekly, monthly, quarterly, semi annually, yearly and bi-annually plan that scheduled by maintenance department. As this time loss is planned and scheduled; it is termed as scheduled downtime (T_{sdt}).

Machine generally can perform same process function for different product. Changing from running one product to another in any machine involved product changeover time loss, waiting for raw material or specification changeover time loss, that can be sum up to denote by (T_{co}).

Setup time losses is normally followed after changeover to perform jig/fixture setup, cleaning & clearing job, specification adjustment, trial processing or consumables item setup. These setup time losses (T_{su}) may also occur during changing shift.

Quality failure investigation by quality engineering department, new product qualification by process engineering, R&D test and other various manufacturing and engineering time losses are categorised under engineering time loss (T_{el}).

Therefore, the time available for productive working can be significant below the maximum time available even in a well managed operation. The actual machine operating time remains, after such time losses are accounted for, is the most important aspects in optimizing PPC.

1.2.3 Machine Idling

Machine may idle due to its machine operator break’s time (meal break or tea break), shift briefing, meeting or simply absenteeism. Machine also frequently interrupted by small outages to do some minor adjustment or assist. A production line with poor line balancing may also cause machine idle waiting for WIP from previous process or workstation. All these are machine idling time losses (T_{id}).

1.2.4 Machine Variation

Each station may consist of several machines or equipment that either similar or different by manufacturer's brand, version or model. However, they perform essentially identical function. Each machine has different manufacturing characteristics; machine speed may vary in different instances of the same processing operation, perhaps because of differences in operator handling and system constants (for example, machine setting parameters) that need to be checked periodically for consistency. These kinds of variations may result in speed losses (T_{sl}).

1.2.5 Process Cycle Time

In shop floor, there is no standard route that all products undertake the different workstation. Each product can have its own routing through a unique sequence of workstations or processes. Cycle time in individual workstation is made up of *move time* (time for parts being moved from previous station), *queue time* (time for parts spend waiting for processing at the station), *setup time* (time for parts waiting for setup the station) and *process time* (time for parts actually being process at the station). For batch processes, to be more detailed, the cycle time components should include *wait-to-batch time* (parts waiting to form a batch), *wait-in-batch time* (average time for parts spends in a batch waiting its turn to be processed) and *wait-to-match time* (occur at assembly station where parts are waiting for other components to be assembled). Process time and all other cycle time components for the manufacture of products are unique and specific to each product type.

1.2.6 Product Throughput Rate

A production line is one in which each workstation can pass work in process (WIP) on when its processing is complete. The WIP includes the items at first process through last process including the one item being processed or held at each process. However, it does not include any raw material held in front of first process as materials are assumed to be always available at any time. A process flow analysis can be used for seeing the sequence of process steps from inputs to outputs in between each workstation. Throughput time is the actual elapsed time for the parts to go through the start and end points of the process routing. The average output (number of units products processed or number of lot processed) of a production process over the throughput time is called throughput rate. Since many different products are produced and each with different processes routing, throughput time and throughput rate for different products is product specific.

1.2.7 Yield Loss

Yield loss is another shop floor basic behaviour that further complicates the PPC problem. It is used to indicate the proportion of defective production output to the total production output. WIP or products are rejected or scrapped at various workstations along product’s specific process routing. Different process yield loss for different types of products will definitely affect the output quantities of production line and inevitable trouble the production planners and practitioners. Thus, to achieve the desired output, a production system must release extra loading into the production line to compensate for yield loss.

The above shop floor basic behaviour may give the impression that PPC is closely associated to variability and randomness that exists in all production system and can have enormous impact on its performance. Therefore, a set of quantitative metrics that can assess, measure and report on how good or bad the production system, is fundamental for performance measures.

1.3 Important Shop Floor Quantitative Metrics

According to Melnyk and Christensen (2000) quantitative metric is defined as verifiable measures that should be consistent and stated in meaningful terms. Anyone should be able to calculate the measures and get the same results if they are given the same information with similar calculating procedure.

To capture and measure on the variability and randomness of the shop floor basic behavior. The quantitative metric can generally divided into two basic categories as follow:

i. Machine capacity
ii. Machine performance

1.3.1 Machine Capacity Metrics

The primary goal of the machine capacity metrics is to minimize the discrepancy by matching the shop floor machine capacity to the demand for its products over time. Generally, management is dependent upon the manufacturing organization to faithfully report all time losses in order to correctly determine machine capacity. The machine capacity metrics is the most important aspects in PPC.

Machine capacity which its technical designer had in mind without considering a variety of time restriction that can limit its operation is the machine design capacity (C_D). It gives maximum theoretical output of a machine that has been assigned for a process within weekly maximum manufacturing hours (T_{max}).

In actual, many organizations would not operate their machines at the shop floor continuously all the time. There are many factors as mentioned earlier to explain such unavoidable manufacturing time loss. Therefore, machines are normally run at a rate less than maximum capacity. The actual capacity which remains after such losses are accounted for is called Effective Capacity (C_E).

Fluctuations in equipment availability, operator availability, WIP availability and/or unplanned situations (power failure, water supply cut off, fire and even included any other natural disaster that may occur) must be taken into consideration as it will play a significant effect in causing manufacturing hour loss, which in turn contributes to down time. Safety Capacity (C_s) express in a form of percentage (%), set aside total units of products produced per single unit machine that can accommodate protection against interruption to the normal operation of the shop floor.

1.3.2 Machine Performance Metrics

Every machine in the shop floor deal with various downtime, operational losses, performance loss and quality problems, which unable it to reach the maximum theoretical design performance. Based on Overall Equipment Effectiveness (OEE) proposed by Nakajima (1988), machine performance relative to its maximum capability can be measured through A_{eff}, P_{eff} and Q_{eff} as explained below:

where,

i. A_{eff} is the availability efficiency that captures:
    - Planned downtime includes days of work off, state holidays, time for overhaul, time for cleaning the workplace, but even development and testing, in some cases, can be considered as a loss;
    - Operational loss includes time for setting up machines, time for changes in production, waiting time for material delivery, and time wasted with bottlenecks or by operator's mistakes, as well as breakdowns;

ii. P_{eff} is the performance efficiency that captures productivity loss due to wrong machine settings, slowing down the production cycle or causing failures, reduced speed, idling and minor stoppages.

iii. Q_{eff} is the quality efficiency that captures loss due to material defects and product rejects, production imperfections, reworks, and repairs decrease efficiency and production effectiveness.

Shop floor basic behaviour and quantitative metrics problems are now the focus of this PPC research. The following problem statement is presented as the underlying of the model development study.

1.4 Problem Statement

Global competitive conditions, new technology development, higher customer expectations, increasing supplier capabilities and so on push for continuing improvement of the PPC system. Shop floor system implemented must be able to react quickly and have the flexibility to adapt to the variability and randomness events encountered.

Depending on the size of the companies, shop floor may have only a few units of machine or hundred units of machine that performed different functions according to the routing of its unit processes. Most machines are running twenty-four hours to supply enough products for the global market demands. Poor computation yielded over capacity commitment which results in failures to keep promised delivery dates, or that is under capacity and result in excessive lead times. For small companies involving only small number units of machines, machine capacity planning is not a complicated task. Therefore, it was not considered in this research.

Many organizations unknowingly invest in more capital to compensate for poor performance machine. Some invest money to supplement capacity that already have but do not exploit. For example, invest in a new machine to increase the capacity while the existing is operating at only 30% of its potential.

In practice, machine capacity and machine performance are not constant over time and greatly related to variability and randomness of shop floor basic behaviour that could change at shift level, daily level or work week level. Together with the high-continuity requirements of its production line, both have become an important PPC issue. Traditional metrics for measuring productivity, throughput, and utilization are insufficient for identifying the problems and underlying improvements for PPC. As such, production system should have a well defined quantitative metric to use as standardized measure for computing machine capacity and judging on the machine performances.

PPC depends on basic rules and principles. From modelling view point, some commercial software are just too simple or too idealistic and do not include in realistic variability and randomness faced in the shop floor. There has not been much effort in deriving widely accepted rules for machine capacity computation and machine performance measurement in shop floor design and control. This research reduces the complexity of shop floor in a production system to a manageable level by restricting the attention to modelling shop floor basic behaviour and quantitative metrics for PPC using a spreadsheet.

The ideal model construction enables input recording of different shop floor behaviors, which can occur within areas of a shop floor. The effective model would have quantitative metrics based on mathematical approach and resides in a spreadsheet for data input and output computation. A significant criterion of the model is that, it can also provide what-if scenarios to help users to generate solution for any practical case study scenarios and requirements. It compares the actual input and output to the planned input and output that routes through production system. The model helps to find hidden production capacity for even better utilization of production machine through machine capacity computation and monitoring. It also provides reason for investments into new machines if machine performance is justified to be cannot further improve.

Making changes to the models of the shop floor system instead of the actual system allows fast acquisition of the knowledge and avoids the risk of costly disruptions to the real system. It builds a description to understand the important factors in the real system and finds a good solution to the problem.

1.5 Research Objectives

This research has several objectives, includes:

1 To provide insights - better understanding of the shop floor behavior and quantitative metrics associated with it.

2 To allow performance prediction - examining machine capacity and machine performance to meet product mix demand over a planning horizon.

3 To perform justification - as diagnostic tools to find underlying cause of the PPC problems exist in the production system based on quantitative metric, the real causes can be identified then.

4 To allow control - aiding the selection of the control policies for the shop floor system.

5 To make decision - finding the best machine capacity and machine performance.

1.6 Scope of the Study

In this research, machine capacity and machine performance problem for PPC will be addressed. The scope is across medium term (tactics) and short term (control) machine capacity and machine performance decisions in PPC horizon.

The research will present a shop floor basic behaviour and quantitative metric model for manufacturing industry, particularly a high mixed low volume production system which can provide a high degree of product flexibility. Machines that perform the same function are classified into many workstations in process oriented layout to satisfy different processing requirements.

In most operation of this kind, volumes of products produced are directly dependent on the customer demand. It is assumed that the demand is given or is based on deterministic demand forecast. Batch processes are used to produce products based on customer order and specifications. Each batch produces a fixed amount of product and consumes a fixed amount of the limited resources as explained by Graves (1999).

This research presents the development of a process-oriented layouts machine capacity computation and machine performance measurement model using spreadsheet modeling technique. The model can assist in address a wide range PPC issues and specific decision problems.

1.7 Outline of the Thesis

The thesis is divided into seven chapters. They are organized as below:

Chapter 1 introduces the general scope of production planning & control (PPC), specific problem of interest and importance to the research community, and addresses the problem statement and associated research objectives.

Chapter 2 presents the literature reviews on previous research work of PPC and quantitative metric measurement in general. It discusses the different perspectives to fill the existing gap between theory and practice related to machine capacity and machine performance for PPC.

Chapter 3 presents the methodology for quantitative modeling OEE using spreadsheet for machine capacity planning. It entails identify and categorize shop floor basic behavior, model development framework, verification and validation approach for the model developed.

Chapter 4 presents the model development of quantitative metrics based on shop floor basic behaviour. The formulation of a set of mathematical equations used for development of the spreadsheet model will be derived.

Chapter 5 provides verification and validation of the PPC model developed. The detail results are discussed to demonstrate the flexibility for execution and proliferation in a wide range of applications through practical case study.

Chapter 6 discusses and compares the results in relation to objectives of the research. It highlights the evidence obtained from the verification and validation findings and outlined extended knowledge of the research area in comparison to what is already known.

Chapter 7 presents a summary and conclusions drawn from this research work in terms of moving towards a disciplinary approach to PPC. This chapter ends with the future research work recommendation.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter reviews the previous and current literature studies related to the PPC system, specifically capacity planning and overall equipment effectiveness (OEE). It begins with discussion on PPC in general to provide a broad review of some existing research on ways to managed uncertainty in production system. It is intended to classify the literatures based on the trend and development.

Literature related to challenges and issues in capacity planning are discussed and model approaches are reviewed. The basic OEE theory is reviewed and various OEE based research work implemented in the manufacturing industry are presented to gain an understanding of the current state of the researches.

Implications of the review will be addressed to identify areas of machine capacity planning and overall equipment effectiveness (OEE) that have not been fully addressed. Summary is made to justify on the background of this research.

2.1 PPC System Development and Evolution

In a broad sense, production planning and control (PPC) is concerned with ensuring operation processes run effectively and efficiently to satisfy customer demand. Complexity of the production system, a varying set of customer's requirements and operation resources require managing the ongoing planning and control activities such as scheduling, coordination and organization.

In this era of company globalization, manufacturing business is facing immense market requirements that change over time. Therefore, it is critical for manufacturing management to make decision with future plan in mind. One very best way is to consistently review the literature of PPC development and evolution to understand the trend of formality and detail.

PPC development and evolution since the beginning of the 1930's to date has been summarized in Figure 2.1 as follow:

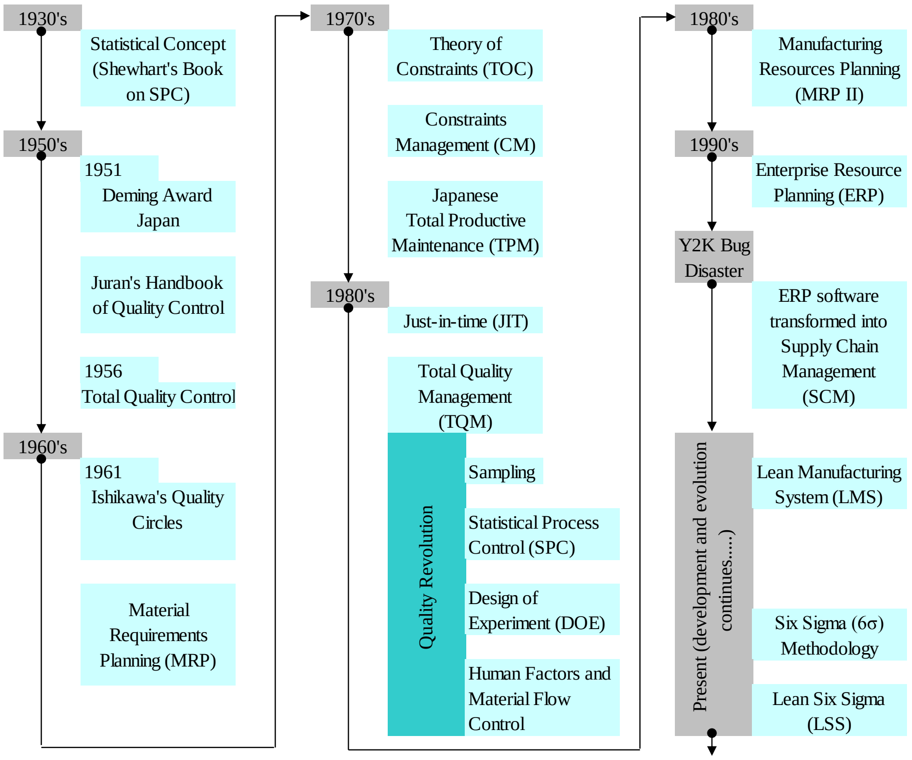

Figure 2.1 PPC Development and Evolution

PPC has been heavily concerned by manufacturers; according to Gilbert et al. (1983) some of the common techniques used were the two-bin system, economic order quantity (EOQ), and reorder point.

Back to 1930s, Shewhart (1931) introduced the concept of statistical methods into quality control. Feigenbaum (1956) published the term total quality control for good quality management. The quality trend of PPC movement widely accepted from 1950s to 1980s under the influence of Deming (1960) and Juran (1964). External quality concerned to customer satisfaction; and internal quality of output from each unit process have both received focus and attention to improve the production system.