Faculty of Industrial and Manufacturing Technology and Engineering

OPTIMIZING MACHINE CAPACITY FOR MEETING VOLATILE DEMANDS: A SIMULATION-BASED DECISION-MAKING APPROACH

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Master of Manufacturing Engineering (Industrial Engineering)

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A thesis submitted in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering)

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DECLARATION

I declare that this thesis entitled "Optimizing Machine Capacity for Meeting Volatile Demands: A Simulation-Based Decision-Making Approach" 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 in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Industrial Engineering.

Signature : ………………..

Supervisor Name : Ts. Dr. Saifudin Hafiz Bin Yahaya

Date : ……………………………………………

DEDICATION

I would like to dedicate this thesis to my family, whose unwavering support and encouragement have been the driving force behind my academic journey. Their love, understanding, and belief in my abilities have provided me with the strength and motivation to overcome challenges and pursue excellence. I am grateful for their sacrifices, patience, and constant encouragement throughout this endeavor. This achievement is a testament to their unwavering faith in me. Thank you for always being there for me.

ABSTRACT

This thesis aims to optimize machine capacity in food processing industry to meet volatile demands. The objectives of the study include identifying current capacity problems, constructing a simulation model to evaluate different blender capacities, validate the model and recommend the best blender configuration. The four objectives are successfully fulfilled following the eight steps of simulation technique framework. AnyLogic software is used to construct a simulation model, for model validation and scenarios testing. Nice scenario testing are performed and the simulated output are examined, an optimum blender configuration is determined through the elimination approach in the selection process. An option of addition of 3000 litre blender is appears to be the best choice among all option as it is able to accommodate from small to extreme demand growth, while creating several advantages on the flexibility in term of resource allocation and operational hours. The study contributes to the existing body of knowledge in the field of capacity utilization and demand volatility management within the food processing industry. Extended study should be continued to evaluate blender configuration effectiveness considering investment, production, labor and refurbishment costs, along with incorporating additional metrics like service level and sales lead time.

PENGOPTIMUMAN KAPASITI MESIN UNTUK MENGATASI PERMINTAAN PASARAN YANG TIDAK MENENTU: PENDEKATAN KEPUTUSAN BERASASKAN SIMULASI

ABSTRAK

Kajian ini bertujuan untuk mengoptimumkan kapasiti mesin dalam industri pemprosesan makanan bagi memenuhi permintaan yang berubah-ubah. Objektif kajian termasuk mengenal pasti masalah muatan semasa, membina model simulasi untuk menilai muatan mesin yang berbeza, mengesahkan model dan mencadangkan tatarajah mesin yang terbaik. Keempat-empat objektif tersebut berjaya dilaksanakan mengikut lapan langkah rangka kerja teknik simulasi. Perisian AnyLogic digunakan untuk membina model simulasi, proses pengesahan model dan pengujian senario. Pengujian sembinan senario dilakukan, dan keputusan yang disimulasikan dikaji, di mana tatarajah mesin optimum ditentukan melalui pendekatan penyingkiran dalam proses pemilihan. Pilihan penambahan mesin 3000 liter kelihatan sebagai pilihan terbaik di antara semua pilihan kerana ia mampu menampung pertumbuhan permintaan dari yang kecil hingga lampau, sambil mencipta kelebihan dalam kebolehlenturan dalam pengagihan sumber dan waktu operasi. Kajian ini menyumbang kepada pengetahuan sedia ada dalam bidang pengurusan muatan mesin dan pengurusan ketidakstabilan permintaan dalam industri pemprosesan makanan. Kajian lanjutan perlu dijalankan untuk menilai keberkesanan tatarajah pengadun dengan mempertimbangkan kos pelaburan, kos produksi, kos buruh, dan kos penyelenggaraan, bersama dengan penilaian metrik tambahan seperti tahap perkhidmatan dan masa mendulu jualan.

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LIST OF SYMBOLS

#	-	number
%	-	percentage
dd/mm/yy	-	day/month/year
hr	-	hour
hr/day	-	hour/day
KG	-	kilogram
kg/hr	-	kilogram per hour
kg/l	-	kilogram per litre
MT	-	metrix tonne
No	-	number

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LIST OF ABBREVIATIONS

AOR	-	Average output rate
AP	-	Annual production
ASS	-	Average shop order size
AVA	-	Availability
BE	-	Back end
CAGR	-	Compound annual growth rate
CaT	-	Calender time
CCP	-	Chance constrained programming
CEP	-	Capacity expansion problem
CT	-	Cycle time
DES	-	Discrete Event Simulation
DOE	-	Design of experiment
DT	-	Dumping time
DTA	-	Decision tree analysis
Etc	-	Et cetera
FE	-	Front end
FMS	-	Flexible manufacturing system
FIFO	-	First in first out
GIS	-	Geographic information system

LR	-	Loading rate
Max	-	Maximum
Min	-	Minimum
MT	-	Mixing time
MTTR	-	Mean time to repair
NA	-	Not available
NPVaR	-	Net present value at risk
PH	-	Public holiday
PO	-	Production order
POT	-	Plant operating time
PT	-	Packing time
RMS	-	Reconfigurable manufacturing system
ROA	-	Real option analysis
SA	-	Simulating annealing
SAP	-	Systems, Applications and Products in Data Processing
SC	-	Staffed capacity
SCU	-	Staffed capacity utilization
SKU	-	Stock keeping unit
SMO	-	Simulation-based multi-objective optimization
SO	-	Sales order
SOPS	-	Number of shop order per shift
SP	-	Stochastic programming
SS	-	Staffed shift
TA	-	Throughput accounting
VaR	-	Value at risk

WD	-	Working days
WH	-	Working hours
WIP	-	Work in progress

LIST OF PUBLICATIONS

1. Chew Woon Ang, Saifudin Hafiz Yahaya, Novi Cahyadi. (2024). A Comprehensive Review of Different Approaches Used by Manufacturing Industries in Handling Capacity Planning Under Demand Uncertainties. Multidisciplinary Revision (in approval process).

CHAPTER 1

INTRODUCTION

Project background

In today's fast-paced and ever-changing manufacturing environment, it is important to invest into right machine to meet the volatile demands. However, deciding on the optimal capacity is always challenging as it involves trade-off between the cost of the investment and the benefits of increased capacity. In order to sustain a given demands over a planning horizon, three tiers of capacity planning are involved in most of the organization, which are long term capacity planning, medium term and short-term capacity planning. For the long-term capacity planning, it always reviews the new and existing product lines and processing technologies where it determines (1) facility location and plant capacities, (2) major supplier plan and integration, (3) production technology and (4) principal operation modes and production methods. The medium term is looking into monthly or quarterly resources requirement and it typically involve a one-year planning horizon. While for short term, it always looks at daily or weekly capacity planning horizon, which is long enough to accommodate each order's lead time. (Chen et. al., 2009)

Based on (Olhager et. al., 2001), capacity is most often treated at an aggregate level which deal with key work centers and forecast of product families. Typical horizon for long term capacity planning is 1 to 5 years when it looks into the capacities that take long time to change, either to acquire new capacity or to reduce the capacity level. The fundamental foundation for such strategy is that capacity comes in large, discrete steps rather than in small increments. Therefore, it is very crucial to decide whether capacity should come first prior to expected changes in demand or the capacity should be acquired when the corresponding level of demands has been acknowledged. In normal operating perspective, capacity can only be changed in a discrete step with a considerable lead time. A significant capacity expansion results the changing in capacity step wise as illustrated in Figure 1.1.

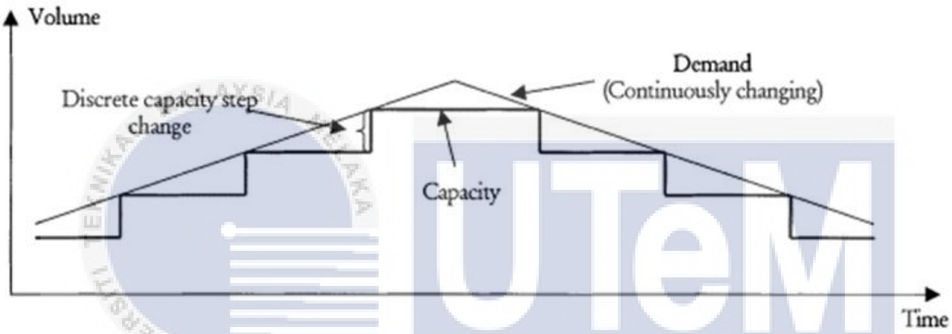

Figure 1.1: Capacity step wise change over continuous demand change
(Olhager et. al., 2001)

The growth in food manufacturing industry in the recent years has an exponential trend however it is challenged with high levels of demand volatility. The Food and Beverage Services Global Market Report expects the global market to grow from $3.2 trillion in 2021 to $3.7 trillion in 2022. For a plant that has reached the maximum capacity utilization, in order to meet the growing demands, existing capacity has to be expanded as a long-term capacity improvement plan (Chou et. al., 2014). Each expansion is triggered when demands has reached certain fixed proportion of the capacity position. Based on (Okunade and Oluwaseun, 2018) capacity utilization is measured in 100% efficiency level in theory, however in real manufacturing environment, due to some setbacks in the production process which coupled with wastages and breakdown, capacity utilization may not exceed 90% maximum level as practical. Each manufacturing firm will determine their optimum level of utilization based on the principle of cost optimization. According to (De Giovanni and Massabò, 2018) in their study on capacity investment under uncertainty, it was discussed that firms always encounter two contrasting forces when planning an investment in a production plant, especially in the high volatile market driven plant. On one hand, the possibility of increased demands makes firm desire to invest in either an expanded capacity or a larger production plant; but on the other hand, the high risk of market's breakdown change the firm decision to conservatively look at smaller investment, eg. invest new or replace a machine.

Table 1.1 describes the characteristics of food processing industry complied from literature (Pieter van Donk, 2000). In recent years, the food industry has changed its supply approach from supply-based to demand-based approach, which is also called "chain reversal". This simply means the consumers are the one telling the manufacturer what they want. As eating and taste perception are getting more individual, product is developed to respond to the preference of individual users, and production has to be operated in more flexible way compared to the past (Melissa et. al., 2018). Bech et. al. (2019) in their case study in food industry on product and process variety management have compared the process manufacturing with other durable goods manufacturing in their on the product variety management. It was discussed that product variety can be managed through postponement, delayed product differentiation in most of the durable goods manufacturing. However, this is not seemed to be feasible for food processing industry with inflexible setup in the process. The challenge is added up with the introduction of reduced order sizes which complicate the planning and production control process in food industry. Finally, these situations have resulted broader product variety from food manufacturing industry, as it has to cater for various demands, individual customer’s taste preference and order size preference.

Table 1.1: Characteristics of food processing industry complied from literature (Pieter van Donk, 2000)

Plant Characteristics
• Expensive and single purpose capacity coupled with small product variety and high volumes. • There are long (sequence dependent) set-up times between different product types.
Product Characteristics:
• The nature and source of raw material in food processing industry often implies a variable supply, quality and price. • Volume and weights measurement are used. • Raw material, semi-manufactured products and end products are perishable
Production process characteristics:
• Processes have a variable yield and processing time. • At least one of the processes deals with homogeneous products. • The processing stages are not labour intensive. • Food industries have a divergent product structure, especially in the packaging stage.

Powder blending process in specific is a challenging process when we look at creating the desired powder properties as the requirement is stringent due to the end application. Typical process involves mixing, drying, separation, agglomeration,