PINCH-BASED TARGETING FOR PRODUCTION PLANNING FOR SMALL AND MEDIUM ENTERPRISE

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DEDICATION

I dedicate this humble effort to my beloved wife
and our lovely children for their continuous
prayers, love, support and understanding

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ABSTRACT

Pinch analysis techniques have been widely used as systematic design tools in the chemical process industry over the past decades. However, there has been very limited work on the use of pinch analysis in the area of production planning. Some of the common problems encountered by Malaysian small and medium enterprises (SMEs) are fluctuation of demand and supply of goods, inadequate warehouse, machine allocation problem, and the lack of factory space. With the application of systematic production planning techniques based on pinch analysis, these problems can now be resolved. The research objective of this dissertation is to develop novel graphical tools for production planning for the SMEs. In this dissertation, new pinch targeting techniques known as *production planning pinch diagram* and *production planning grand composite curve* (PPGCC) are presented to assist production planning in the SMEs. The research methodology adopted was from similar graphical tools utilized for the recovery of energy, material resources, carbon capture and storage, production supply chain and human resource planning in the chemical process industry. The targeting techniques are graphical in nature where pinch point that acts as production bottleneck can be identified and opportunities for operational changes can be explored easily. Four illustrative examples and four industrial case studies were done to demonstrate how pinch analysis could be used to solve the various production planning problems faced by the SMEs. The case studies show that pinch analysis is practical for the manufacturing industries and provides tangible benefits such as cost savings from reduction of outsourcing and lead time, as well as better cash flow management. The developed methodology in this dissertation can also be extended to a broad range of applications, such as large scale manufacturing, logistics, agriculture, aquaculture, livestock, infrastructure development, forestry, medical, automotive, immigration, town planning and construction.

ABSTRAK

Teknik-teknik analisa jepitan (*pinch analysis*) telah digunakan secara meluas sebagai alat rekabentuk yang sistematik dalam industri proses kimia sejak beberapa dekad yang lalu. Namun begitu, penggunaan analisa jepitan dalam bidang perancangan pengeluaran didapati sangat terhad. Antara masalah umum yang dihadapi oleh indusri kecil dan sederhana (IKS) di Malaysia adalah melibatkan permintaan dan bekalan barangan yang tidak menentu, gudang yang tidak mencukupi, masalah peruntukan mesin dan juga dari segi kekurangan ruang kilang. Masalah-masalah ini boleh diselesaikan dengan menggunakan aplikasi jepitan sistematik yang berasaskan perancangan pengeluaran. Objektif penyelidikan bagi disertasi ini adalah untuk membangunkan alat grafik *novel* bagi perancangan pengeluaran buat kegunaan IKS. Di dalam disertasi ini, teknik *menyasar jepitan baru dan keluk komposit utama perancangan pengeluaran* (PPGCC) telah dibentangkan untuk membantu perancangan pengeluaran di syarikat IKS. Metodologi penyelidikan yang digunapakai adalah dari alat grafik yang serupa digunakan untuk proses mendapatkan tenaga, sumber bahan, pengumpulan dan penyimpanan karbon, rantaian bekalan pengeluaran dan perancangan sumber manusia di dalam industri proses kimia. Teknik-teknik yang menyasar adalah berbentuk grafik secara amnya di mana titik jepitan yang bertindak selaku kejejalan pengeluaran dapat dikenalpasti dan peluang untuk perubahan operasi boleh diterokai dengan mudah. Empat contoh ilustrasi dan empat kajian kes industri telah dilakukan untuk menunjukkan bagaimana jepitan perancangan pengeluaran ini dapat menyelesaikan masalah yang dihadapi oleh syarikat-syarikat IKS. Kajian kes telah menunjukkan bahawa analisa jepitan adalah pendekatan yang praktikal untuk industri pembuatan dan dapat memberi faedah yang ketara seperti penjimatan kos dari pengurangan penyumberan luar, pengurangan masa penghasilan dan juga pengurusan aliran tunai secara lebih baik. Kaedah yang dibangunkan untuk IKS ini boleh diperluaskan buat pelbagai aplikasi lain seperti di dalam proses pembuatan pada skala yang besar, logistik, pertanian, akuakultur, ternakan, pembangunan infrastruktur, perhutanan, perubatan, automotif, imigrasi, perancangan bandar dan juga pembinaan.

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CHAPTER 1

INTRODUCTION

1.1 Background Problem

Most companies especially small medium enterprises (SMEs), face seasonal demand and production problem, which lead to the emergence of lean and peak periods. Such variation in demand and supply is normally beyond the manufacturer's control. In current practise, the approach to the problem is to plan on production capacity or storage space, in order to accommodate the varying demand. Production planning issues are often addressed through the use of mathematical model or systematic quantitative decision support techniques. For example, linear optimization models are used for multi-site production environment (Kanyalkar *et al*., 2005, Kanyalkar and Adil, 2007); while Gunther *et al*. (2006) integrates production planning and worker training considering machine and worker availability, operation sequence and multi-period planning horizon. Besides, analytical approaches where uncertainties are described as probability distributions have also been presented (Feng *et al*., 2011). Various models and techniques for production and distribution are recently reviewed by Fahimnia *et al*. (2013). However, most of these techniques require specialized technical knowledge that may not always be possible for the staffs of SMEs. Therefore, simple and intuitively appealing techniques are required to aid in production planning and coordination especially in SMEs.

Pinch analysis techniques have been widely used as systematic design tools in the chemical process industry over the past decades. The techniques were initially developed for the design of heat-recovery systems for industrial energy conservation (Linnhoff *et al*., 1982). This methodology was later extended into various mass integration techniques (El-Halwagi and Manousiouthakis, 1989; El-Halwagi, 1997, 2006) for efficient use of *mass separating agents* for pollution prevention. Later, pinch analysis techniques were developed for material recovery systems, focussing on the efficient use of process water (Wang and Smith, 1994; El-Halwagi *et al*., 2003; Manan *et al*., 2004; Prakash and Shenoy, 2005; Agrawal and Shenoy, 2006; Foo, 2009, 2012), as well as industrial gases (Alves and Towler, 2002; El-Halwagi *et al*., 2003; Agrawal and Shenoy, 2006; Foo and Manan, 2006; Foo, 2012). Aside from the traditional applications, pinch analysis has also been extended into a variety of non-conventional areas such as financial management (Zhelev, 2005), supply chain management (Singhvi and Shenoy, 2002; Singhvi *et al*., 2004; Foo *et al*., 2008), *emergy* analysis (Zhelev and Ridolfi, 2006), carbon-constrained energy planning (Tan and Foo., 2007; Lee *et al*., 2009), carbon capture and storage (Tan and Foo, 2009; Sahu *et al*., 2013; Ooi *et al*., 2013, 2014), short-term scheduling of batch processes (Foo *et al*., 2007) and human resource planning (Foo *et al*., 2010). However, there has been very limited work on the use of pinch analysis for the area of production planning.

An earlier attempt to use pinch analysis approach for production supply chain has been reported by Singhvi and Shenoy (2002). The authors later extended the work to cover for multiple products manufacturing (Singhvi *et al*., 2004). In these earlier works, graphical targeting tools were proposed to determine the minimum production rate for known customer demand across a given planning horizon. Subsequently. Ludwig *et al*. (2009) extended the techniques for production with seasonal demand, where different production strategies were evaluated based on cost parameters. An algebraic-equivalent tool to determine the minimum production rate was reported by Foo *et al*., (2008), which incorporated the consideration of maximum and minimum inventory limits. In these previous works, the main objective is to determine the production rate based on the seasonal forecast for the planning horizon. However, all the above techniques do not address the minimization of outsourcing resources, neither do they explore opportunities for operational changes.

1.2 Importance of the Study

Due to global changes in economic, globalization of the markets, change in customer needs and competition increase, new businesses have been developed and are rapidly expanding (Javadi *et al*., 2012). Under the prevailing rapid change trend, manufacturers today are subjected to constant change and ever increasing complexity. This confronts manufacturers with various threats and challenges. As such, keeping an efficient operation in order to keep up with the competition is no longer an initiative, but a crucial survival means to ensure a manufacturer's continuous existence

Manufacturers often struggle to increase their productivity and capacity to keep up with demand. As such, they need to continually change their work processes to support growth, especially when there are resource constraints. Process integration strategies such as pinch analysis can help manufacturer to apply efficient production planning through a systematic approach to identify and improve efficiency, eliminate waste, integrate their work processes and by instituting a philosophy of optimization (Foo *et al*., 2010).

Process integration particularly pinch analysis focuses on operational efficiency and optimization that add value from timeliness and volume perspective which form the basic principle of operational excellence in manufacturing. There is no question that operational efficiency is an essential ingredient for survival in today's manufacturing world. Companies must strive to create high quality and low cost products that can get to customer in the shortest time. In this research, the author has strongly recommended the application of pinch analysis for better production planning which can enhance the operational efficiency of manufacturing.

In this dissertation, novel graphical tools for production planning for SMEs are proposed. These newly proposed tools can be used to optimize warehouse space and production capacity for production machinery, which are common challenges in most SMEs. In addition to that, it also helps to minimize their outsourcing problem and to explore opportunities for operational changes. As a result, the manufacturing plant is able to reduce idle space and/or excess machines capacity, to integrate its existing operation, and to improve its operational efficiency leading to higher profits.

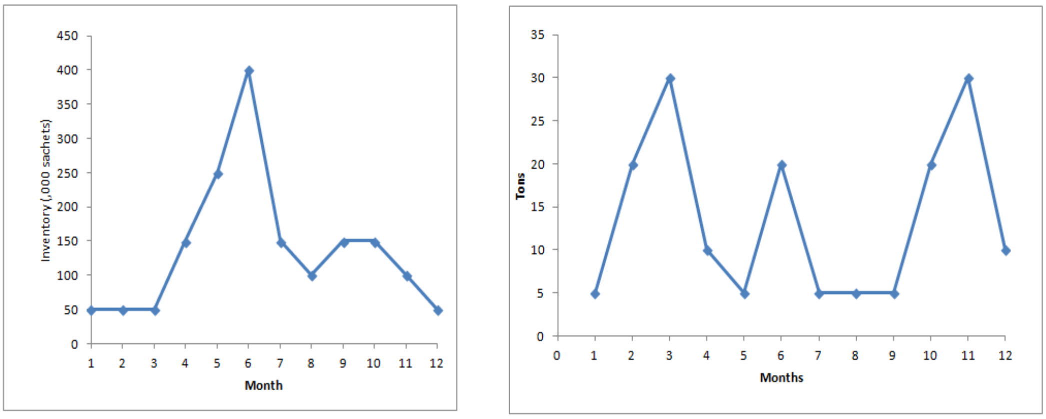
1.3 Problem Statements

Supply and demand of goods are usually beyond the manufacturers' control. However, to certain extent, control of time and capacity adaptation is still possible. Note that machine capacity and warehouse space can either be fixed or variable in most cases. For instance, if factory or warehouse is a standard industrial lot with fixed dimension; or packaging machine is available in standardized capacities, this is classified as *fixed-capacity with variable time problem.* On the other hand, in case where factory, warehouse or packaging machines are available at a continuous range of capacities; i.e. manufacturer could acquire them according to their exact requirement, those units can then be classified as a *variable-capacity* and *variable time problem*. For example, such cases usually occur in pharmaceutical and allied industries (herbaceutical, cosmeceutical, bioceutical, cosmetic, herbal and traditional medicine). These problems have grown in term of their importance in recent years due to the recognition of SMEs as the generative engine behind economic growth, its substantial contribution to the country's GDP and one of the main sources of employment.

In this dissertation, novel graphical tools for production planning are proposed. These newly proposed tools are demonstrated with case studies based on Malaysian SME factories. The following are some specific problems that are commonly encountered by most Malaysian SMEs and these two companies.

i) Fluctuation of demand and supply of goods

Fluctuation of product demand and supply of raw materials are common challenges faced by Malaysian SMEs. Thus, it creates a peak and lean periods in the planning horizon. The peak may occur once or even twice in the case of seasonal demand for instance during summer or winter depending on the nature of the product (see Figure 1).



(a) (b)

Figure 1: Product Demand with (a) Single peak (b) Double peak

ii) Inadequate warehouse allocation problem

The problem arises when a company/facility seeks to maximize its internal resources such as storage space while minimizing outsourcing requirements. The goal of the company is to reduce idle space or outsourcing when internal space is inadequate to meet its increasing demand.

iii) Inadequate machine allocation problem

As demand of goods increase, SME seeks to maximize the use of its machineries while minimizing their outsourcing requirements. The main objective of the SME is to reduce idling or excess machine capacity and outsourcing wherever possible. As a result, this will improve the operational efficiency of the factory thus increasing its profits.

iv) Lack of factory space optimization

This problem arises when a company/facility seeks to maximize use of its internal resources, such as production capacity, due to increase in demand of goods; while minimizing outsourcing requirements. Note that the problem is more serious in Malaysian SMEs due to the typical lack of access of such firms to adequate financing for expansion of facilities. Thus Malaysian SMEs will often simply rent readily available industrial space for storage, or expansion of new production lines. Therefore, proper production planning in the Malaysian SMEs presents unique challenges.

1.4 Research Objective

The goal of this research is to develop novel graphical tools for production planning for SMEs. The research hypothesizes that there are big opportunities for improvement in production planning, operational efficiency and profitability, if these graphical tools for production planning are used. These tools should be user friendly and do not require specialized technical knowledge that may not always be available in Malaysian SMEs.

The objective of this dissertation is to develop graphical tools, and to demonstrate their uses for production planning in the SMEs for production and operation improvement. This will ensure a better use of various production resources such as warehouse space, machine, workers, and production time.

The objectives of this study include the following:

i) Development of new graphical tools for production planning in SMEs.
ii) To optimize the use of internal resources such as warehouse space, sachet -filling machines, workers, finances, in order to minimize outsource requirements.

iii) To explore opportunities for operational changes using the newly developed graphical tools.

iv) To demonstrate the practicability of these graphical models for production planning in two local SME plants, i.e. nutraceutical and cosmeceutical factories.

1.5 Scope of Study

The main aim of this dissertation is to improve the overall production planning and the operational efficiency of Malaysian SMEs. Therefore, the proposed process integration techniques were applied to solve the following problems:-

a) Improving fermentation tanks availability, toothpaste tube filling machine usage, warehouse usage, sachet-filling machines usage, packing workers allocation and renovation time.
b) Exploring opportunities for operational changes
c) Determination of exact timing when external resources are needed.
d) Minimizing outsourcing thus improving profit margins of the company.

These operations are considered to be the important characteristics which would enable the company to show improvement in term of operational efficiency and profitability.

This research, however, does have some limitations and constraints. Firstly, the scope has been focused on two industries which the author is familiar and currently working there. This was used as a sample of the study which is supposed to represent the Malaysian SME particularly the nutraceutical and cosmeceutical sector. The other aspects such as aggregate supply chain, financial pinch, equipment pinch and human resource pinch was not covered at all, as these aspects have been explored in previous studies (Singhvi *et al*., 2004; Zhelev, 2005; Foo *et al*., 2007 and Foo *et al*., 2010).

The other limitation is that when applying production planning pinch, a finite time planning horizon is required. The sink and source sources are non-renewable or reusable during the planning horizon. Should there be any outsourcing, it has to be from external sources. Internal sinks are considered to be fully utilized and non-recycle able during the planning horizon.

1.6 Structure of this Dissertation

This dissertation is divided into six chapters.

Chapter 1 highlights the seasonal demand and production problems faced by the SMEs which lead to lean and peak periods. These problems are beyond the manufacturer's control. The development of pinch analysis techniques over the years has been explained. Importance of this study emphasizes the need for manufacturer to be highly efficient to be able to survive in today's globalized market.

Literature review presented in Chapter 2 covers the development and use of pinch analysis as systematic design tools in the chemical process industry over the past decades. The techniques were initially developed for the design of heat recovery system, was later extended into various mass integration techniques. The technique was later developed for general resource conservation networks extended into a variety of non-conventional areas such as financial management, supply chain management, carbon-constrained energy planning, carbon capture and storage, short-term scheduling of batch processes and human resource planning.

Chapter 3 describes the methodology of the research, which is development of graphical tools for production planning. These newly proposed tools can be used to optimize internal resources such as warehouse space, production capacity for production machinery, which are common challenges in most SMEs.

Chapter 4 describes four illustrative examples. The first two examples describe the production planning for warehouse allocation with fixed capacity and variable time problem and production planning for sachet-filling machines with variable capacity and variable time problem. The third and fourth examples illustrate production planning for a Chia seed powder factory and financial planning for a nutritional food processing factory.

Chapter 5 outlines four industrial case studies using the newly developed techniques in Chapter 4 at Life Science Corporation and Cosmescience Sdn. Bhd. This chapter discusses how the application of these techniques has improved the efficiency of the manufacturing processes. Two examples were used for each factory. For Life Science Corporation, the allocation of fermentation tanks and packing workers were demonstrated. On the other hand, construction of a new plant and toothpaste tube filling machine allocation problems were demonstrated for Cosmescience Sdn. Bhd.

The research is concluded in Chapter 6. Possible future works and extensions to other areas of application are suggested. These include manufacturing, service, logistic, agriculture, veterinary, aquaculture, fisheries, forestry, contract farming, infrastructure development and even construction industries.

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