STUDY ON A MAXIMUM PAPER FIBRE RECOVERY NETWORK DESIGN

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ABSTRACT

This work presents the development of a mathematical model for maximum paper fibre recovery network. This can be achieved by implementing the mathematical approach on design and modelling of paper fibre recovery network. The purposes of this study are to design a mathematical model for paper fibre recovery network where it considering a multiple paper characteristics. This work involved few steps, firstly, gathering of limiting data on paper fibre, followed by representation of superstructure, developing of mathematical formulation and next application of model in GAMS software in order to get optimal maximum fibre recovery and lastly, implemented the model in the urban case study. The model develop can simultaneously target and design of paper fibre recovery network. It is less tedious and more effective compared from previous method from previous researches. A significance amount of fresh fibre consumption in paper manufacturing can be reduced at the end of this study. As a result, the percentage reduction of fresh fibre consumptions after application of proposed technique is 32.20% and 26.17% for high quality paper and low quality paper respectively.

KAJIAN TERHADAP REKA BENTUK RANGKAIAN PEMULIHAN SERAT KERTAS MAKSIMUM

ABSTRAK

Kerja ini membentangkan tentang pembangunan model matematik untuk pemulihan serat kertas yang maksimum. Ini boleh dicapai dengan melaksanakan pendekatan matematik bagi reka bentuk dan model rangkaian pemulihan kertas serat. Tujuan kajian ini adalah untuk mereka bentuk model matematik untuk pemulihan rangkaian kertas serat dan melaksanakan model dalam kajian kes Bandar di mana ia mengambil kira ciri-ciri kepelbagaian kertas. Kerja ini melibatkan beberapa langkah, pertama, mengekstrak data terhad ke atas gentian kertas, diikuti oleh perwakilan mahastruktur, membangunkan rumus matematik dan seterusnya model diaplikasi dalam perisian GAMS untuk mendapatkan pemulihan serat yang optimum dan akhir sekali, model diaplikasi dalam kajian kes bandar. Model yang dibangunkan pada masa yang sama boleh mensasar dan reka bentuk rangkaian pemulihan kertas serat. Ia adalah kurang membosankan dan lebih berkesan berbanding kaedah yang diperkenalkan oleh penyelidik sebelum ini. Jumlah penggunaan serat kertas yang segar dalam pembuatan kertas boleh dikurangkan pada akhir kajian ini. Hasilnya, pengurangan peratusan konsumsi serat segar selepas penggunaan teknik yang di cadangakan adalah masing-masing 32.20% dan 26.17% untuk kertas berkualiti tinggi dan kertas berkualiti rendah.

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LIST OF SYMBOLS

Da_j	Flow rate of high quality paper fibre demand
Db_j	Flow rate of low quality paper fibre demand
Da_1	Demand on high quality paper fibre, Magazine
Da_2	Demand on high quality paper fibre, Manila Card
Db_1	Demand on low quality paper fibre, Newspaper
Db_2	Demand on low quality paper fibre, Tissue
Db_3	Demand on low quality paper fibre, A4 Paper
Db_4	Demand on low quality, Corrugated Box
FF	Fresh Fibre
Sa_i	Flow rate of high quality paper fibre source
Sb_i	Flow rate of low quality paper fibre source
Sa_1	Source on high quality paper fibre, Magazine
Sa_2	Source on high quality paper fibre, Manila Card
Sb_1	Source on low quality paper fibre, Newspaper
Sb_2	Source on low quality paper fibre, Tissue
Sb_3	Source on low quality paper fibre, A4 Paper
Sb_4	Source on low quality, Corrugated Box
WF	Waste Fibre

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter provides the overview of the current local and global waste paper outlook. The background of the research will describe next followed by the problem statement. This followed by the objective and scope of the study which involves the development of new systematic technique for a maximum paper fibre recovery network design based on mathematical programming approach.

1.2 WASTE PAPER OUTLOOK

Paper has reinvented the way we communicate, record history, and write down literature. It is portable, smaller, and thinner, and has triggered the inventions of new

cleaning products, printing, and even foods. Just imagine a world without paper. It is then that you will truly understand its value and importance. In the production of pulp and paper, it shows that 77% of the publishing sector expected to increase from 1995 to 2020 (Print Net Incorporated Website, 2008). Logically of course there are a lot of trees will be cut down to fulfill the demand of paper. As a human, we have to preserve our forest not only for our future generation but also for our significance of life in other to prevent global warming in the environment.

Malaysia has a total capacity pulp and paper production at over 1 million ton per year. The country is a net importer of pulp, paper, and paper board, and progressively tends to decrease its dependency. However, the self-sufficiency is growing at a slow rate. The Malaysian pulp and paper industry is heavily dependent on imported fibre, particularly virgin pulp, and is also facing the need to find a new source of fibre to strengthen and retain the quality of secondary fibres as the use of recycled paper is growing in Malaysia. The graph in Figure 1.1 shows the Malaysia pulp production and consumption. Start from 1992, the production of pulp increasing simultaneously from 90 000 ton per year to 125 000 ton per year at 2004. At 1965 the consumption of pulp start to grow from 10 000 ton per year up to 200 000 ton per year at 2004. This particularly result shows the growth of paper industries in Malaysia.

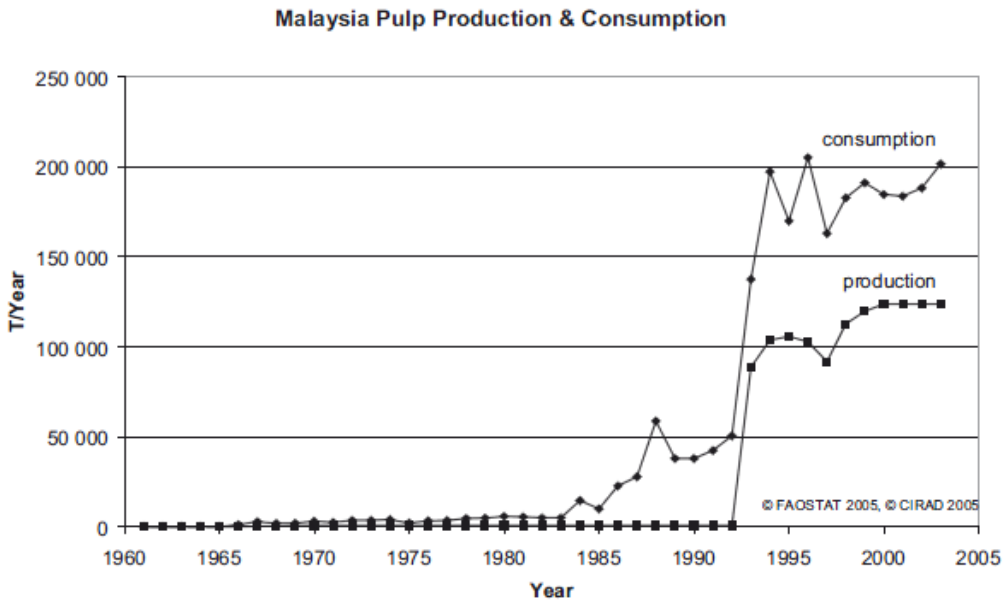

Figure 1.1 Malaysia pulp production and consumption

(Source: Asia Pro Eco Program ,2006)

The pie chart in Figure 1.2 represents the main uses of recovered paper in United States. Overall, the highest percentage of recovered paper collected in U.S. is exported (41%), with containerboard (29%) and recycled boxboard (12%) representing another 41%. Less than 6% of recovered paper is used today for printing and writing grades (Paper life cycle, 2008).

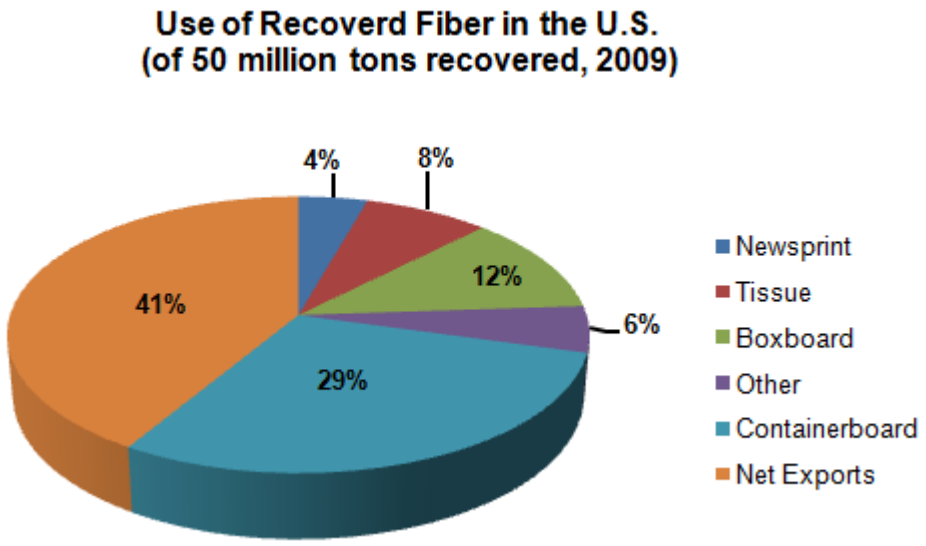

Figure 1.2 Use of recovered fiber in the U.S.

(Source: Paperrecycles.org, 2008)

On the other hand, paper and paper-based packaging is by far the largest component of solid waste in landfills, most of which can be recovered and recycled. According to the U.S. Environmental Protection Agency (EPA), of the 250 million tons of municipal solid waste (MSW) generated in the United States in 2008, nearly 31% was paper. Any paper that can be recovered, but is not, has an economic and environmental cost. The graph in Figure 1.3 shows paper recovery rates in U.S. and Canada. The rates increase every year from 2000 with 45% to 75% in 2010.

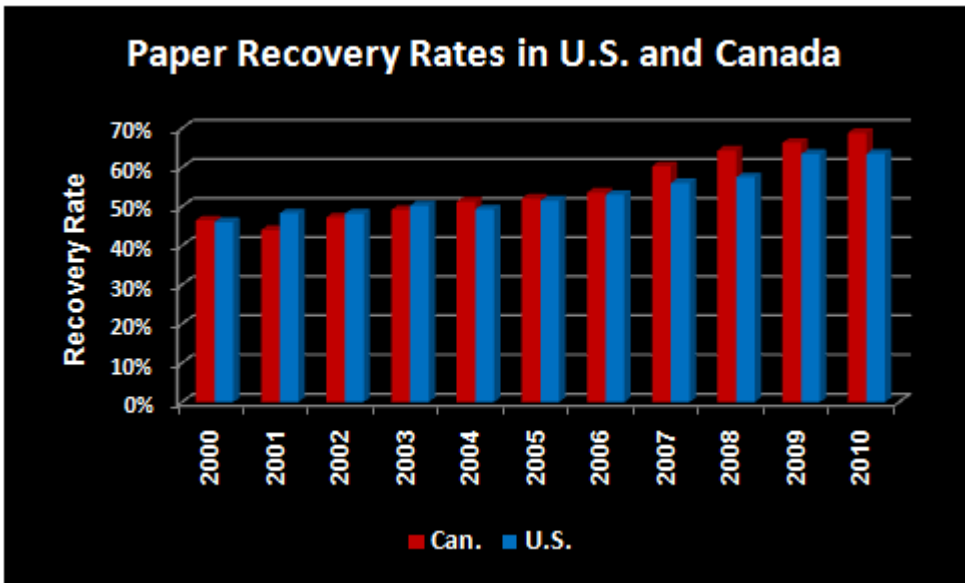

Figure 1.3 Paper recovery rates in U.S. and Canada

(Source: Pulp and paper products council, 2009)

According to Paper Life Cycle website, paper is the most prevalent material in municipal solid waste (MSW), and as a result, paper recycling can help to reduce the amount of MSW. Americans recycled more than 50 percent of the paper used in 2007, but this amount still not enough to reduce waste paper. Recycling reduces greenhouse gas emissions, conserves natural resources, and saves landfill space. So it is our initiatives to manage the waste wisely so that the extinction of forest will not become worst.

1.3 RESEARCH BACKGROUND

Paper and packaging are essential components of modern life. Communication, food, and consumer products are just a few of the things that are improved upon and more easily accessible as a result of paper and packaging. Although we might consider most paper products essentially the same, paper has thousands of applications, and how different paper types are manufactured has everything to do with how its ultimate purpose. For example, a coffee cup needs to have distinct performance attributes compared to a newspaper.

The mix of fibers are determined by the demands of the people who are using the product. People use paper for many different reasons, such as cleaning and drying, storing other goods, and communicating. As such, different types of fibers are blended together depending on the distinct strength, brightness and absorbency needs for different grades of paper. 115 billion sheets of paper are used annually for personal computers (World watch Institute). An important aspect of the forest products supply chain is by recycling. The use of recycled fiber can reduce the demand for fresh fiber from forests and avoid greenhouse gas emissions. This method has been a major concern all over the world. According to Debunking the Myths of Recycle Paper Website (2000), waste paper can be disposed in three ways that are buried, burnt or recycled. Out of the three methods mentioned there, recycle is the best alternative solution to overcome problems of logging in a large scale.

There are several researches have been done on the synthesis of paper fibre recovering network by using several techniques. The techniques that have been introduced are pinch analysis by Kit et al. (2010) and Property Cascade Analysis (PCA) by Foo et al. (2006).

Kit et al. (2010) has come out with a method that focused on post-consumer waste paper recycling. His worked applying the pinch analysis concept to determine how post-consumers waste paper recycling can be maximized to produce various types of recycle paper. Although the technique have provide an interactive, quick and efficient guidelines to conduct paper fibre recovery network, but the method is quite tedious and complicated. On the other hand, a mathematical model for designing and modeling system introduced by Hamzah et al. (2012) was only focused on single property of fibre paper. Hence, in order to overcome this limitation, the development of a new systematic approach by using mathematical programming technique is proposed in this work.

1.4 PROBLEM STATEMENT

Every ton of recycled paper saves about 17 trees (Purdue Research Foundation and US Environmental Protection Agency, 1996). Unfortunately 10,000 trees are cut down annually in China to make holiday cards (Xinhua News Agency). Reflects to our environment 20 years ago and now, there are too many differences in term of pleasure, pleasant, beauty etc. This situation become worst because of the world condition becomes advance as deforestation occur everywhere. How disappointed is deforestation

give too much negative impact to our environment and world. The raising of sea level, global warming and green house effect is one of the bad phenomena happened because of deforestation. To perceive at these problems, recycling is one of the possible ways to reduce deforestation.

1.5 OBJECTIVE

The main objective of this study is to develop a mathematical model for designing and modeling a system in order to get the maximum paper fibre recovery network.

1.6 SCOPE

The main purpose is to develop a mathematical model to achieve maximum paper fibre recovery. This study focus on how the post-consumer waste paper recycling can be maximized to produce various recycles paper types by maximizing the type of paper characteristics. This study will overcome the limitation of model that had been proposed by Hamzah et al. (2012) by presenting a simultaneous target and design of paper fibre recovery network.

1.7 RATIONALE AND SIGNIFICANCE

This study will provide a method to determine the maximum recycle fibre that we can obtain from the post-consumer waste paper fibre instead of other method that is less reasonable and inconvenient.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter summarises all the researched and worked that have been done by previous researches. A general view on the study and design of paper fibre recovery network is described in Section 2.1. Next, the previous worked on paper fibre recovery network is described next followed by the review on previous worked on mathematical modelling.

2.2 A GENERAL REVIEW ON STUDY AND DESIGN OF PAPER FIBER RECOVERY NETWORK

Paper as a packaging and writing material is produced by pressing moist fibres that can be obtained from woods, rags or grasses and then drying them into flexible

sheets. The various types of paper are from tissue until the corrugated box. In order to reduce the usage of the fresh fibre, recycling has been introduced. Nowadays, paper is everywhere and of course the need for it is essential. By applying this method, the forests products chain can be sustained for long period of time as well as the greenhouse effect from the deforestation can be minimized. Focusing on the desire to be friendly to the earth and its resources makes recycling become important. Consumers use paper to meet many different needs and each required different properties such as fibre length, brightness and pulping process. In order to achieve different kinds of needs and properties, both of fresh and recycled fibres are blend together in varying proportions. The demands on paper keep increase years by years, so it is impossible to sustain long-term demands without fresh fibre. Hence, recycling method should implement to overcome this situation. By recycling pollution is also reduced by 95 percent when used paper is made into new sheets.

In this paper, in order to find an easiest way to obtain the recycling fibre from post-consumers waste paper, a mathematical model has been in developed. Modelling is defined as a process of application of fundamental knowledge or experience to simulate or describe the performance of a real system to achieve certain goals (Nirmalakhandan, 2002). Meanwhile, mathematical modelling is a transformation of the system under study from its natural environment to a mathematical environment in terms of abstract and equations (Nirmalakhandan, 2002).

2.3 PREVIOUS WORKS ON PAPER FIBER RECOVERY NETWORK USING PINCH ANALYSIS TECHNIQUE

Nowadays, recycling is a common practice among people around the world, but somehow researches and published literatures that deal with the paper mixing is very limited (Kit et al., 2010). Byström and Lönnstedt (1997) introduced a linear programming technique on the optimal combination of energy recovery and recycling of waste paper for paper and board production. Their work includes designed a model with a function to maximize the profit, waste paper distribution and energy recovery. Moreover it is also considered the impact of paper recycling on environment and economics. The proposed model was successfully implemented in paper fibre industry.

Zhang et al. (1997) also have introduced linear programming of paper industry, but in a different way. They studied on the impacts of increased paper recycling on the U.S pulp and paper sector by using North America Pulp and Paper (NAPAP) model. This model was consisted of two phases; static and dynamic. By computes a multi-region and multi-commodity equilibrium at a given time, static phase took place. Meanwhile in dynamic phase, it forecasts the amount of pulp, paper and paperboard exchanged in multi-region market and the corresponding prices.

PCA or Property Cascade Analysis has been introduced by Foo et al. (2006). PCA has been introduced to overcome the limitation of tediousness graphical method. By implementing PCA in pulp and paper industry process, the rejected products from machine were recycled back as feed to the process after treated. Hence, by recycling the

broke paper, the resource usage can be maximized and fresh fibre consumption can be reduced. It is important to note that PCA gives great impact in paper fibre recovery network research. In their work, Foo et al. (2006) was only focused on paper broke from rejected waste fibre in papermaking plant. The application of pinch analysis in paper fibre recovery network is also important analysis that has been introduce by Foo et al. (2006). Pinch Analysis is well known as a systematic tool for optimal design of resource utilization networks including heat (Furman et al., 2002), water (Jezowski et al., 2010), mass and gas.

Later, Kit et al. (2010) proposed a graphical approach for simultaneous targeting and design of a paper fibre recycling network. This method is divided by two main steps, firstly a graphical approach called source-sink composite curve (SSCC) was used to establish the maximum paper recycling network. Next, from the SSCC, a source and sink allocation curve (SSAC) and Network Allocation Diagram (NAD) were constructed to design the maximum paper recovery network. This work applied the concept of pinch analysis using graphical approach. Their work focused on how the post-consumers waste paper recycling can be maximized to produce the different kind of recycle paper types.

2.4 PREVIOUS WORKS ON PAPER FIBRE RECOVERY NETWORK USING MATHEMATICAL PROGRAMMING APPROACH

Since the researches and published literature review on paper fibre recovery network were limited, the review was done on mathematical modeling. Mathematical

programming technique has emerged primarily to overcome the limitations encountered by the graphical approaches particularly for large-scale and complex problems as well as cost optimality. Mathematical programming is effective tool for minimizing or maximizing an objective function subjects to constraint relationships among the independent variables. It is typically done by simultaneously considering all factors contributing to overall network cost effectiveness and operability. In recent years, several mathematical programming approaches has been widely implemented in order to minimize utilities in a plant such as heat (Chuei and Lien, 1996), water (Hul et al., 2007) and hydrogen (Hallale and Liu, 2001).

Hamzah et al. (2012) have done a research on design and modeling of paper fibre recovery network by using mathematical programming approach. The author introduced Model for Optimal Design of Paper Fibre Network (MODPFN). The objective of this worked was to develop a mathematical model for designing and modeling a system in order to get the maximum paper fibre recovery network. They focus on how the post-consumer waste paper recycling can be maximized to produce various recycles paper type. The mathematical programming was said more suitable approach for the maximum paper fibre recovery network.

From Hamzah et al. (2012) the step involving in the modeling of paper fibre recovery network were firstly, the variables specifications, followed by the equation specification, model statement and solve statement. After that, the mathematical formula obtained were going to implemented in programming then lastly, the minimum paper fibre targets and design was produced. However their worked only focus on one type of

paper characteristic which is water content inside paper, but somehow the other characteristic of paper contribute more in reducing the consumption of fresh fibre in producing paper. This worked will overcome the tediousness and drawbacks from graphical approach by Kit et al. (2010).