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EFFECT OF OVERALL EQUIPMENT EFFECTIVENESS IMPROVEMENT OF CORRUGATING M
ACHINE USING TOTAL QUALITY MANAGEMENT ON CARBON FOOTPRINT OF CORRUGAT
ED BOARD.

Mr. Long Giang Nguyen

A Dissertation Submitted in Partial Fulfillment of the Requirements
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By	Mr. Long Giang Nguyen
Field of Study	Imaging Technology
Thesis Advisor	Associate Professor Aran Hansuebsai, Ph.D.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

....Dean of the Faculty of Science

(Associate Professor Polkit Sangvanich, Ph.D.)

THESIS COMMITTEE

....Chairman

(Associate Professor Pichayada Katemake, Ph.D.)

....Thesis Advisor

(Associate Professor Aran Hansuebsai, Ph.D.)

....Examiner

(Assistant Professor Chawan Koopipat, Ph.D.)

....Examiner

(Associate Professor Chavalit Ratanatamskul, Ph.D.)

....Examiner

(Assistant Professor Suchitra Sueeprasan, Ph.D.)

....External Examiner

(Associate Professor Pontawee Pungrassamee)

ลอง เกียง เหวียน : ผลของการปรับปรุงการวัดประสิทธิภาพโดยรวมของเครื่องจักรของเครื่องทำกระดาษลูกฟูกด้วยการจัดการคุณภาพโดยรวมต่อคาร์บอนฟุตพริ้นท์ของแผ่นกระดาษลูกฟูก (EFFECT OF OVERALL EQUIPMENT EFFECTIVENESS IMPROVEMENT OF CORRUGATING MACHINE USING TOTAL QUALITY MANAGEMENT ON CARBON FOOTPRINT OF CORRUGATED BOARD.) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: อรัญ หาญสืบสาย, 143 หน้า.

กระบวนการผลิตที่เป็นมิตรต่อสิ่งแวดล้อมเป็นแนวโน้มอุบัติใหม่ของอุตสาหกรรมการผลิต ซึ่งจะเห็นได้ว่าบริษัทผู้ผลิตสินค้า ต่าง ๆ เริ่มให้ความสนใจทั้งด้านรักษาสิ่งแวดล้อม และการสร้างผลกำไรไปพร้อมกัน ตัวอย่างเช่น โดยทั่วไปได้มีการประยุกต์ นำวิธีการ การวัดประสิทธิภาพโดยรวมของเครื่องจักร (OEE) ไปใช้ปรับปรุงกระบวนการผลิตผ่านเทคนิคการจัดการคุณภาพ โดยรวม (TQM) เพื่อเพิ่มผลผลิตและลดต้นทุน แต่มีข้อสังเกต ว่ายังไม่ได้มีการพิจารณานำไปวัดผลด้านสิ่งแวดล้อมที่เกิดขึ้น ได้แก่ การลดการปล่อยก๊าซเรือนกระจกหรือค่าคาร์บอนฟุตพริ้นท์ (CFP) และความยั่งยืนของธุรกิจในการได้ ผลกำไร เป็นต้น ดังนั้นงานวิจัยนี้ ได้ศึกษาผลของการปรับปรุงการวัดประสิทธิภาพโดยรวมของเครื่องจักรของเครื่องทำกระดาษลูกฟูกด้วยวิธี การการจัดการคุณภาพโดยรวมต่อค่าคาร์บอนฟุตพริ้นท์และอัตราผลกำไรของแผ่นกระดาษลูกฟูกที่ได้ การทดลองได้ทำการ วัดค่า OEE ของเครื่องจักรที่โรงงานแห่งหนึ่ง ค่าการปล่อยก๊าซคาร์บอนได ออกไซด์ และค่าผลกำไรต่อแผ่นกระดาษลูกฟูกที่ได้ การทดลองนี้ได้ดำเนินการที่ประ เทศเวียดนาม จากนั้นได้นำเสนอแบบจำลองความสัมพันธ์ระหว่างการเพิ่มค่า OEE ของ เครื่องทำกระดาษลูกฟูกกับปริมาณการลดก๊าซคาร์บอนได้ออกไซด์และอัตราผลกำไรต่อแผ่นกระดาษลูกฟูก 1 ตร.ม. การทด ลองได้ทำการศึกษากับเครื่องทำกระดาษลูกฟูกที่ โรงงานอีกแห่ง พบว่าให้แนวโน้มในลักษณะเดียวกันของการเพิ่มค่า OEE ของเครื่อง จักรที่มีผลต่อการลดลงของคาร์บอนฟุตพริ้นท์และอัตรากำไรของแผ่นกระดาษลูกฟูกที่ได้ ซึ่งเครื่องจักรที่ใช้ในการ ทดลองควรมีสภาพที่ใกล้เคียงกัน ปัจจุบันอุตสาหกรรมผลิตกระดาษลูกฟูกของประเทศเวียดนามยังคงใช้เครื่องทำกระดาษ ลูกฟูกมือสองอยู่มากกว่าร้อยละ 90 งานวิจัยนี้แสดงให้เห็นว่า การหาความสัมพันธ์ของการเพิ่มค่า OEE ของเครื่องทำกระดาษ ลูกฟูก กับการลดค่าคาร์บอนฟุตพริ้นท์และอัตรากำไรของแผ่นกระดาษลูกฟูกมีความเป็นไปได้ และการนำเทคนิคการจัดการ คุณภาพโดยรวม หรือ TQM จะเป็นเครื่องมือสำคัญในการช่วยเพิ่มค่า OEE ของเครื่องจักร

ภาควิชา เทคโนโลยีทางภาพและการพิมพ์ ลายมือชื่อนิสิต ....

สาขาวิชา เทคโนโลยีทางภาพ ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

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LONG GIANG NGUYEN: EFFECT OF OVERALL EQUIPMENT EFFECTIVENESS IMPROVEMENT OF CORRUGATING MACHINE USING TOTAL QUALITY MANAGEMENT ON CARBON FOOTPRINT OF CORRUGATED BOARD.. ADVISOR: ASSOC. PROF. ARAN HANSUEBSAI, Ph.D., 143 pp.

Environmental friendly production is an emerging trend in industrial production. Enhancing environmental protection and ensuring company's profitability have gained great attention from manufacturers. The application of Overall Equipment Effectiveness (OEE) using Total Quality Management (TQM) to reflect efficiency of production has been widely implemented in the manufacturing process. However, the full advantage of OEE using TQM techniques as a measure to simultaneously facilitate reduction of carbon dioxide (CO2) emissions and to sustain the existing profitability has not been utilized. This study aimed to investigate the application of OEE using TQM techniques to improve the manufacturing process of corrugated board production using two indicators including CO2 emission and profitability. The research showed a model of measuring OEE, CO2 emission and Profitability. The proposed model was a useful tool in predicting Carbon Footprint (CFP) and Profitability when improving OEE. The experiment was done in Vietnam. The tendency of OEE, CFP and Profitability was similar in both experiments. It suggested that the corrugating machines should have the same conditions. In Vietnam, nowadays there are over 90% of second hand corrugating machines used in corrugated box industry. The study clearly demonstrated the relationship between OEE and CFP and Profitability of corrugated paper producers in that when improving OEE, CFP would decrease and Profitability would increase. The TQM techniques used in this study were one of the suggestions for improving OEE.

Department:	Imaging and Printing Technology	Student's Signature	....
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Chapter 1

Introduction

1.1 Rationale

Environmental friendly production is an emerging trend in the industrial production. Enhancing environmental [1] protection and ensuring company's profitability have gained great attention from any manufacturers. The use of Overall Equipment Effectiveness (OEE) to reflect efficiency of production has been widely applied in manufacturing process. However, full advantage of OEE as a measure to simultaneously facilitate reduction of carbon dioxide (CO_2) emissions by Total Quality Management (TQM) and to sustain the existing profitability has not been utilized [2] . This study aimed to investigate the use of OEE to improve manufacturing process of corrugated paper production by TQM using two indicators including CO_2 emission and profitability. The research showed the model how to measure OEE, CO_2 emission and Profitability.

Today, corrugated packaging has been rapidly growing in the printing and packaging industry [3] . All products which have been circulating in the market are using corrugated packaging and these products are increasingly demanded for safety, aesthetics, compact and light, and diverse types. Production of corrugated paper is a particularly important stage in the manufacturing process of corrugated packaging. It is also a decisive step which decides on quality, durability, and force bearing capacity. In addition, protection of environment during production process is also concerned in this production stage. These require corrugated paper producers to develop an effective tool to balance among optimization of production, environmental protection, and profitability.

Sustainable development is one of the major challenges for industrial activities including manufacturing corrugated packaging. To grow a business sustainably, the agreement between environmental pollution and healthy ecosystems is to be addressed. Previous studies have shown that Carbon Footprint (CFP) plays a key role in the implementation of sustainable development strategies in printing [4, 5] as well as in corrugated packaging industries. Prediction of environmental impact caused by corrugated packaging could be achieved through performing a process named Life Cycle Assessment (LCA), and LCA has been expressed by a simpler form such as Life-cycle CO_2 emission [6] . On the other hand, Overall Equipment Effectiveness (OEE) is used to evaluate entire production process to ensure a high performance of equipment [7] . Therefore, the combination of CFP and OEE in manufacturing corrugated paper can be applied to improve sustainability. Up to date, little publication has been reported on this research area.

For the CFP, calculation of CO_2 emissions from the production, consumption, transportation and disposal or recycling, has been performed followed Thai Green House Gas Management Organization (TGO) [5] . Emission of CO_2 affecting environment in the production of corrugated paper was previously identified from the used amounts of input paper and glue powder, electricity consumption for machine operating and lighting [4] . This paper did not focus on altering the amounts of input paper and glue powder but improving environmental pollution via improving OEE. OEE comprises of Availability, Performance, and Quality which were used to measure effectiveness of corrugating machine. These three factors were experimented separately thus individually contributing to improvement of OEE. Environmental load depends on waste of time, input materials and energy. The focus of this study was to reduce CFP by controlling speed of corrugated machine, the amounts of input paper, electricity consumption during production of corrugated paper.

Profit is also the target of companies. Profit is addressed by profit of margin representing percentage of the profit gained over the sales price. Solutions to environmental issues would be more feasible only when current profit is secured. Therefore, the improvement of OEE to reduce CFP should take into account profit of margin to ensure the feasibility.

Total Quality Management (TQM) has been recognized and used during the last decade to develop a quality. TQM is necessary to reach competitiveness but the way to achieve this is not easy, especially in printing field. OEE improvement by TQM on profitability is the need of packaging company, that is the model to measure OEE and to analyze the profitability by TQM technique.

1.2 Research objectives

The overall objective of this study is to investigate the effect of OEE improvement of corrugating machine using TQM on carbon footprint of corrugated board. The specific objectives are as follows:

- To study the effects of OEE of the corrugating machine on Carbon Footprint emission of corrugated board.

- To apply TQM techniques to improve OEE of the corrugating machine

1.3 Research hypotheses

CFP was reduced when OEE of the corrugating machine was improved.

Increasing OEE of the corrugating machine resulted in increasing Profitability.

1.4 Scope of study

The survey and data collection in this study were carried out at the currently operating corrugated box manufacturer in Ho Chi Minh city, Vietnam.

The data were collected over the period of 12 months focusing on the stage of processing corrugated paper.

Over 200 datasheets related to single wall corrugated paper will be collected and analyzed.

1.5 Thesis organization

The dissertation was presented from Chapter 1 to Chapter 7.

Chapter 1 was the introductory chapter which includes rationale, research objectives, research hypotheses, and scopes of this entire study.

Chapter 2 summarized the previous works in summarization which provided the background understanding relating to corrugated board, OEE, CFP, Profitability, TQM.

Chapter 3 was the experiment in factory 1

Chapter 4 proposal the prediction model

Chapter 5 applied the prediction model to factory 2

Chapter 6 was results and discussion

Chapter 7 was conclusions and recommendations

Chapter 2

Literature review

2.1 Corrugated paper board production

There are several production section of corrugated packaging production: corrugated paper board production, cutting off, printing, slitting and scoring, slotting and creasing or die cutting, stitching or gluing. Corrugated paper board production is the first section of corrugated packaging production, the input material is flat paper in roll and the output is the corrugated paper board in roll [3] .Corrugated paper board production effects directly to the final quality of ending product, to the cost, the profitability and also to the production time.

Corrugated cardboard is typically used to make packing or shipping containers. Though there can be found a variety of cardboard boxes in the market, corrugated cardboard boxes are still considered the most suitable for object packaging and protecting from any damages, especially for long distance shipping purposes.

Corrugated boxes not only confirm the safety and protection of the product while shipping, but it also offers the durability, cost effectiveness, lightness, strength and recyclability. As a result, this creates a great advantage for product transportation.

Corrugated cardboard is realized easily and made of paper. It has an arched layer that is called "fluting", and between the smooth sheets is "liner". Corrugated cardboard is mainly used to make boxes which have one layer of fluting between two smooth sheets. However, there is a variety of them with different flute size and thickness.

Corrugated cardboard is a special material that is very durable, versatile, innovative and light [8] . It is commonly used for custom-manufactured shipping containers, packaging and point-of-purchase displays and numerous non-traditional applications such as pallets, children's toys, furniture and so on.

What parameters should be considered while designing corrugated boxes?

The design of the boxes is to improve the grade of corrugated board, inner supports, flute direction and box design. If the boxes are required to store products in humid conditions for a long time, they must have good moisture resistance and extra strength. Furthermore, stacking strength is also affected by method of loading boxes. Loading boxes in vertical columns creates the best performance, whereas stacking them in an interlocking manner may cause a reduction in its efficiency and performance [9].

The strength of a corrugated box can be examined by carrying out the ‘Box Compression Testing’. This test is used to gauge the box, stack of boxes and unit load under controlled conditions. The degree of control varies for static and dynamic compression. The size of a corrugated box and its construction determines its compression strength. These parameters are checked by using Actual Package Testing.

What are the specifications of a corrugated box?

When you look for the specifications of a corrugated box, the format which you receive will look like this:

<Paper weight><outer liner paper>/<walls of the box with its flute type>/<inner liner paper>

Paper Weight:

Paper weight is generally specified in the terms of grams per square meter (gsm). In manufacture of standard cartons, the paper used is normally ranged from 125 gsm to 150 gsm. However, if the box is used for heavy duty purposes such as export, paper weighing 300 gsm is applied.

Outer liner:

The paper outside the box is called the outer liner paper. Generally, the outer liner paper is normally made up of virgin craft paper. However, nowadays, the composition contains about 12 % of recycled material.

Inner Liner:

Inner liner paper is used on the inside of the box. It is completely made up of recycled material, virgin board, a mixture of newspaper waste and so on. Though this may not seem as appealing and strong as the outer liner one, it has an advantage of reducing the weight of the box considerably, being environmentally friendly and fully recyclable.

What are the types of corrugated boxes used in industries?

The factors which are considered while planning the design of a corrugated box are shocks due to shipping hazards, tremor, humidity and compression. However, if it becomes worse, the corrugated box must survive from fire Additionally, being a fitting protection for the product, a corrugated box should be designed in a cost effective manner in order to meet the customer requirements, logistical wants and machine necessities.

The shape in which the corrugated box is manufactured is based on its end use. The followings are the box types which are normally used in packaging and shipping industries.

Slotted boxes:

Slotted box is one of the most commonly used kinds of corrugated box in industry. Its types consist of the half slotted box, regular slotted box, and so on. A slotted box is used for packaging and shipping various materials with a minimal waste production. It is usually made from one piece of corrugated board which is glued, stitched or taped. The shipment of these boxes is in a flat manner and can be used as soon as delivered.

Self-Erecting boxes:

Self-erecting boxes or widely known as auto bottom boxes have an added security and safety due to the folding and locking mechanism made out of flaps at the lower end of the box. They are considered to be extremely strong and sturdy to meet storing requirements, especially for assembly lines as they are effortlessly put together and also beneficial for conveyor systems with top seating automatic tapers.

Folder boxes:

The folder type of corrugated boxes is made from an individual piece of corrugated cardboard that gives it a continuous and level bottom. The side walls are linked to the ends of the corrugated cardboard at the end. In order to boost the design of the box, handles, locks and display panel are added according to the customer's requirements. They are at the large detached corrugated boxes that are used to pack huge or unevenly shaped parts.

Rigid boxes:

Bliss- style boxes or rigid boxes are also known are among of the most robust and hard-wearing packing materials. They consist of 3 portions (two end pieces and a body) that are pasted or sewed together. The flaps used to make the joints can be on the end pieces, the body or both. Normally, they have six or more linkages and upon being stuck down, they constitute an extremely firm and durable frame.

Telescope Boxes:

Telescope boxes are one of corrugated boxes that are unique. Some examples of telescope boxes are, the full telescope design container, the design style container, etc. Telescope type of corrugated boxes is widely applied in industries. It involves 2 parts: the cover and a detached bottom. It is also referred to as the body on which the cover usually comfortably fits or 'telescopes' the box. The cover accounts for nearly two-thirds of the depth of the box. Telescope boxes are largely used to package shoes, watches, jewelry, and so on.

What are the types of printing methods employed for corrugated boxes?

There are various types of printing methods employed on the corrugated box in order to get the desired output, including:

Flexo printing:

It is one of the most primary techniques used for printing on corrugated box, and is also a cost effective printing method to get basic graphics on the surface of the corrugated box. It is used to print the company or package content using simple line art and text using 1-3 colors.

This process is utilized for the printing of higher end graphics with 4 process colors. Due to the use of 4 plates, the overall expense also goes up. The four colors used to provide a greater visual impact. An additional advantage to flexo process is that the photo quality images can be used for printing on the corrugated box.

Screen printing:

It is another method of making graphic intensive print on the corrugated box. It is also the most effective printing method for short run quantities. The size limitations are large and more than four colors used for printing.

Offset printing:

It can be used to apply offset printing of high quality, but it requires a significant investment from clients. It gives a higher result than flexo printing and is largely applied in food and beverage industry.

Box Structure

Corrugated fiberboard or combined board consists of two main parts: the linerboard and the medium which are made of a special type of heavy paper named containerboard. The linerboard is a flat piece adhering to the medium. The medium is a wavy, fluted paper lied in the middle of the liners [10] .

The Single Face: One medium is glued to one flat sheet of linerboard.

The Single Wall or the Double Face: The medium is laid between two sheets of linerboard.

The Double Wall: Three sheets of linerboard are glued to two mediums in between

The Triple Wall: Four sheets of linerboard are glued to three mediums in between

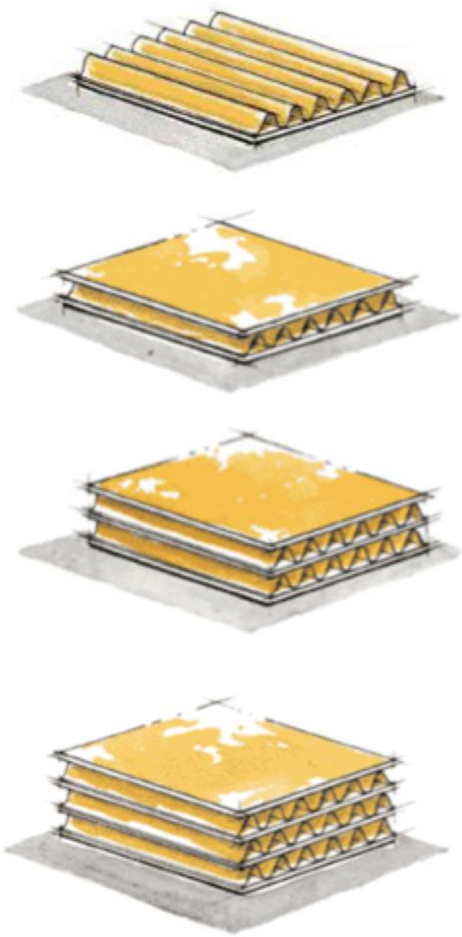

Figure 2. 1 Four kinds of corrugated board

Flutes

For thousand years, architects have found that an arch with the proper curve is the strongest way to span a given space. Many inventors of corrugated fiberboard have applied this same principle to paper in order to put arches in the corrugated medium. These arches are regarded as flutes. When anchored to a linerboard with a starch-based adhesive, they are able to endure against bending and force from every direction.

When a piece of combined board is situated at its end, the arches will create rigid columns and be capable of supporting a great deal of weight. When pressure is put on the board side, the space in between the flutes performs as a cushion to protect the container's contents. In addition, the flutes also act as an insulator to protect products from sudden temperature changes. Meanwhile, the vertical linerboard strengthens the flutes and protects them from any damages as well.

Board corrugation or flute refers to S shaped arches or waves of the corrugated box, presented between the boards. These flutes running parallel to the surface of the corrugated board play an important role in making the box strong and rigid. Moreover, flutes also help to regulate temperature inside the box.

Flutes are considered with several standard shapes or flute profiles (A, B, C, E, F, see Figure 2.2). A-flute, the first to be developed, is the largest common flute profile. The next is B-flute which is much smaller. C-flute is followed and is between A and B in size. E-flute is smaller than B and F-flute is smaller and the same for others.

The following types of flutes are used in corrugated boxes:

B flute :

- Having a thickness of 1/8".
- Having 40-50 flutes per foot.
- Providing the second highest arch size.
- Providing greater crush resistance and stacking strength.
- Generally used in the packing of canned goods and displays.

C flute :

- Having a thickness of 11/64"
- Having 39-40 flutes per foot.
- Forming a medium between type A flute and type B flute.
- Being the most common type of flute used in corrugated boxes.
- Exhibiting good cushioning, stacking and printing properties.
- Being used in the packaging of furniture, glass and dairy.

E flute:

- Having a thickness of 1/16"
- Having 94 flutes per foot.
- Making the board extra thin in turn and reducing its weight and size.
- Imparting the best crush resistance.

- Being an excellent choice for printing purposes and die cut custom boxes.

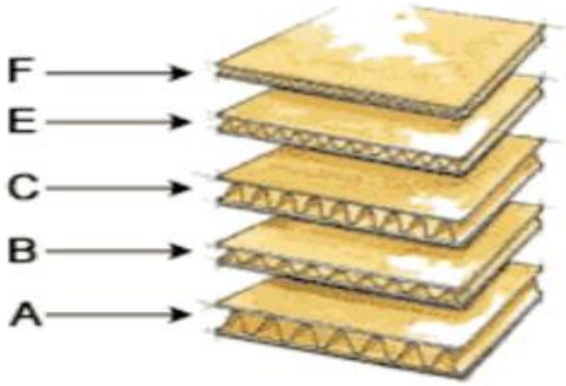

Figure 2. 2 Corrugated board flute

Beside these five most common profiles, new flute profiles which are both larger and smaller than those above mentioned are being created for more specialized boards. Generally, larger flute profiles create more vertical compression strength and cushioning, whereas smaller flute profiles provide enhanced structure and graphic capabilities for primary packaging.

Furthermore, different flute profiles are able to be joined in one piece of combined board. For example, in a triple wall board, one layer of medium can be A-flute, whereas the other two layers may be C-flute. Besides, mixing flute profiles in this way helps designers manipulate the compression strength, cushioning strength and total thickness of combined board.

Box Dimensions

Length, width and depth are internationally used to express dimensions. The box's dimensions are described by opening an assembled box from the top or the side depending on how it is filled. The opening of a box is a rectangle which has two parallel sides. The longer is considered its length, and the shorter is considered its width. The side perpendicular to length and width is considered the depth of the box.

Dimensions must be accurately classified for either the inside or the outside of the box in order to make sure the proper fit for the products shipped or stored. Meanwhile, palletizing and distributing the boxes mainly depends on the outside dimensions. As a result, the box manufacturers must be informed about the dimension which is the most important to customers.

Corrugated boxes weight

Corrugated boxes are made from corrugated paper which is glued to the flat facing of a flat paper made of the same material. To produce a corrugated paper from a flat paper, a corrugating machine is used. One layer of flat paper is passed through heated fluting rolls and glued at the tips so that it can make contact with the other paper. The two sheets then get pasted and are wound in rolls. This roll is called a 2-ply corrugated board or a single face corrugated board. 3-ply, 7-ply and 9-ply corrugated cardboard can be made by using a board cutting machine to cut the board, gluing the 3-ply paper over it. Board to board can be pasted to get corrugated boards of various thicknesses.

Since the box is of a definite thickness, the outer and inner dimensions vary. The size of the box is always given in terms of inner dimensions. Normally, while considering the dimensions of a corrugated box, the length is mentioned first, which is the longest dimension of the opening, followed by the width and depth. It is ideal to maintain a proportion of 2:1:2 (L:W:D). However, if corrugated boxes of different dimensions have to be produced, make sure to minimize the wastage.

It is important to measure the weight of the corrugated boxes in order to calculate their cost and strength. The weight of a corrugated box is equal to the area of the sheet times the weight per cubic meter of the sheet.

The area of the sheet can be calculated by taking the length of the sheet required and then measure the total width of the sheet required. This can be done by using the format given below:

Length of the sheet required ‘a’ = 2L+2W+2”

Width of the sheet required ‘b’ = W+H

Where

L= length of the box

W= width of the box

H= Height of the box

2 inches is the stitching margin

The weight per square meter of the sheet depends on two parameters- the number or piles and the grams per square meter (gsm) of the paper. Around 45% of extra material when compared with plain paper depending on the size of the flute is consumed for corrugating means. Accordingly, the weight per square meter of a 3-ply corrugated board will be:

gsm of bottom liner + gsm of bottom liner + (1.45 * gsm of media)

Corrugated cardboard is generally used to make packing or shipping containers. Though there are various other types of cardboard boxes, corrugated cardboard boxes are the most suitable for maintaining the safety of the object they carry, especially for long distance shipping purposes. Besides being a fitting protection for the product that it has to hold, a corrugated box has to be designed in a cost effective so as to satisfy the customer's needs, logistical needs and machine requirements.

A few facts about corrugated boxes:

- Corrugated boxes were invented in China in the 15th century and patented in England in 1856.
- It was originally used as the lining in tall hats and patented as a shipping material in 1871.
- These boxes are fully recyclable and biodegradable.
- Old corrugated cardboard boxes are the most recycled products by weight. Since 1960, the recycling values of old corrugated boxes have increased by 305 percent.
- The amount of corrugated boxes that is generated in one year can reach weight of 29.7 million tones. That means there is 195 pounds per person of corrugated boxes manufactured per year.
- A monumental amount of corrugated box is recycled every year. Over 22.76 million tones go for recycling with a rate of 76.6 percent.
- Recycling a corrugated box is 75% less energy than making a new one.

- This product becomes totally useless from fully recyclable if it is contaminated by oil or water.

- Another fact about the corrugated box is that this medium usually has more recycled content than linerboard.

- It is also the third largest product disposed of by weight.

- A corrugated box can even be composited if shredded properly.

- Its landfill volume is 26.3 million cubic yards. This makes it the second largest item in landfills by volume.

- The largest amount of waste products of corrugated boxes comes not from the factories, but from departmental stores and large markets.

- The weight of the corrugated boxes has reduced by 10 to 15% in the last decade due to linerboard light weighting.

Corrugated boxes are the best choice in cases where absolute safety of the product is required. There are boxes offering fire retardant as well as water resistant. They offer great resistance to pressure from stacking, making them the ideal choice for easy transportation. Due to their quality and safety, they are widely used in food industries. There are options available to manufacture corrugated boxes depending on the customer's needs as well. By this way, a specialized box can be made for the product to ensure the maximum productive outcome.

Environmental Responsibility.

Corrugated box, which is made from a natural renewable resource, has a great environmental record. It is frequently produced by using high percentage of secondary fiber (including old corrugated containers, old newspapers and even straws); therefore, diverting these materials from the municipal solid waste stream is very necessary.

For instance, in 2006, 25.2 million tons of corrugated materials were gathered and recycled in the USA. That was about 76.4 percent of all container board produced in the same year. Thus, corrugated box has the best recycling rate of any packaging material used today. And it has been used and reused for many times to store and move items around houses, stores and offices.

In addition, the use of corrugated constructions with high performance linerboard helps to reduce the basis weight as well as decrease a significant source of raw materials.

Furthermore, water-based inks are now used exclusively for printing graphics on corrugated containers instead of using lead-based inks and solvents which seriously pollute the air and water that used to wash down printing equipment.

2.2 Overall Equipment Effectiveness (OEE)

OEE features a form of assessment that recognizes the percentage of planned production time that is accurately productive. Obtaining the highest score in OEE means perfect production: manufacturing only good parts, as fast as possible, with stop time.

OEE is the most practical method to monitor and improve the effectiveness of manufacturing processes such as machines, manufacturing cells, assembly lines.

OEE is simple and practical. It takes the most common and important sources of manufacturing productivity loss, places them into three primary categories and distills them into metrics that provide an excellent gauge for measuring where you are - and how you can improve!

OEE is frequently used as a key metric in TPM (Total Productive Maintenance) and Lean Manufacturing programs and gives you a consistent way to measure the effectiveness of TPM and other initiatives by providing an overall framework for measuring production efficiency [11] .

Analyzing OEE begins with Plant Operating Time, the duration your facility is stared and ready to operate the equipment.

From Plant Operating Time, make out a time category called Planned Shut Down, which includes every event excluded from the efficiency analysis due to no intention of running production (such as breaks, lunch, maintenance, or other stop periods). Thus, the remain available time is at your Planned Production Time.

OEE, with the goal of limiting or eliminating losses, starts with Planned Production Time and scrutinizes efficiency and productivity losses that may occur. Hence, three common categories of losses should be considered: Down Time Loss, Speed Loss and Quality Loss [9] .

The calculation of OEE is based on three underlying factors: Availability, Performance, and Quality [12] . Each factor captures a different perspective of how close your manufacturing process is to perfect production.

Availability:

An Availability score of 100% represents that the process is under constant operation during planned production time (non-stop running)

Availability aims to Down Time Loss, which comprises all Events that interrupt the planned production for a proper length of time (normally several minutes to be considered long enough to log as a tractable Event) due to equipment failures, material shortages, and changeover time. Changeover time included in OEE analysis is a form of down time, so it cannot be able to eliminate changeover time. In most cases, it can be probably reduced. The remain available time is called Operating Time.

Performance

A Performance score of 100% means when the process is running it is running with a possible fastest speed (at the theoretical maximum speed; each part at the Ideal Cycle Time).

Performance depends on Speed Loss, which consists of all factors that influence the maximum possible speed, such as machine wearing, substandard materials, and operator inefficiency. The remain available time is called Net Operating Time.

Quality

A Quality score of 100% means no defects have been detected (just good parts are manufactured).

Quality takes into account Quality Loss, which causes produced pieces that do not satisfy quality standards and require to be redone. The remain time is called Fully Productive Time. The goal is to maximize Fully Productive Time.

Figure 2. 3 Four Loss of OEE

A different way to examine the three factors is in terms of loss (Figure 2.3 and Table 2.1):

- Availability Loss comprises of all events that stop planned production for an appreciable amount of time (usually several minutes). Equipment failures, unplanned maintenance, material shortages, and changeovers can be considered as good examples.

- Performance Loss contains all factors leading the process to run at less than the maximum possible speed when running (including both slow cycles and small stops). Examples include machine wear, substandard materials.

- Quality Loss contains productivity lost from manufacturing parts that do not satisfy quality standards after the 1st pass (like the concept of first pass yield). This contains scrap and parts that require rework.

Table 2. 1 Type of OEE Loss

OEE Loss	OEE Factor
Planned Shutdown	It is not the part of OEE calculation.
Down Time Loss	- *Availability* means the ratio of Operating Time to the Planned Production Time (less Down Time Loss). - Being calculated as the ratio of Operating Time to the Planned Production Time. - 100% *Availability* means the process runs without any recorded interruptions.
Speed Loss	*Performance* means the ratio of Net Operating Time to Operating Time (less Speed Loss). Being calculated as the ratio of Ideal Cycle Time to Actual Cycle Time, or alternately the ratio of Actual Run Rate to Ideal Run Rate. 100% *Performance* means the process constantly runs at its theoretical maximum speed.
Quality Loss	*Quality* means the ratio of Fully Productive Time to Net Operating Time (less Quality Loss). Being calculated as the ratio of Good Pieces to Total Pieces. 100% *Quality* means there are not any rejected or redone pieces.

Since the core concepts of OEE help to recognize the causes of productivity loss, we can find out productivity losses by understanding the Six Big Losses (Table 2.2)

The key goal of TPM and OEE programs is aim to reduce and/or eliminate the Six Big Losses – the most common causes of efficiency loss in manufacturing. The table below shows how they relate to the OEE Loss categories [13] .

Table 2. 2 Sig Big Loss and OEE Loss

Six Big Loss Category	OEE Loss Category	Event Examples	Comment
Breakdowns	Down Time Loss	- Tool Failures - Unplanned Maintenance - General Breakdowns - Equipment Failures	It is flexible to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	- Setup/Changeover - Material Shortages - Operator Shortages - Major Adjustments - Warm-Up Time	This loss is usually addressed through setup time reduction programs.
Small Stops	Speed Loss	- Obstructed Product Flow - Component Jams - Misfeeds - Sensor Blocked - Delivery Blocked - Cleaning/Checking	Typically including stops under five minutes and not requiring maintenance personnel.
Reduced Speed	Speed Loss	- Rough Running - Under Nameplate Capacity - Under Design Capacity - Equipment Wear - Operator Inefficiency	Anything keeps the process running at its theoretical maximum speed (Ideal Run Rate or Nameplate Capacity).
Production Rejects	Quality Loss	- Scrap - In-Process Damage - In-Process Expiration - Incorrect Assembly	Any rejects during warm-up, startup or other early production due to improper setup, warm-up period, etc.

By understanding what the Six Big Losses are and some of the Events that contribute to these losses, we can concentrate on how to monitor and correct them [10]. Categorizing data makes loss analysis much easier in order to collect data fast and efficiently throughout the day and in real-time.

Breakdowns

Eliminating unplanned Down Time is critical to improve OEE. Other OEE Factors cannot be addressed if the process is down. It is not only important to know how much and when Down Time your process is experiencing, but it is also to attribute the lost time to the specific source or reason for the loss (tabulated through Reason Codes). With Down Time and Reason Code data tabulated, Root Cause Analysis is applied to begin with the most severe loss categories.

Setup and Adjustments

Setup and Adjustment time is measured from the last good part produced before Setup to the first consistent good parts produced after Setup. This generally includes substantial adjustment and/or warm-up time so as to consistently produce parts satisfying the quality standards [14] .

Tracking Setup Time together with an active program (SMED – Single Minute Exchange of Dies program) is critical to decrease this loss [14].

Creative methods of reducing Setup time have widely been used by assembling changeover carts with all tools and supplies that are necessary for the changeover in one place. As a result, coarse adjustments are no longer necessary.

Small Stops and Reduced Speed

Small Stops and Reduced Speed are considered to be the most difficult to monitor and record among Six Big Losses. Cycle Time Analysis should be utilized to pinpoint these loss types [10] .Thus, recording data for Cycle Time Analysis requires to be automated in most processes due to quick cycles and repetitive events rather than by manual data-logging.

The errant cycles used for analysis can be automatically categorized by comparing all completed cycles with the Ideal Cycle Time and filtering the data through a Small Stop Threshold and Reduced Speed Threshold. The reason why Small Stops need to be analyzed separately from Reduced Speed is that the root causes are typically different (refer to the Event Examples in the previous table).

Startup Rejects and Production Rejects

Startup Rejects and Production Rejects can be recognized easily during startup and steady-state production. Any parts requiring to be redone should be regarded as rejects. Observing these rejects occurring during a shift and/or job run can help pinpoint potential causes.

Often a Six Sigma program, a common metric will be achieved if the defect rate is fewer than 3.4 defects per million “opportunities”, is used to pay attention to a goal of achieving “near perfect” quality.

World Class OEE

OEE is the ratio of Fully Productive Time to Planned Production Time (refer to the OEE Factors section for a graphic representation) [15]. In fact, however, OEE is measured as the product of its three contributing factors:

OEE = Availability x Performance x Quality

This calculation makes OEE a severe test. For instance, if these three contributing factors are 90.0%, the OEE will be 72.9%. Nevertheless, the generally accepted World-Class goals (Table 2.3) for each factor are absolutely different from each other.

Table 2. 3 OEE World Class

OEE Factor	World Class
Availability	90.0%
Performance	95.0%
Quality	99.9%
OEE	85.0%

Generally, every manufacturing plant is different. Taking an example, if a plant has an active Six Sigma quality program, it will not be satisfied with a first-run quality rate of 99.9%.

Worldwide studies indicate that the average OEE rate in manufacturing plants is 60%. As is shown in the above-mentioned table, a World Class OEE is considered to be 85% or better. Obviously, there is room for improvement in most manufacturing plants!

Calculating OEE

As described in World Class OEE, the OEE calculation is based on three OEE Factors: Availability, Performance, and Quality.

Availability

Availability takes into account Down Time Loss, and is calculated as:

$$\text{Availability} = \frac{\text{Operating time}}{\text{Planned production time}}$$ (Equation 2. 1)

Performance

Performance takes into account Speed Loss, and is calculated as:

$$\text{Performance} = \frac{\text{Actual running speed}}{\text{Standard running speed}}$$ (Equation 2. 2)

Ideal Cycle Time is the minimum cycle time that the process achieves in optimal circumstances. It is sometimes called Design Cycle Time, Theoretical Cycle Time or Nameplate Capacity.

Performance is capped at 100% to ensure that if any error is made in specifying the Ideal Cycle Time or Ideal Run Rate, the effect on OEE will be limited.

Quality

Quality takes into account Quality Loss, and is calculated as:

$$\text{Quality} = \frac{\text{Good board}}{\text{Total paper usage}}$$ *(Equation 2. 3)*

OEE

OEE takes into account all three OEE Factors, and is calculated as:

OEE = Availability x Performance x Quality (Equation 2. 4)

The percentage of planned production time that is truly productive can be determined by OEE and categorizes all losses into intuitive, actionable categories. Applying OEE in isolated manufacturing processes can be extremely beneficial since it can measure equipment performance [19]. Production should plan for Breaks and changeovers time. In general, if time can be used for value-added production (i.e., manufacturing to meet customer needs as opposed to manufacturing for inventory) it should be included in OEE. The conditions in which all losses are tracked and that the true capacity of equipment is exposed is enforced. OEE, at its best, should be part of a balanced approach to fostering productivity. Solely focusing on OEE can encourage teams to overproduce (leading to excess inventory), run equipment beyond rated parameters (potentially leading to safety issues), overstaff processes (reducing labor productivity), or other counterproductive behaviors.

Once a baseline OEE score has been established for a piece of equipment, tracking OEE over time provides an objective measure of how much progress has been made towards improving manufacturing productivity.

Taking advantage of OEE is to trigger improvement through tools targeted at each type of loss. For example, TOP LOSSES and SMED are very effective for addressing Availability Loss, SHORT INTERVAL CONTROL is very effective for addressing Performance Loss, and STANDARDIZED WORK is very effective for addressing Quality Loss [16].

In the short term, OEE detects the total chance for improvement (sometimes referred to as "uncovering the hidden factory") for a given piece of equipment (or process).

In the long term, OEE assist you in driving improvement through a greater understanding of losses. In addition, it offers an objective way to set improvement targets and track progress towards reaching those targets.

OEE measurement is typically applied by a cross-discipline manufacturing team and then handed over to management to drive sustained long-term enhancement.

2.3 Carbon Footprint (CFP)

A "carbon footprint" is a measure of the greenhouse gas emissions related to an activity, group of activities or a product. Most of our daily activities creates greenhouse gas (GHG) emissions. human activities contribute the most to the production of carbon dioxide. Direct GHG emissions sources are often easy to recognize – for example burning fossil fuels for heating and transport. It is sometimes less obvious that products and services also cause indirect emissions throughout their life-cycles. Energy is required for production and transport of products, and greenhouse gases are also released when products are disposed of at the end of their useful lives.

Despite the fact that carbon footprint is not new, there is currently there is no universal definition of a carbon footprint. Definitions may differ in terms of which activities and greenhouse gases should be included within the scope of a carbon footprint assessment, and the level of detail. Carbon footprint methodologies vary from simple online calculators to complex life-cycle analysis. Automated web-based calculators (for example the BP and BSkyB household calculators) tend to only cover carbon dioxide emissions. Some carbon footprint definitions recently studied by ISA (2007) also only mention carbon dioxide. Other definitions and methods include all Kyoto greenhouse gases and measure emissions regarding 'carbon dioxide equivalents', for example Carbon Trust [10] .

Thanks to the rising public awareness of global warming, carbon footprint has been paid more attention. The global community now realizes the urge to decrease greenhouse gas emissions to cope with climate change.

Businesses, not currently regulated under the Kyoto protocol, may want to pre-empt future regulations, and may find marketing advantages in being 'green'. Calculating a carbon footprint can be a major first step towards making quantifiable emissions reductions. This may result in long term financial savings and reducing climate-change impact [10] .

'Carbon neutral' is another popular term that is often not well understood. Something that is 'carbon neutral' has a carbon footprint of zero. An organization, for example, that wants to reduce its climate change impact will usually first calculate its carbon footprint and then identify areas of its operations where emissions reductions can be made. Most of the time the possibility of reducing a carbon footprint to zero is relatively low, and enterprises may choose to invest in projects that produce emissions reductions to 'offset' the emissions that they cannot decrease internally. Emissions reductions (also known as ‘offset’) are sold in tones of equivalent and can come from a range of projects such as renewable technologies, energy efficiency projects, land-use change projects [10] .

2.4 Profitability

Profit is a financial benefit that is realized when the revenue gained from a business operation exceeds the expenses needed to maintain. Lord Keynes remarked that ‘Profit is the engine that drives the business enterprise’ [17] . Every business should earn sufficient profits to survive and grow over a long period of time. It is the index to the economic progress, improved national income and rising standard of living. No doubt, profit is the legitimate object, but it should not be over emphasized. Management should try to maximize its profit keeping in mind the welfare of the society. Thus, profit is not only beneficial to owners but it is also related with the interest of other stakeholders of the society. Profit is the yardstick for judging not just the economic, but the managerial efficiency and social objectives also.

Profitability means ability to make profit from all the business activities of an organization, company, firm, or an enterprise. It shows how efficiently the management can make profit by using all the resources available in the market. According to Harvard & Upton, “profitability is the ‘the ability of a given investment to earn a return from its use.”

However, the term ‘Profitability’ is not synonymous to the term ‘Efficiency’. Profitability is an index of efficiency; and is considered as a measure of efficiency and management guide to better efficiency. Although profitability is a major yardstick for measuring the efficiency, the extent of is not necessarily a final proof of efficiency [18]. Occasionally satisfactory profits can mark inefficiency and conversely, a proper degree of efficiency can be accompanied by an absence of profit. The net profit figure simply shows a satisfactory balance between the values receive and value given. The change in operational efficiency is only one of the factors on which profitability of an enterprise largely depends. Moreover, there are many other aspects influencing the profitability.

Sometimes, the terms ‘Profit’ and ‘Profitability’ are used interchangeably. As a matter of fact, difference between the two terms is present. Profit is an absolute term while the profitability is a relative concept. However, they are closely related and mutually interdependent, holding important roles in business.

Profit demonstrates total income earned by the enterprise during the specified period of time, while profitability refers to the operating efficiency of the enterprise. It is the ability of the enterprise to make profit on sales. It is the ability of enterprise to get sufficient return on the capital and employees used in the business activities.

As Weston and Brigham rightly states “to the financial management profit is the test of efficiency and a measure of control, to the owners a measure of the worth of their investment, to the creditors the margin of safety, to the government a measure of taxable capacity and a basis of legislative action and to the country profit is an index of economic progress, national income generated and the rise in the standard of living”, whereas profitability is a result of profit. In other words, no profit drives towards profitability [19].

Businesses having same amount of profit may be various in terms of profitability. That is why R. S. Kul Shrestha has precisely commented that profit in two different business concern may be similar but it usually occurs that their profitability varies when measured in terms of size of investment”.

2.5 Total Quality Management (TQM)

Total Quality Management (TQM) is an enhancement to the conventional way of doing business. This technique has been proved to ensure survival in international competition. The culture and actions of an organization can be transformed by changing only the actions of management [20]. Total Quality Management (TQM) is a comprehensive and structured approach to organizational management that seeks to improve the quality of products and services through ongoing refinements in response to continuous feedback. The three words mean:

Total - Makeup of the whole

Quality - Degree of excellence a product or service provides

Management - Act, art, or manner of handling, controlling, directing etc.

Therefore, TQM is an art of managing the whole to achieve excellence [10]. TQM is also defined as both a philosophy and a set of benchmarks that represent the foundation of a continuously improving organization. It is an application of quantitative methods and human resources to improve all the processes within an organization and exceed customer needs at present and in the future [21]. TQM integrates fundamental management techniques, existing improvement efforts and technical tools under a disciplined approach.

TQM is based on the following principles:

- Top management is mainly in charge of product quality. An organizational structure, product design process, production process and incentive must be created, which helps to encourage and reward good quality.

- Quality should be customer focused and evaluated using customer-based standards-- A product is not easy to use and a service is not courteous and prompt if customers do not say they are [22]. This fact forces organizations to work closely with their customers to identify customers' needs in the products and how they receive value from the products.

- The production process and work methods should be designed consciously to reach quality conformance-- Using the right tools and equipment, mistake-proofing processes, training workers in the best methods and providing good work environment help to prevent defects rather than catching them. Besides, tightly synchronized production systems with fast communication among workers promote fast identification and solution of quality problems.

- Each employee holds responsible for achieving good product quality-- This translates into self-inspection by workers themselves rather than by separate quality control personnel [22]. It requires workers to cooperate in identifying and solving quality problems.

- Quality cannot be examined in a product therefore it is necessary to make it right the first time-- Making it right or doing it right the first time should be the aim of all workers [13]. Methods such as poka-yoke and structured machine setups which increase the chance of doing it right the first time should be utilized as much as possible.

- Quality should be monitored to identify problems quickly and correct quality problems immediately-- Statistical methods can play a helpful role in checking quality and recognizing problems quickly. But self-inspection and assessment of work by employees and customer assessments of quality are central factors of the quality supervising mechanism.

- Constant improvement is crucial-- Outstanding product quality is the result of workers striving to improve product quality and productivity on a continuing basis by experience and experimentation [13] . Nevertheless, continuous improvement cannot occur without organizational structures, work procedures and policies.

- A wide range of organizational mechanisms has been utilized to enhance continuous improvement, such as work teams, quality circles and suggestion systems. Each of these methods utilizes workers who are directly involved in the production process as a primary source for improvement ideas. Some experts, nevertheless, believe that separate improvement teams should be used to initiate and guide improvement projects.

- Companies should work closely with their suppliers and extend TQM programs to them to guarantee quality inputs-- For many manufacturing companies, purchased components and materials account for over 50% of their production costs. Similarly, the costs of goods intended for resale make up for approximately 80% of the costs. If suppliers are providing low-quality components, the purchasing company will not be able to obtain a high level of quality in goods and services it produces. In fact, many enterprises now want suppliers to have quality management programs certified by customers or by a recognized certification organization, such as the International Organization for Standardization (ISO) [10].

A committed and involved management should provide long-term top-to-bottom organizational support. This means all employees' participation in a quality program. A quality council is needed to develop a clear vision, set long-term goals and direct the program. A yearly quality improvement program involves input from the entire workforce. Managers need to be involved in quality improvement teams and also act as coaches to other teams. TQM is a constant activity and should be embedded in the culture. It means that it is not just a one-time program [12].

Effective involvement and utilization of the entire work force. TQM is an organization- wide challenge that is everyone's responsibility. All employees should be trained in TQM, statistical process control (SPC) and other appropriate quality improvement skills to effectively participate in project teams. Incorporating internal customers and, for that matter, internal suppliers on project teams is a brilliant approach. Those affected by the plan should be involved in its development and implementation. They are the ones who understand the process the most [11]. Changing behavior is the goal. People should come to work not only to do their jobs but also to think about how to improve their jobs. Employee empowerment should be implemented even at the at the lowest possible level to perform processes in an optimum manner.

An unwavering focus on customers, both internally and externally. The key to an effective TQM program is its focus on customers. An excellent place to start is by satisfying internal customers [18]. One should always listen to the "voice of the customer" and emphasize on design quality and defect prevention. Do it right the first time and every time because customer satisfaction is the most important consideration.

Constant improvement of business and production process. There should be a continual striving to increase all business and production processes. Quality improvement projects such as on-time delivery, order entry efficiency, billing error rate, cycle time, customer satisfaction, scrap reduction and supplier management are good areas to start. Technical techniques such as SPC, benchmarking, quality function development, ISO 9000 and designed experiments are tremendous for problem solving [18].

Considering suppliers as partners-- Averagely, 40% of the sales dollars is the purchase of product or service, therefore, the supplier quality should be outstanding. A partnering relationship ought to be created. Both parties have as much to gain or lose based on the success or failure of a product or service. The focus should be on quality and life-cycle costs rather than on price. The number of suppliers should be small so that proper partnering can occur.

Create performance measures for the processes. Performance measures such as uptime, percent nonconforming; absenteeism and customer satisfaction should be identified for each area. These measures should be available to everyone. Quantitative data are indispensable to measure the continuous quality improvement activity.

TQM aims to provide a quality product and/or service to customers that will, in turn, raise productivity and reduce cost. With a higher quality product and lower price, competitive position in marketplace will be increased. This series of events will allow an organization to achieve its objectives of profit and growth with greater ease.

TQM techniques:

2.5.1 The 5 Whys

To get at the core of why the unexpected event or challenge happened, you need to dig deeper. Instead of stopping at one, you need to ask why five times.

The core idea of the 5 Whys system is exactly what it sounds like: ask the question “Why?” five times to understand the root cause of an issue. It was developed by Taiichi Ohno, the father of the Toyota Production System. “Observe the production floor without preconceptions,” he advised his staff. “Ask ‘why’ five times about every matter.” [9]

By asking and answering “Why?” five times, you can drill down to the core issue, which is often hidden behind symptoms. “The root cause of any problem is the key to a lasting solution,” Ohno said [6].

The 5 Whys system is most successful when used to solve simple to moderately challenging issues. If you’re using 5 Whys for complex issues, you need to be more careful. With complex problems, there are often multiple causes. Using the 5 Whys could lead you down a single path, causing you to overlook the other underlying issues.

Because the 5 Whys is relatively easy, it can be a great tool for kicking off brainstorming around a problem before you take a more in-depth approach [23].

The 5 Whys method does have some limitations:

- The person leading the 5 Whys must have expert knowledge about the problem and possible issues. If the cause is unknown to the person doing the problem-solving, the method may not lead to the true cause. In the earlier example, it’s doubtful that someone with zero mechanical knowledge would have detected the missing filter on the pump intake.

- The success of the method greatly depends on the facilitator's skills. One wrong answer may completely throw off the questioning, leading to a wrong conclusion.

- An assumption of the 5 Whys method is that there is that presenting signs from one cause [24] . For complicated problems, this may not be successfully applied. A 5 Whys analysis may not uncover all of the causes that are related these symptoms.

How the Method Works

1. Gather your team.

First, invite people who have experience with the issue and the process you are going to fix to the 5 Whys meeting.

2. Choose a facilitator for your meeting.

The facilitator will lead the discussion, ask the 5 Whys, and keep the team concentrated on the issue.

3. Define the problem.

Discuss the problem with your team, and then concentrate on creating a clear and concise problem statement. In order to begin, answer the questions. What is going on, when did it happen, where did it happen, and who found the problem.

Write your problem statement on a board.

4. Ask why five times.

The first why should cover why the problem is going on. The method will be at its best if your answer is backed up facts. No by guessing allowed. Avoid going down the path of deductive reasoning, which can muddy the process. Answer each question rapidly in order to prevent the team from going down rabbit holes and jumping to conclusions.

Keep asking why until you feel that you've examined each path and can go no further. If your first why generated more than one reason, you can now go back and repeat the process until you've explored those routes, as well.

5. Tackle the root causes.

By now, you should have recognized one true root cause. Discuss what countermeasures can be adopted to prevent the issue from happening again. Responsibilities for these countermeasures to the group member may be assigned by the facilitator

6. Supervise your countermeasures.

The process doesn't stop there.

Supervising how effectively your measures solved or minimized the problem is crucial. If zero change is noted, you may have identified the wrong root cause and need to repeat the process.

2.5.2 Single-Minute Exchange of Dies (SMED)

Single-Minute Exchange of Dies (SMED) is a collection of techniques for considerably decreasing the time it takes to complete a changeover. SMED was first developed by Shigeo Shingo, a Japanese industrial engineer [9].

In SMED, the changeover process is broken into a sequenced list of steps called elements. The essence of SMED is to convert as many elements as possible to "external" (performed while the equipment is running), and to remove or streamline the remaining elements.

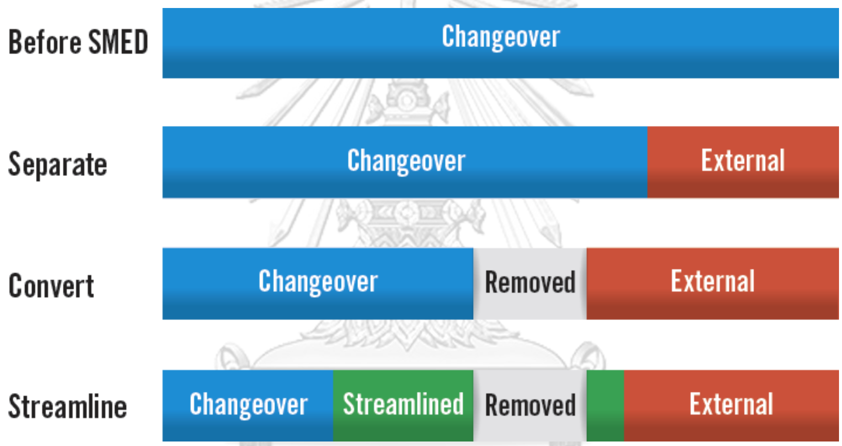

Figure 2. 4 SMED process

SMED projects is comprised of three conceptual stages (Figure 2.4): Separate (move elements to external), Convert (modify elements so they can be external, or remove them completely), and Streamline (complete elements faster) [25].

Separate

During this stage, elements that can be operational with almost no change while the equipment is running are recognized and moved "external" to the changeover (i.e., performed before or after the changeover). This stage is fertile ground for rapid wins.

Examples of elements that may be able to be separated contain retrieving tools, materials, or instructions before the changeover; executing cleaning tasks external to the changeover; and performing final quality checks for previous production external to the changeover.

Convert

In this stage, remaining elements are inspected to determine if they can be modified in some way to be external, or if they can be abolished. The result is a list of candidates for further action. This list should be created on a priority basis so the most potential candidates (i.e., the ones with the best cost/benefit ratio) are acted on first.

Examples of converting techniques contain preparing parts in advance (e.g., preheating dies); using duplicate jigs to perform alignment and other adjustments before the changeover; modularizing equipment (quick changing a pre-prepared modular part instead of modifying a fixed part); and adjusting equipment.

Streamline

In this stage, the remaining elements are reviewed to simplify them so they can be completed in a short time. Top priority should be internal elements to support the primary goal of shortening the changeover time. As in the prior stage, a simple cost/benefit analysis should be applied to prioritize actions.

Examples of streamlining techniques contain removing bolts in favor of quick release mechanisms; eliminating adjustments in favor of standardized settings; removing motion by rearranging the workspace; utilizing mobile racks to rapidly provide access to tools and parts; and making parallel operations with many team members.

In the short term, SMED lowers manufacturing cost by decreasing downtime and providing smoother startups (both of which improve OEE).

In the long term, SMED allows smaller lot sizes, better responsiveness to customer demand, and reduced WIP (work in progress) and inventory levels.

Steps to apply SMED:

Choose a Pilot Area

Spending time to select the optimal target area for your pilot SMED program will improve the odds of a successful outcome. Teams often select the process with the longest changeover. Instead, seek for a process with the following characteristics:

- The changeover is short enough to fully grasp and long enough to have important room for improvement (e.g., 30 to 60 minutes)

- Large variations occur in changeover times (usually this shows excellent potential for improvement)

- There are multiple opportunities to perform the changeover each week (so proposed improvements can be quickly tested)

- Employees in the prospective pilot area are engaged and motivated (eagerness and a desire to succeed are important drivers)

- Success will Improve the Constraint (bringing immediate, bottom-line benefits)

Start with a Meaningful Baseline

Explicitly define how to measure the length of changeovers to ensure they are measured consistently. For example: “Changeover time is measured from the last good part of the previous job at normal production speed, to the first good part of the next job at normal production speed.”

Once you have a simple and clear definition in your head, capture a baseline time. A good way to do this is to video a “normal” changeover. This video can also be used to create the initial list of SMED elements [26]. Be aware of the “Hawthorne Effect” – changeover times may temporarily develop as a simple result of observing the process.

Be curious

There is great power in assuming that any problem can be solved. The most effective SMED teams presuppose that every element can be made external – they just need to find the best way. The following questions (Table 2.4) help reinforce this way of thinking.

Table 2. 4 Question for SMED

Stage	Question
Separate	Can this element, as currently performed or with minimal change, be completed while the equipment is running?
Convert	If there was a way to make this element external to the changeover what would it be? How could we do it?
Streamline	How can this element be completed in less time? How can we simplify this element?

Capture Best Practices as Standardized Work

Companies are sometimes concerned that SMED will cause operators to rush through changeovers, compromising quality or safety. In practice, an effective SMED program captures best practices as Standardized Work, which is integral to repeatability, quality, and safety. Be certain to have a process for keeping work instructions up-to-date (as living documents) and disseminated (through training).

A good byproduct of SMED and standardized work is that it helps to guarantee the startup phase of manufacturing after a changeover contains no defects and downtime that are often related with startup.

Focus First on “Human” Improvements

When implementing SMED it is useful to consider two broad categories of improvement:

- Human (achieved through preparation and organization)

- Technical (achieved through engineering and optimization)

Human improvements are typically faster and less expensive than technical improvements. In other words, quick wins and the fastest progress usually come from human improvements [25].

Avoid the temptation, especially with technically proficient teams, to focus on technical improvements. Instead, focus first on human improvements.

2.5.3 Standard operating procedures - SOP

Standard operating procedures with informative instructions describing how to perform a routine activity are documented. In order for the business to be consistent, the employee must follow the procedures faithfully. Safety and efficiency for departments are maintained by the standards such as: Sales and customer service, Production/operations, Employee training, Financial, Legal.

A standing operating procedure should be simple and easy to understand. It also needs to include actions steps. Employees are supposed to know what to do any cases and informed of safety concerns.

The standing operating procedures should be the basis for training any new employees. They should also be updated annually to ensure they stay relevant to the current needs of the organization.

Nevertheless, not many businessmen fully appreciate the importance of standard operating procedures. They already coached their employees so why do they need a written document outlining the process as well?

Here are just a few of the reasons why your business needs standard operating procedures:

Finance and cost efficiency

When the same task is completed many different ways, it will always take longer to complete. Having a standard operating procedure in place streamlines the process so employees can accomplish more in less time.

Maintain consistency

Having a standard operating procedure in place ensures that regardless of who is working, business processes are being completed the correct way.

Improved communication

Standard operating procedures make your employees' jobs easier because no longer do they have to guess as to how they should be performing their jobs. And they don't have to try to rack their brains to remember what you told them when they were first hired.

Accountable employees

How can you assess your employees if you don't have written standards in place? With the absence of standard operating procedures, employee evaluations become a matter of personal opinion, which is hardly fair to your employees.

Safer work environment

When employees execute the same tasks in completely different ways, it is not only unproductive it is actually a burden for your business. Standard operating procedures ensure that employees perform their job functions in a safe and consistent manner.

One of the biggest misunderstandings about standard operating procedures is that they will cause businesses to become rigid and inflexible. This article in the Harvard Business Review does a great job of explaining how having systems in place for employees to follow actually makes businesses more flexible.

Here are five steps to follow when creating your standard operating procedure:

Creation of a list of your business processes

Firstly, organize a meeting among the and employees about the duties they perform in their daily work. This will let them to initiate the creation of detailed list of processes that need standard operating procedures.

Based on this, the list can be reviewed and any redundancies can be found. This list will help to create a starting point for creating your standard operating procedure.

Process planning

In this step, a format for your process is needed. Should it be under the form of a step-by-step guide or a diagram? From there you can create a template. You will also need to decide how your standard operating procedure will be made visible to your employees. Should you create an online version for it?

Employee Discussion

After having a list of processes and you have created your template, you need to talk to your employees. This is important because you can’t fully understand the process unless you have spoken with the people who actually perform it on a daily basis. Merely speaking with management is not sufficient.

Write and review the process

One you have spoken with your employees, instantly insert your notes to the template. Based on this, you can review your standard operating procedure with employees once again and obtain input from your managers. You should also identify who will be responsible for supervision and maintenance of the standard operating procedure.

All of your standard operating procedures should read the same way while still distinctly describing the roles of each area of your business.

Maintain the process

Even when the process is completed, your job is not done. To maintain the relevance and usefulness, you must update it every year.

Thanks to A written standard operating procedure, your employee knows how they should be doing their job and the reasons behind it. Naturally, when employees know why they are doing something, they are more like to do it.

Standard operating procedures are time-consuming to create at first but the benefits are worth it. And they will save you a lot of time and frustration down the road [12].

Standard operating procedures are comprehensive, written instructions on how to execute a routine business task. They are easy to read and explain every detail of the process being described. It should be noted that a good standard operating procedure focus more on how it should be done than what needs to be done. A standard operating procedure is a must-have for any businesses.

Standard operating procedures will give you a better insight into your business processes. All employees will tend to perform the business processes in the same way.

Standard operating procedures at your disposal will also give you the option to scale your business more quickly. This results from the easy replication of these processes throughout the organization. Many businesses select to apply standard operating procedures by showing written documents in areas where they will be easily seen.

2.5.4 5S

One of the methods of shaping an organization approach to its business is to assess its workplace organization capability & visual management standards [26].

5S involves people through the use of 'Standards' and 'Discipline'.

It is not only focus on housekeeping, but paying attention to maintain the standards & discipline to manage the organization - all achieved by daily upholding & showing respect for the workplace.

The 5 Steps are as follows:

Sort: Sort out & separate that which is needed & not.

Straighten: Rearrange needed items so that they are ready & easy to use. Clearly identify locations for all items so that anybody can find them & return them after the completion of the task.

Shine: Clean the workplace & equipment on a regular basis in order to maintain standards & identify defects.

Standardize: Revisit the first three of the 5S on a frequent basis and enforce the condition of the Gemba applying standard procedures.

Sustain: Stick to the rules to maintain the standard & continue to improve every day.

5S is associated with workplace organization and create a solid foundation upon which many organizations base their drive for nonstop improvement. It is equally applicable & successful in all sectors helping to attain good results [9].

It is a systematic and methodical approach allowing teams to organize their workplace safely and efficiently.

The discipline to check & repair equipment is included & adopted. The full process is monitored through the use of team generated audit documents, completed on an agreed frequency by responsible owners within the Gemba.

Chapter 3

Experiment

3.1 Study design

The survey and data collection in this study were carried out at the currently operating corrugated box manufacturer in Ho Chi Minh City, Vietnam. The data were collected over a period of 12 months focusing on the stage of processing corrugated paper. At least 300 datasheets related to single wall corrugated paper were collected and analyzed. Figure 3.1 shows the diagram of corrugated paperboard production. Table 3.1 indicates 4 steps to improve OEE for CFP reduction including profitability consideration.

Table 3. 1 Steps in improvement of OEE

	Step 1: Survey of current status	Step 2: Analysis & selection of methods to improve OEE	Step 3: Practice to improve OEE	Step 4: Process, analysis of the collected data
Required data collection	Manufacturing time Input materials Electricity consumption	Interviewing direct manufacturers Identifying stage(s) for improvement	Alternation in manufacturin g process	Manufacturing time Input materials Electricity consumption
Methods of implementa tion	Calculating OEE, CFP, Profitability.	Questions were asked to workers	Four improvement practices	Relation of OEE, CFP, Profitability

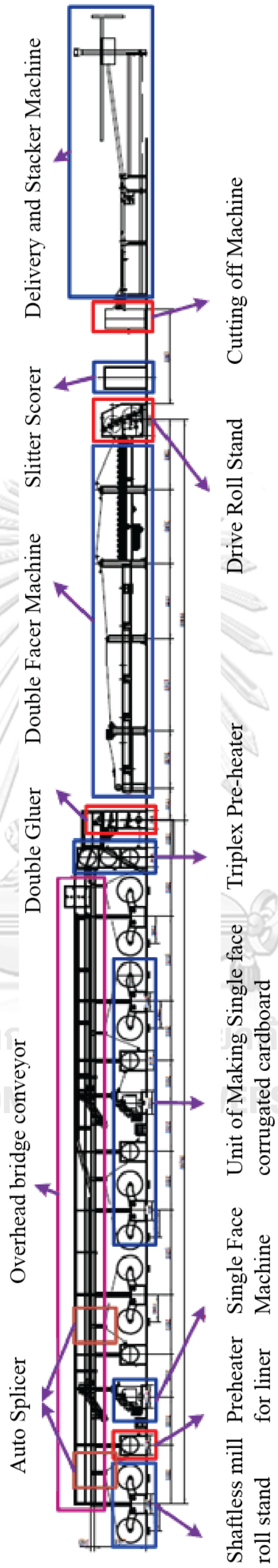

Figure 3. 1 The diagram of corrugated paper board production

3.1.1 Data collection

Data were collected on a daily basis from individual orders input on corrugating machine since each order has different specifications. The parameters including CFP and Profitability were calculated for the same unit of 1 square meter ($1m^2$) based on the data from each order. The intensive frequency of data collection could ensure the reliable calculations of total available time and operating time which were used for the prediction of OEE, CFP and Profitability.

Table 3. 2 Data sheet of corrugating machine

DATA SHEET OF CORRUGATING MACHINE			
Date		No. of order	
Starting production time (h:m)		No. of board per width	
Ending production time (h:m)		No. of ply	
Starting break time (h:m)		Roll paper dimension (cm)	
Ending break time (h:m)		Paper weight (g/m2)	
Starting electricity indicator (kw)		Income roll paper weight (kg)	
Ending electricity indicator (kw)		Remaining roll paper weight (kg)	
Glue powder using (kg)		Weight of 1 board (kg)	
		Length of board (cm)	
		Width of board (cm)	
		No. of good board (sheet)	
		Starting of net operating time (h:m)	
		Ending of net operating tim (h:m)	

The data sheets (Table 3.2) were manually filled by the well-trained technicians who are directly in charge for operating the corrugating machine. The collected data were then keyed into excel sheets and analyzed. Later on, data collection and analysis were performed by a web-based.

Table 3. 3 Data collection and unit

No.	Data collection	Unit	No.	Data collection	Unit
1	Date	dd/mm/yyyy	12	Roll paper dimension	cm
2	Starting production time	h:m	13	Paper weight	gsm
3	Ending production time	h:m	14	Income roll paper weight	kg
4	Starting break time	h:m	15	Remaining roll paper weight	kg
5	Ending break time	h:m	16	weight of 1 board	kg
6	Starting electricity indicator	kw	17	Length of board	cm
7	Ending electricity indicator	kw	18	Width of board	cm
8	Glue powder using	kg	19	No. of good board	sheet
9	No. of order	no.	20	Starting of net operating time	h:m
10	No. of board per width	no.	21	Ending of net operating time	h:m
11	No. of ply	no.			

Table 3.3 shows the data needed to be collected and their unit. The starting and ending production time (Items 2 and 3) were carefully recorded to calculate the total available time. Break time was calculated based on starting and ending break time (Items 4 and 5) while net operating time was determined followed Items 19 and 20. These three parameters were used to compute the indexes including A (Availability), P (Performance), and Q (Quality) which were subsequently used for the estimation of OEE.

Electricity consumption indexes at the starting and ending (Items 6 and 7) were used to compute the amounts of electricity consumed (in the unit of kilowatt, kW). The amount of glue powder consumed (Item 8) represented the amount of input materials for the manufacturing process. This was the main data set for identification of CFP, price and profitability per $1m^2$ of the finished paper product.

Data collected from Item 9 to Item 19 were utilized to determine the total amount of paper consumed (kg), by-products (kg), finished product (m^2), and the rate of net operating (meter per min). These data supported the quantification of OEE, CFP and Profitability.

The data of 300 data sheets of corrugating machine operating under five main conditions (A) No impact, (B) Impact 1, (C) Impact 1 + Impact 2, (D) Impact 1 + Impact 2 + Impact 3+4, (E) Impact 1 + Impact 2 + Impact 3+4 + Impact 5, were gathered for a period of 12 months. Data were repeatedly collected (30 working days) at each impact condition.

3.1.2 Data analysis:

3.1.2.1 OEE measuring

OEE is widely used by manufacturing companies to evaluate performance of equipment. OEE is calculated using three values A, P, and Q (Availability, Performance, and Quality, respectively) which were computed according to the data collected directly from the corrugating machine.

Availability is the ratio of operating time and planned production time which takes into account the down time loss. Down time loss indicates ending production time, for example, warm-up time and preparing time for starting the production. This time also includes amount of time to perform adjustment of the machine to produce a desired quality of the finished product. In addition, it also comprises time for changing order and cleaning activity before completing an order. Down time loss directly influences on A, therefore, down time loss was impacted to improve A thus improving OEE. In this study, down time loss was reduced to increase A. Calculation of A was indicated in *Equation 3.1*.

$$\text{Availability} = \frac{\text{Operating time}}{\text{Planned production time}}$$ *(Equation 3. 1)*

where:

Planned Production Time = Production Time – Break Time *(Equation 3. 2)*

Operating time = Planned Production Time – Total Down Time *(Equation 3. 3)*

Performance is the ratio of the actual running speed over the standard running speed (*Equation 3.4*). The speed loss of equipment represents all factors leading to minimization of the speed, for instance, unqualified input materials or inefficient operation of equipment. Performance is the main indicator to assess actual running speed and designed running speed.

$$\text{Performance} = \frac{\text{Actual running speed}}{\text{Standard running speed}}$$ *(Equation 3. 4)*

where:

Actual running speed = Total meter production / Operation time *(Equation 3. 5)*

Quality relates to quality loss which represents unqualified finished products. In this study, quality loss was indicated by the difference between the amount of input paper and the amount of paper in finished product. Quality was calculated by the ratio between good board and total paper usage as indicated in *Equation 3.6*.

$$\text{Quality} = \frac{\text{Good board}}{\text{Total paper usage}}$$ *(Equation 3. 6)*

where:

Total paper usage = input paper – remaining paper *(Equation 3. 7)*

OEE was calculated by the product of A, P, and Q as indicated in Equation 4.

OEE = Availability x Performance x Quality *(Equation 3. 8)*

OEE provides useful information for evaluation of performance of equipment on a daily basis. In the present study, options were made to improve OEE by which CFP and Profitability were also assessed.

3.1.2.2 CFP measuring

Carbon footprint (CFP) is defined as total amount of CO_2 and other greenhouse gases directly or indirectly generated from anthropogenic activities and other biological processes. CFP is used as an indicator to measure the level of pollution caused by a manufacturing process. In the current study, CFP was calculated for each unit of finished paper product (m^2). The calculation process of CFP was indicated in Figure 3.2. The two main input materials for production of corrugated paper were paper and glue powder in which paper and glue powder were purchased and transported for 30 and 40 km from the supplies to the manufacturing place, respectively. The amount of electricity used was divided into two parts including machine operation and lighting. Seventy percent of the finished paper product could be recycled whereas 30% could be discharged into the landfill. Carbon emission factors were obtained from Thailand National Database [3]. The data were consistently used for calculation of CFP except the intentional impacts to result in changing CFP for the purposes of this study. Specifically, the impacts to improve OEE caused change of CFP. It was assumed that the change of CFP was only dependent on the purposeful impacts.

CFP OF CORRUGATING MACHINE

Date 03-Nov-16

Item	Amount usage	Carbon emission factor *	CO2 emission (kg)	%	Total CO2 emission (kg)	%
Raw materials					1,730.53	81.54
Paper (kg)	1,720.00	0.995400	1,712.09	80.67		
Glue(kg)	35.00	0.527000	18.45	0.87		
Manufacture					348.52	16.42
Electricity usage (kw)	571.33	0.609300	348.11	16.40		
Lighting in plant (kw)	0.68	0.609300	0.41	0.02		
Recycle waste					0.46	0.02
Paper waste (kg)	275.26	0.001670	0.46	0.02		
Disposal					2.96	0.14
Land fill (kg) - 30%	433.42	0.002930	1.27	0.06		
Recycle (kg) - 70%	1,011.32	0.001670	1.69	0.08		
Transportation					39.95	1.88
Paper (ton/km)	51.60	0.764000	39.42	1.86		
Glue (ton/km)	1.40	0.378100	0.53	0.02		
Tota (kgCO2e)			**2,122.43**	**100.00**	**2,122.43**	**100.00**
Per 1m2 (kgCO2e)			**0.19**		**0.19**	

* Thai National Data Base

Figure 3. 2 CFP values per 1m^2 corrugated board

3.1.2.3 Profitability measuring:

Profitability was determined based on profit of Mark-up (Equation 3.10) from cost price and selling price as indicated in Table 3.4. Cost price depends on the total paper, glue powder, and electricity consumed. These parameters would be changed once an impact was performed which could result in increasing or decreasing the cost price. The cost of input paper, glue powder, electricity and labor was fixed during the study period to ensure the cost price can be changed due to direct impacts on the manufacturing process. Selling price was computed depending on the price of 1-layer board paper multiply by the total corrugated board and the fixed price of 1 layer board.

Percent of Profit Margin = (Profit / Selling price) * 100 *(Equation 3. 9)*

Percent of Profit Mark-up = (Profit / Cost price) * *100* *(Equation 3. 10)*

Where:

Profit = Selling price – Cost price *(Equation 3. 11)*

Table 3. 4 Profitability measuring

PROFITABILITY OF CORRUGATING MACHINE	
Date	03-Nov-16
COST PRICE (USD)	840.26
Total paper usage (kg)	1,720.00
Price of roll paper (USD/kg)	0.41
Price of glue (USD)	21.95
Price of electricity (USD)	72.72
Price of worker (USD)	41.96
SELLING PRICE (USD)	1,157.08
Total corrugated board (m2 of 1 ply)	11,313.70
Price of 1 ply board paper (USD/m2)	0.10
PROFIT (USD)	316.82
PERCENTAGE OF PROFIT MARGIN (%)	27.38
PERCENTAGE OF PROFIT MARK-UP (%)	37.70

3.2 Equipment and material

3.2.1 Corrugated board production machine

Vietnam VJ 200 Series 2/3/5/7 Ply Corrugated cardboard production lines are consist of YZJ2 hydraulic mill roll stand, DW3 Single Facer, MY1 Outer Liner Pre-heater, XY1 Core Medium Pre-heater, DY1 Double Pre-Heater, TJ3 Single Pasting Glue Machine, GQ4 Single Overhead Convey Bridge, SM4 Double Facer , ZCD2 Main Drive System, ZQY NC Slitter Machine, HQ2 NC Rotary Cutting Off Machine, DM2 Manual Counting Stacker, ZG -I Steam System, ZJX -IGlue Making & Recycling

System, KY-IAir Compressor System, DK3-IElectric Control System, SZ trolley and rail.

Year: 1998

Driven Type: Electric

Voltage: 380v

Power: 180KW

Place of Origin: Vietnam

Brand Name: CKNI

Model Number: CKNI-1400

Dimension(L*W*H): 45*3*5m

Weight: 60T

Main parts manufacturers:

* Rolling Bearings: Harbin, Wafangdian, Luoyang.

* Mounted Bearings: Fujian, Henan, Guangdong

* Frequency Motors: Shandong, Jiangsu.

* Geared Motors: Taiwan

* Cotton Ribbon : Liaoning

* Upper & Lower Corrugated Roller s: Shanghai, Jiangsu

* Glue and Doctor Roller: Shanghai, Jiangsu

* Low - voltage electrical appliances: Schneider(France), Chint

* Air Cylinder: Zhejiang

* Oil Seals: Hebei

* Steam Trap: Taiwan

* Encoder: Korea

* Suction Fan: Guangdong

* NC Slitter : Shandong, Hebei

* PLC Controller: Taiwan

* Frequency Converter: Taiwan

* Touch Screen: Beijing Kunluntongtai

3.2.2 Paper

Corrugated board consists of one or two outer plies, the flutes and, in multi-ply types of corrugated board, of one or more intermediate plies. The outer plies use the test liner paper while the intermediate plies use the corrugated medium paper. In this study, the specifications of test liner paper and corrugated medium paper are shown in tables 3.5 and 3.6, respectively.

Table 3. 5 Test Liner Paper

Particulars	Unit	100gsm	115gsm	125gsm	150gsm	180gsm	200gsm
Grammage Variation	%	+/-5	+/-5	+/-5	+/-5	+/-5	+/-5
Burst Factor Range	%	16 to24	16 to24	16 to24	16 to24	16 to24	16 to24
Cobb 1 mt (max) TS	gsm	40-45	40-45	40-45	40-45	40-45	40-45
Cobb 1 mt (max) BS	gsm	60-70	60-70	60-70	60-70	60-70	60-70

Table 3. 6 Corrugated Medium Paper

Particulars	Unit	100gsm	115gsm	125gsm	150gsm
Grammage Variation	%	+/-5	+/-5	+/-5	+/-5
Burst Factor Range	%	14 to22	14 to22	14 to22	14 to22
Cobb 1 mt (max) TS	gsm	35-40	35-40	35-40	35-40
Cobb 1 mt (max) BS	gsm	50-60	50-60	50-60	50-60

3.2.3 Glue powder

Glue powder using in this study was bought from China, the specification as the following details:

Material: high strength corn starch

Industrial Use: Packing,Specialize for laminating machine

Place of Origin: Shandong, China (Mainland)

Brand Name: G&Z

Model Number: GZ101

Product name: Glue powder used for corrugated board flute laminator

characteristics: weather-persistent, quick-drying, stong adhesion

appearance: white free flowing powder

water glue making: no need heating

smell: no peculiar smell

environmental: green and environmental protection

add other glue reinforcing agent: no

Certificate: CE, ISO

adhesion: stronger

dry time: 3-5m

3.2.4 Microsoft Excel Software

All of the calculations in this study were calculated by equacation inputting in Microsoft Excel 2011 software. The Prediction model also based on the Microsoft Excel software calculation.

3.3 Experiment 1

3.3.1 Survey of current status

The data were collected within 30 working days by the machine operators. Values of OEE, CFP, and Profitability were calculated based on the software presented in sections 3.1.2.1, 3.1.2.2 and 3.1.2.3.

Figure 3.3 and Figure 3.4 present the current status of OEE, CFP and Profitability of corrugated paper machine.

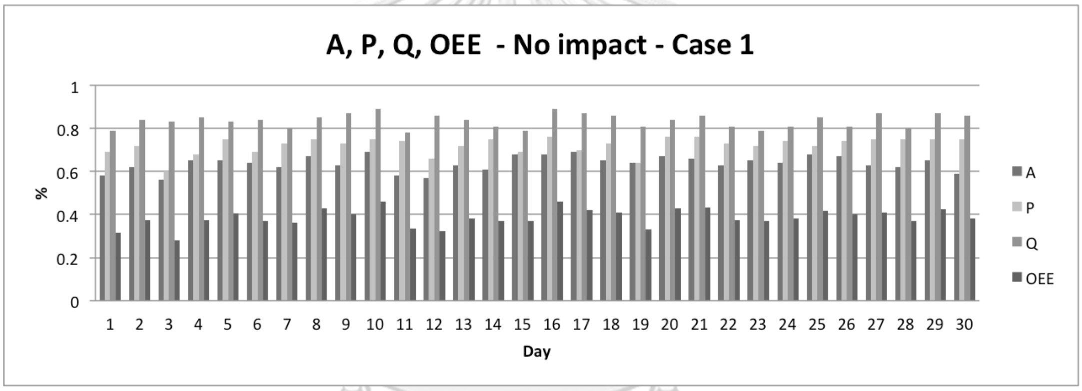

Figure 3. 3 Current status of A, P, Q, OEE in case study 1.

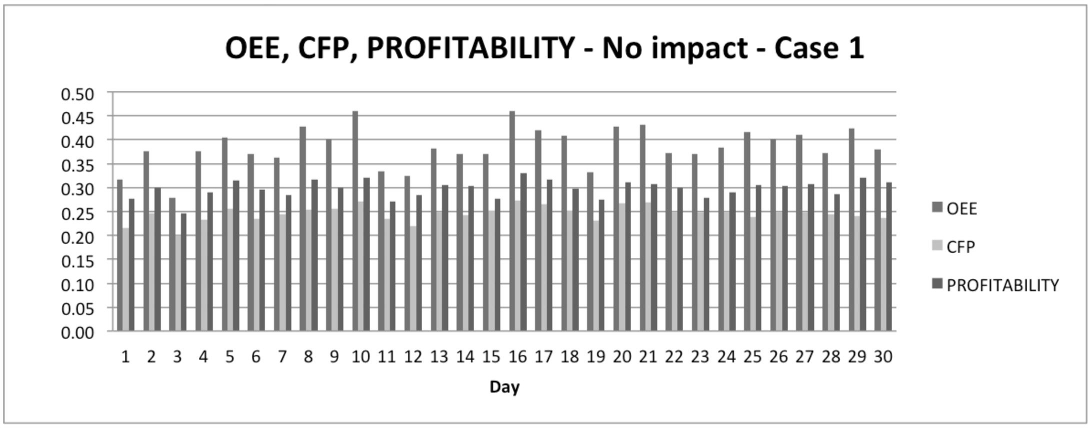

Figure 3. 4 Current status of OEE, CFP and Profitability in case study 1

3.3.2 Analysis and selection of methods for improvement of OEE

Ishkawa technique is used to determine the areas for improvement of OEE

Ishikawa diagram (also called fishbone diagram, herringbone diagram, cause-and-effect diagram, or Fishikawa) is causal diagram that shows the causes of a specific event or problem. The purpose is to break down (in successive layers of detail) root causes that potentially contribute to a particular effect.

Common uses of the Ishikawa diagram are product design and quality defect prevention to identify potential factors causing an overall effect. Each cause or reason for imperfection is a source of variation. Causes are usually grouped into major categories to identify these sources of variation.

The categories typically include:

• people: anyone involved with the process;

• methods: how the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws;

• machines: any equipment, computers, tools, etc. required to accomplish the job;

• materials: raw materials, parts, pens, paper, etc. used to produce the final product;

• measurements: data generated from the process that are used to evaluate its quality;

• environment: the conditions, such as location, time, temperature, and culture in which the process operates.

How to create a “fish diagram”?

• create a head, which lists the problem or issue to be studied;

• create a backbone for the fish (straight line which leads to the head);

• identify at least four "causes" that contribute to the problem; connect these four causes with arrows to the spine; these will create the first bones of the fish;

• brainstorm around each "cause" to document those things that contributed to the cause; use the 5 Whys or another questioning process such as the 4P's (Policies, Procedures, People and Plant) to keep the conversation focused;

• continue breaking down each cause until the root causes have been identified.

Figure 3.5 indicates the final results of Ishikawa method that the main causes of hindering the improvement of OEE in corrugated paper machine have been identified such as poor standard of operation, improper procedure, untidy work area, lack of quick change, lack of proper training.

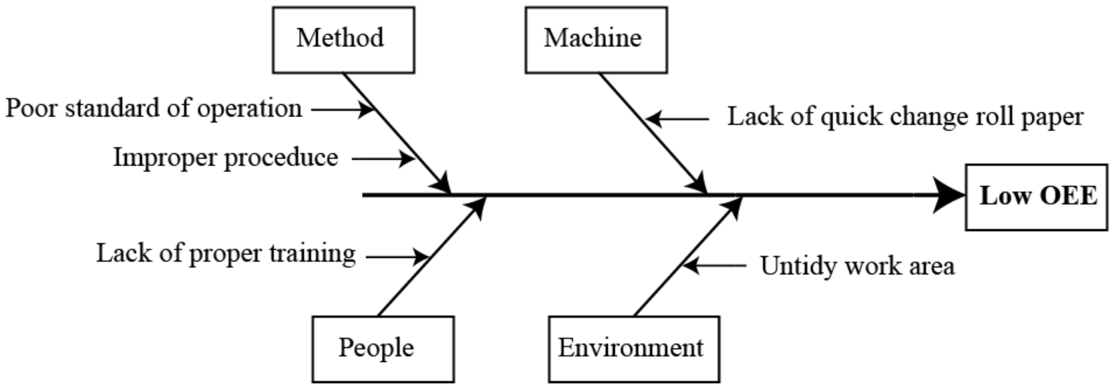

Figure 3. 5 Results of Ishikawa to improve OEE

3.3.3 Implementation of improvement of OEE

For the principal causes that prevent improvement of OEE, several TQM techniques were used to improve OEE. TQM has a corresponding technique that solves each problem. Table 3.7 shows TQM techniques used for each cause and predicted the most potential improvement in the OEE index (A or P or Q).

Table 3. 7 TQM techniques used to improve OEE factors.

Causes	TQM technique	OEE improvement by
Improper equipment	5 whys	A and P
Lack of quick change roll paper	SMED	A
Poor standard of operation	SOP	P and Q
Lack of proper training	SOP	Q
Untidy work area	5S	A and P

3.3.3.1 Improvement of OEE using technique "5 whys" to fixing problem of improper equipment

The aim of the method is to find equipment, components that are not suitable for the production of corrugated paper, equipment and parts that are the causes of "availability loss", "performance loss" and "quality loss". In corrugated paper production process, curing process is a process that greatly affects time of machine startup and actual production. These two factors directly affect A and P of corrugated paper machine. The "5 whys" method was applied by asking "why" to find out root causes of curing process.

Manufacturing process for corrugated paper:

+ Preparation: Preparing glue powder/ Accelerating temperature for corrugated head and drying head/ Preparing rolling paper/ Loading paper/ Loading glue

+ Adjustment: Adjusting paper/ Adjusting glue/ Adjusting paper size cutting/ Producing paper at slow rate/ Testing quality of paper produced/ Accelerating producing paper rate/ Testing quality of paper produced

+ Production: Stabilizing loading paper/ Producing according to order

In this production process, the steps of preparation and stabilizing production rate were the two direct impacts on OEE. Two questions were asked to all well-trained workers to improve OEE.

Table 3. 8 Problem statement 1

Problem statement 1: preparation time was so long?	
Question	Answer
1. Why was the preparation time so long?	- Because the waiting time for curing process was so long.
2. Why was the waiting time for curing process so long?	- Because the curing machine requires at least 30 min to reach a desired temperature
3. Why does the curing machine take 30 min to reach the required temperature?	- Because the temperature increased slowly
4. Why was the temperature slowly increased?	- Because the curing process had low efficiency.
5. Why did the curing process have low efficiency?	- Because initial requirement of temperature was at such level

Table 3. 9 Problem statement 2

Problem statement 2: low producing rate?	
Question	Answer
1. Why was the production rate low?	- Because the speed of the machine was dependent on curing temperature.
2. Why was the speed of the machine dependent on curing temperature?	- Because the curing temperature was unstable.
3. Why was the curing temperature unstable?	- Because the difference between the lowest temperature and highest temperature was too large.
4. Why was the difference of temperature high?	- Because there was large difference of heat sensors
5. Why was the difference of heat sensors so high?	- Because it was that initial design.

The solutions for these two problems: using higher capacity of thermal controller and reducing difference of the thermal sensors. Two devices were installed for the improvement:

- Installation of a device that enables a higher current of electricity, the temperature in the thermal plate could reach 245°C within 5 minutes instead of 30 minutes in the case of no impact.

- Installation of a thermal sensor surrounding the thermal plate. This sensor will send a signal to an auto circuit breaker to switch off the power when the temperature is higher than 250°C or to switch on the power when the temperature is lower than 245°C. Thus, the temperature is always in the range 245-250°C.

3.3.3.2 Improvement of OEE by technique "SMED" to solve problem of "Lack of quick change roll paper"

The method of SMED was applied to minimize time for shifting ordering which directly influenced "Availability loss" and thus improving OEE.

Figure 3.6 shows the steps of loading paper, shifting ordering in three ply corrugated paper production.

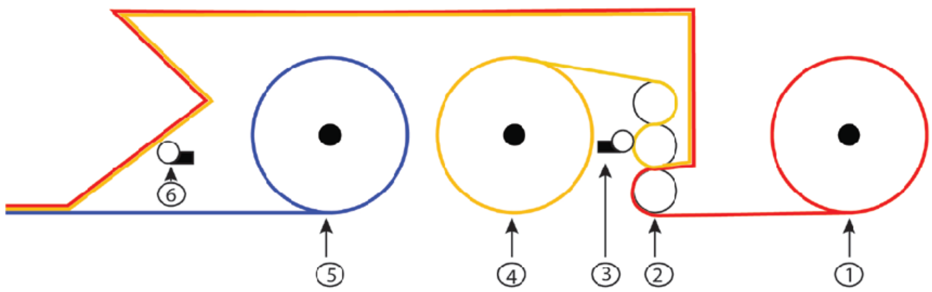

Figure 3. 6 Diagram of three-layer corrugated paper production.

Step 1: determining size of rolling paper.

Step 2: moving the rolling paper to the position (1), (4), (5)

Step 3: uploading paper (placing rolling paper onto the iron shaft and lift the rolling paper up and fixing it)

Step 4: initiating corrugation system (2)

Step 5: placing glue into the glue container (3), adjusting glue at its ends

Step 6: starting rolling paper (1) and (4) let the paper enter the corrugation system once the glue compartment reached properly desired temperature

Step 7: adjusting rolling papers between position (1) and (4)

Step 8: adjusting the thickness of glue layer

Step 9: letting two layers of paper (1) and (4) getting through the glue tip (6) to integrate to the rolling paper (5)

Table 3. 10 Converting internal activities to external activities

Activities	Current	Planned	Time (mins)	Time taken for internal activities only (mins)
Step 1	Internal	External	6	
Step 2	Internal	External + Internal	15 (12 + 3)	3
Step 3	Internal	External + Internal	15 (12 + 3)	3
Step 4	Internal	External	4	
Step 5	Internal	Internal	6	6
Step 6	Internal	Internal	4	4
Step 7	Internal	Internal	3	3
Step 8	Internal	Internal	2	2
Step 9	Internal	Internal	3	3
Total			58	24

In Table 3.10, the time of order-shifting significantly shortened from 58 min to 24 min when applying SMED. This was an important factor in reducing "availability loss" and significantly improving OEE.

3.3.3.3 Improvement of OEE using technique "SOP" to solve problem of "Poor standard of operation" and "Lack of proper training"

The "SOP" approach generated a specific process of working with detailed steps so that the operators could accurately implement to ensure stability and optimization of the production process. The stability and optimization directly influenced "Performance Loss", "Quality Loss" and OEE was significantly improved.

Currently, operation of a corrugated paper machine requires four workers and the individual tasks are as follows:

- Worker 1 (team leader): reading the order and requesting the other 3 workers to get 3 rolls of paper following the order.

- Worker 1: initiating the machine, making glue and placing it in the container.

- Workers 2, 3, 4: moving papers to the accurate position in production, entering the paper once the machine reached the desired temperature, adjusting quality and size of corrugated papers according to the order.

- Machine operating: two workers control the speed, glue, and quality at the corrugated generation part; the other two workers standing at the end of the final steps of production to check quality and size of the produced paper.

- Order completed: three workers unloading the remaining paper and placed it back in the storage. The team leader prepares for the production of the next order.

With this way of operation, the time for preparation was too long, especially during the operation, time calibration, and troubleshooting affecting the speed of the machine and quality of paper produced. This directly affected “performance loss”, “quality loss”, and OEE could not be high. Generation of SOP is essential to improving OEE through improved P and Q.

The steps in creating standard operating procedure template:

Creation of a list of business processes

Firstly, organize a meeting among the and employees about the duties they perform in their daily work. This will let them to initiate the creation of detailed list of processes that need standard operating procedures.

Based on this, the list can be reviewed and any redundancies can be found. This list will help to create a starting point for creating the standard operating procedure.

Process planning

In this step, a format for the process is needed. Should it be under the form of a step-by-step guide or a diagram? From there template can be created. The standard operating procedure will be made visible to employees.

Employee Discussion

After having a list of processes and created template, talking to employees is the need. This is important to make sure the fully understand of the process with the people who actually perform it on a daily basis. Merely speaking with management is not sufficient.

Write and review the process

The employees should be discussed, instantly insert notes to the template. Based on this, the standard operating procedure can be reviwed with employees once again and obtain input from managers. The workers who will be responsible for supervision and maintenance of the standard operating procedure should be identified

All of the standard operating procedures should read the same way while still distinctly describing the roles of each area of business.

Maintain the process

Even when the process is completed, the job is not done. To maintain the relevance and usefulness, the update should be done every year.

Table 3. 11 SOP of corrugated board production

NO.	Job description	Implementer	Time (min)
	Preparation		
1	Reading the order	Team leader	5
2	Placing paper into the correct position	Three workers	5
3	Initiating the machine	Team leader	10
4	Primary adjustment following the order of production	4 workers	10
	Loading paper		
5	Placing paper onto iron shaft	Three workers	3
6	Loading paper	Three workers	3
7	Adjusting following order of production	Four workers	3
	Loading glue		
8	Preparing glue	Team leader	2
9	Placing glue in the container	1 worker	6
10	Adjusting the amount of glue	1 worker	3
	Adjusting the length		

11	Adjusting the length following the order of production	1 worker	5
	Unloading paper		
12	Unloading paper out of production	Three workers	2
13	Removing paper out of iron bar	Three workers	2
14	Placing unused paper to the storage place	Three workers	3

Workers were required to comply with the SOP (Table 3.11). After 3 months of operation, speed of the machine was stable, quality of paper sheets was significant higher than before application of SOP.

3.3.3.4. Improvement of OEE by technique "5S" to solve problem of "untidy work area"

5S was not only dealt with controlling the area around the workplace but was also used as a "Standard" and "Discipline". With good operation of 5S, time for preparation of the machine and production time was optimized, directly affecting "Availability loss", "Performance loss" and OEE would be improved.

The 5S was conducted step by step following instruction of professional managers. The 5S is not only applied in corrugated machine but it was also used in the other stages of the company.

SORT

Separate items which are required and not-required. Dispose the items which are not required.

• Take Pictures of the area and display in a notice board

• Include all the members in the area for segregating required and not-required items in their workplace

• All the unwanted items to be sent to a Red Tag Area with a red tag mentioning the date, item name and why it is not required

• Senior Management to focus on disposing the items in the Red Tag area

• Items that are required only would go to the subsequent steps

SET IN ORDER

Arrange all the required items based on the place of requirement. “A place for everything and everything in its place”

• After Sorting out the unnecessary items, the needed items have to be classified by use and arranged as following:

- To minimize search time and effort

- To facilitate easy return and retrieval

- Place each item in a designated address

• In simple terms - “A place for everything and everything in its place”

SHINE

Clean your machines, workplace daily. Follow a cleaning schedule. Follow Preventive Maintenance for machines

• This involves cleaning the work place including machines, tools, floor, walls and other areas.

• On cleaning, a lot of abnormalities like cracks, loose nuts, bolts, oil leakage, loose wires, etc. can be detected and rectified

• Follow Preventive Maintenance Check list provided by the Machine Manufacturer - as per the schedule

• Cleaning is inspection and a health check

• Clean your workplace every day - for 10 minutes

• Maintain a cleaning schedule at your workplace

STANDARDIZE

Ensure all the above 3 steps are followed by all the employees in the company. Create Visual Indications, SOPs so that the best practices don't slip back to original condition.

• Maintain all the above "3S" regularly by providing Visual Controls, SOPs, Training and use of colors for identification

• This stage is when 5S become systematic and starting to become the culture of the organization

SUSTAIN

5S becomes a culture of the organization. Regular audits, training, competitions, rewards and recognitions ensure that 5S sustains in the organization.

• 5S becomes a part of the everyday work and becomes a culture of the company

• The greatest benefits of 5S is to help people to focus and acquire Self-Discipline. People's behavior is a reflection of the environment

• Conduct regular 5S audits and recognize the teams and give them rewards. Conduct 5S Slogan Contests, Internal competitions, regular training to employees (by employees)

• Everybody should feel proud to take part in 5S

Plan to apply 5S:

1. Form a 5S Team to implement 5S in your company. This should contain members from all important functions. Can be a mix of supervisors, operators and managers

2. Divide the company in to multiple zones (based on the layout) and give names to each zone (interesting names?)

3. Implementation should happen zone-wise. All the employees in a zone are part of the 5S team of that zone.

4. One member would act as the 5S zone leader. He/She would also be a part of the 5S Apex Team

5. Train the 5S Apex Team on 5S. This team should train the zonal 5S teams regularly

Implementation method:

1. Identify a Pilot Zone for starting 1S (Which zone is looking very bad? and can we achieve faster results there? Will the team cooperative?)

2. Start 1S in this Pilot Zone (max. time period - 7 to 10 days and document the benefits / progress)

3. Move to a next zone for implementing 1S. In the first pilot zone, start 2S.

4. People who did 1S in the Pilot Zone would act as the trainers for the employees in the second Pilot Zone.

5. Move to 3rd Zone (for 1S). Do 2S in second zone and 3S in the first zone.

6. Horizontal deployment across the company

After three months of applying 5S, the working area of the corrugated machine is clean, and time of preparation and operation was clearly improved. The OEE would be certainly better through improving “Availability loss”.

3.3.4 Process and analysis of the collected data

The process of improving OEE through TQM techniques was carried out under the direct instruction of TQM expert. Five impacts were made consequently over 12 months. Data were collected (Table 3.12) continuously using structured data collection forms. The data was collected for the period of 30 days for analysis.

Table 3. 12 TQM technique apply time and collecting data time.

TQM technique	Applying time (day)	Collecting data time (day)
Impact 1 - 5 whys	60	30
Impact 2 - SMED	75	30
Impact 3+4 - SOP	120	30
Impact 5 - 5S	60	30

Figure 3.7, Figure 3.10, Figure 3.13, Figure 3.16 demonstrate data of the parameters of A, P, Q, and OEE for impacts 1, 2, 3+4, 5, respectively that were recorded for the period of 30 days of single impact. All of the values of these days are lower than the value of World Class values of A, P, Q and OEE. It means that the OEE still can improve by improving A, P, Q respectively.

Figure 3.8, Figure 3.11, Figure 3.14, Figure 3.17 indicate values of OEE, CFP, and PROFITABILITY calculated on a daily basis for every impact. All of these Figures show the relations among OEE, CFP and Profitability. All the days of all impacts show that the highest value is OEE, the lowest value is CFP and the medium value is Profitability. It means that when improving OEE, the changing trend of values of CFP and Profitability in every day is stable.

Figure 3.9, Figure 3.12, Figure 3.15, Figure 3.18 depict a change of the parameters of the two consecutive impacts. All parameters were changed after being impacted by one TQM technique, but this change was not the same for all impacts. Figure 3.9 shows the most improving of A when applying “5 whys” technique and the lowest increasing is Q. Figure 3.12 also shows the highest increasing of A when applying “SMED” and the lowest increasing also is Q. Figure 3.15 shows the most increasing of Q when applying "SOP" technique and the lowest improving is A. Figure 3.18 shows the lowest increasing of Q and a very low improving of A and P when applying "5S" technique.

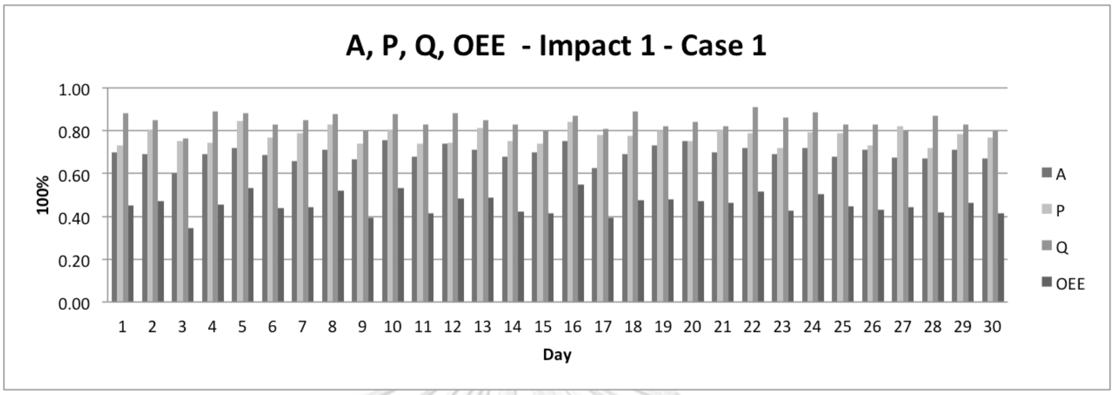

Figure 3. 7 A, P, Q, OEE under the impact 1 – case study 1

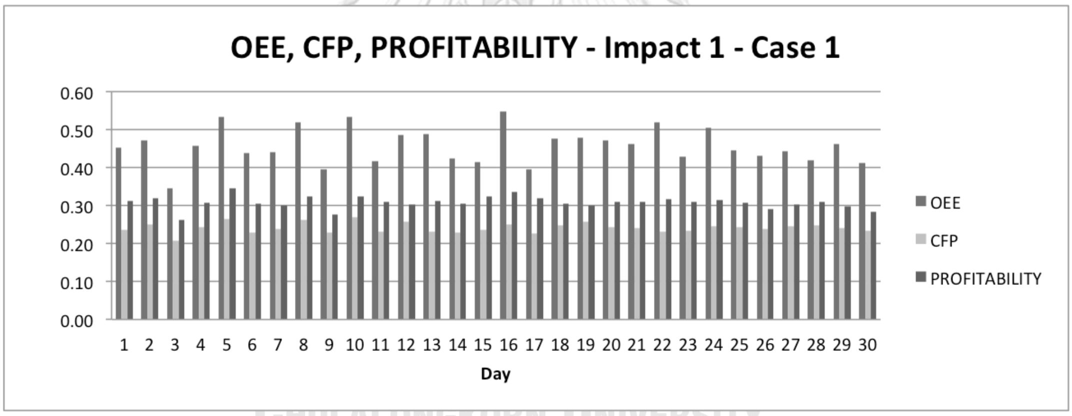

Figure 3. 8 OEE, CFP, Profitability under impact 1 – case study 1.

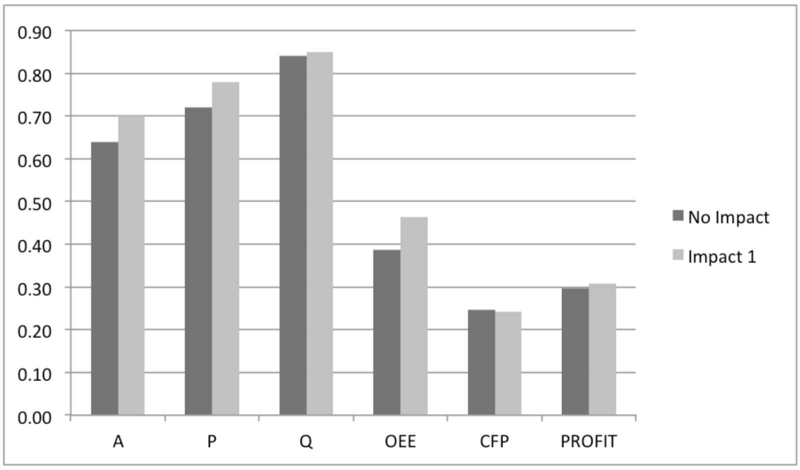

Figure 3. 9 A, P, Q, OEE, CFP and Profitability in "No impact" and "Impact 1"

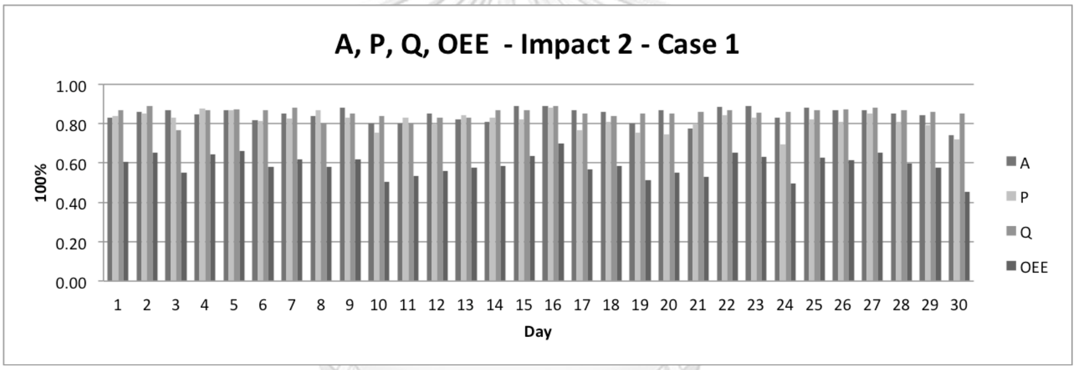

Figure 3. 10 A, P, Q, OEE under impact 2 – case study 1

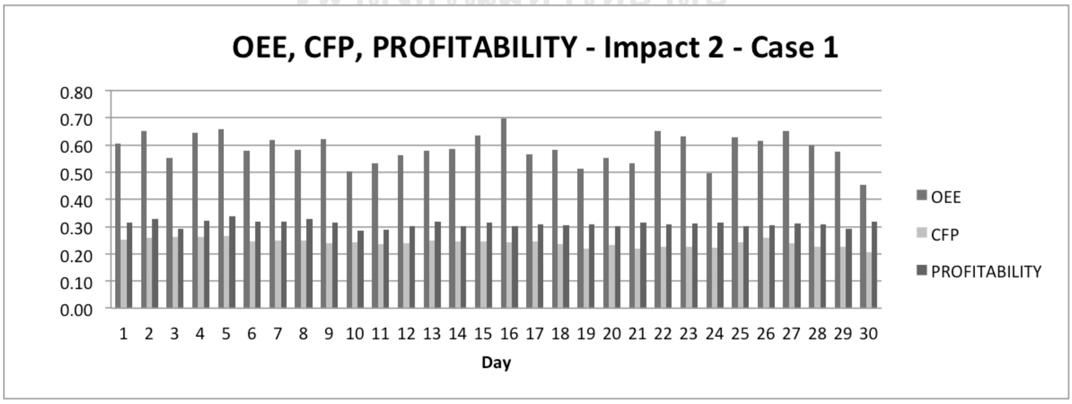

Figure 3. 11   OEE, CFP, Profitability under impact 2 – case 1

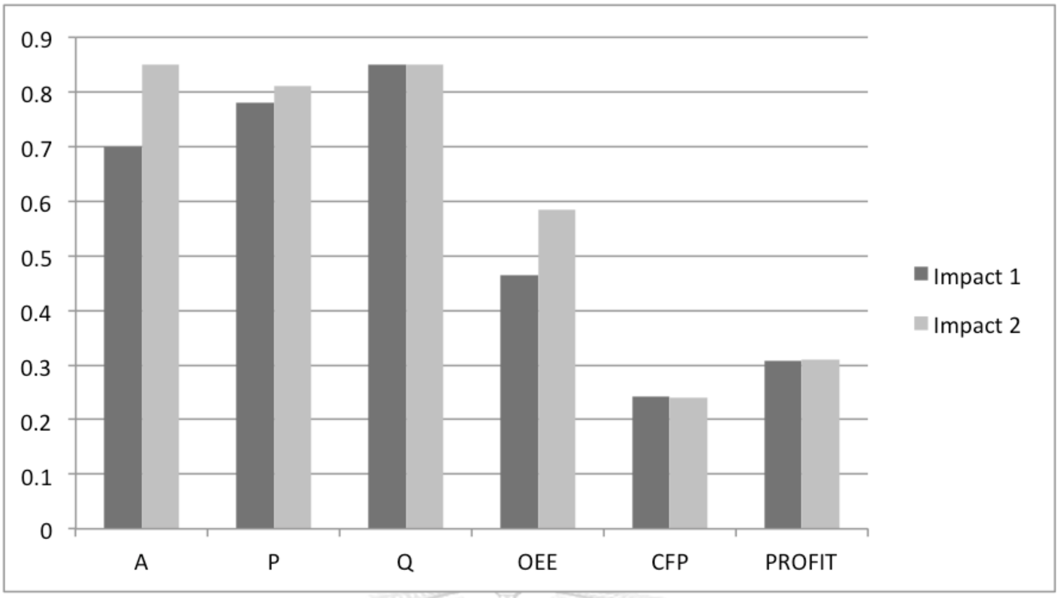

Figure 3. 12 A, P, Q, OEE, CFP and Profitability in "Impact 1" and "Impact 2"

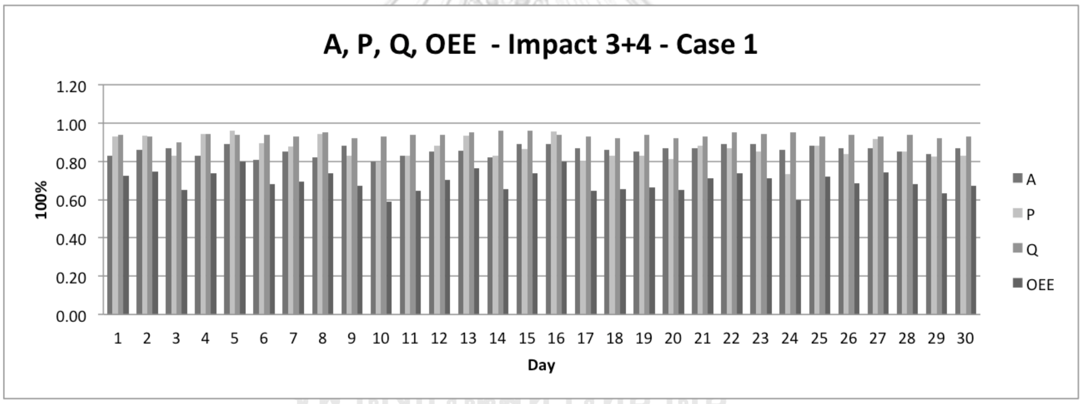

Figure 3. 13 A, P, Q, OEE under impat 3+4 – case study 1

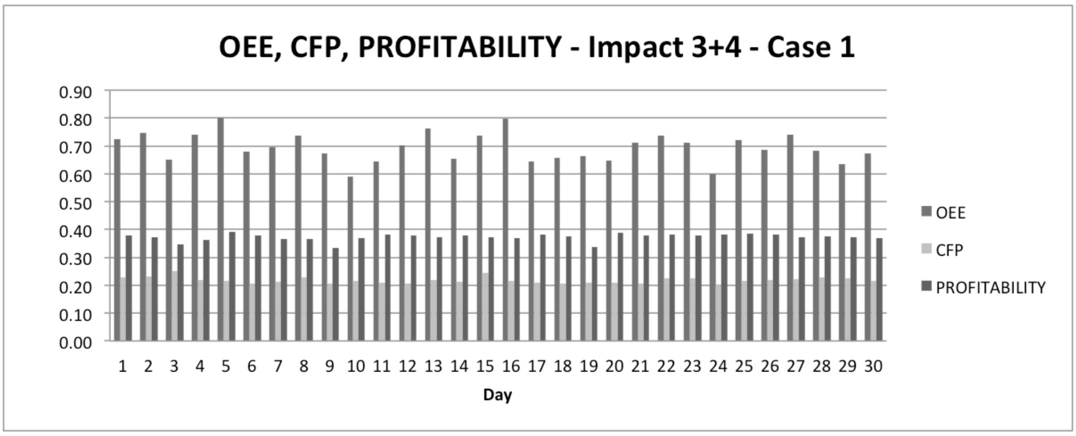

Figure 3. 14 OEE, CFP, Profitability under impact 3+4 – case 1

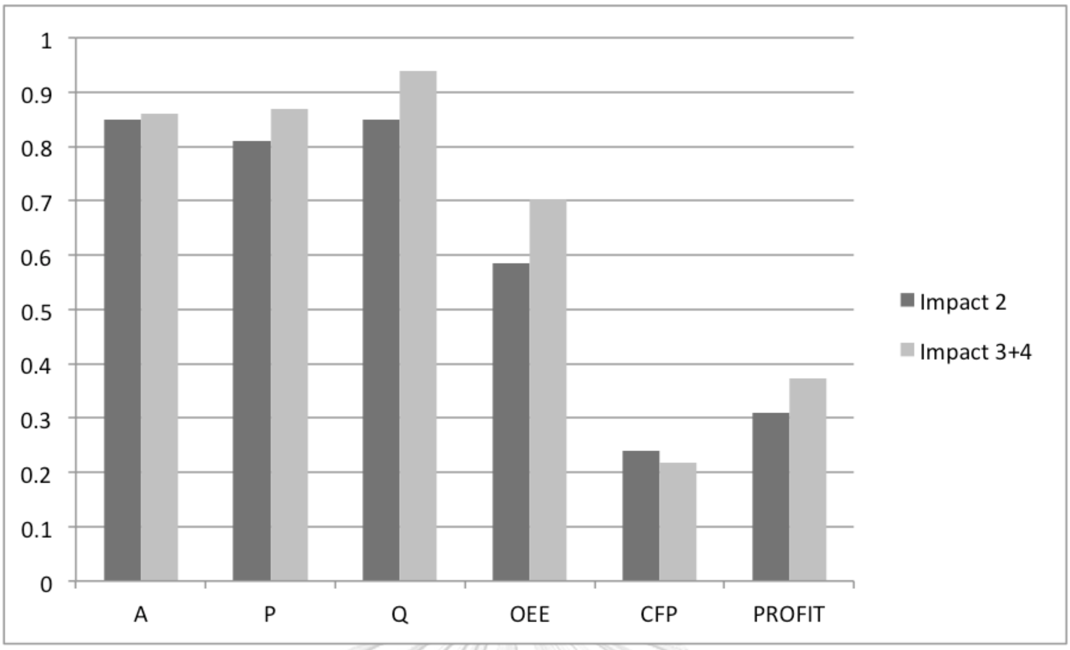

Figure 3. 15 A, P, Q, OEE, CFP and Profitability in "Impact 2" and "Impact 3+4"

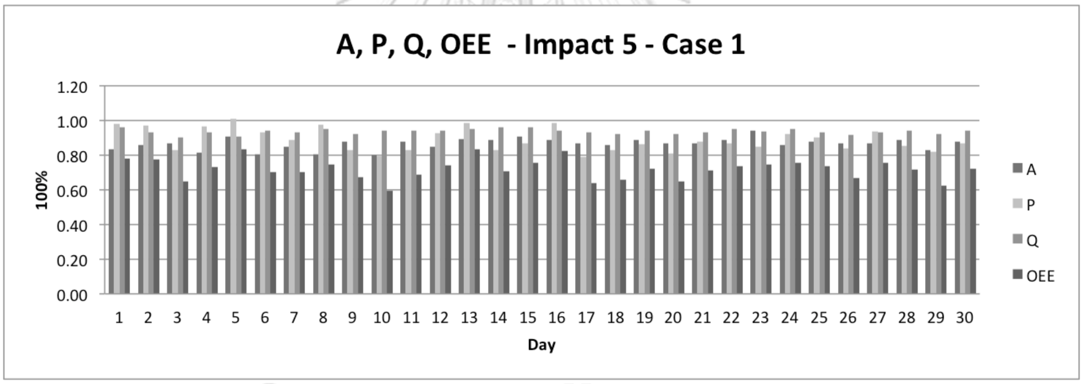

Figure 3. 16 A, P, Q, OEE under impact 5 – case study 1

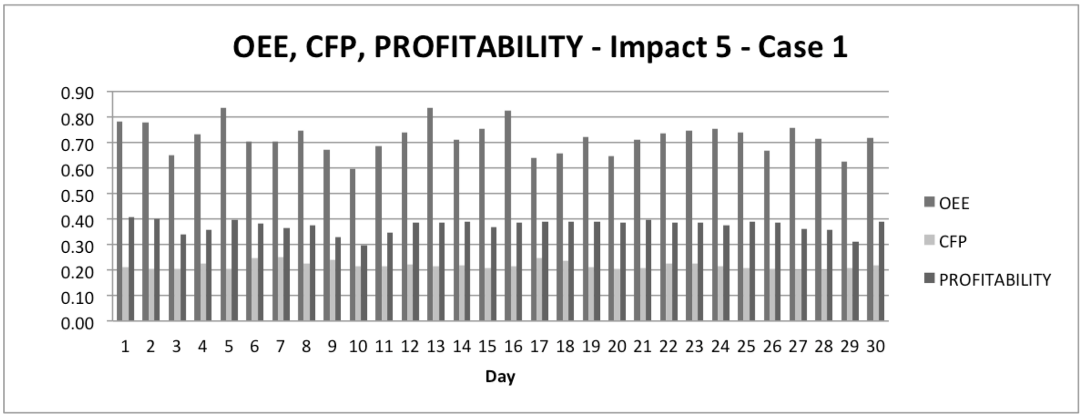

Figure 3. 17 OEE, CFP, Profitability under impact 5 – case study 1

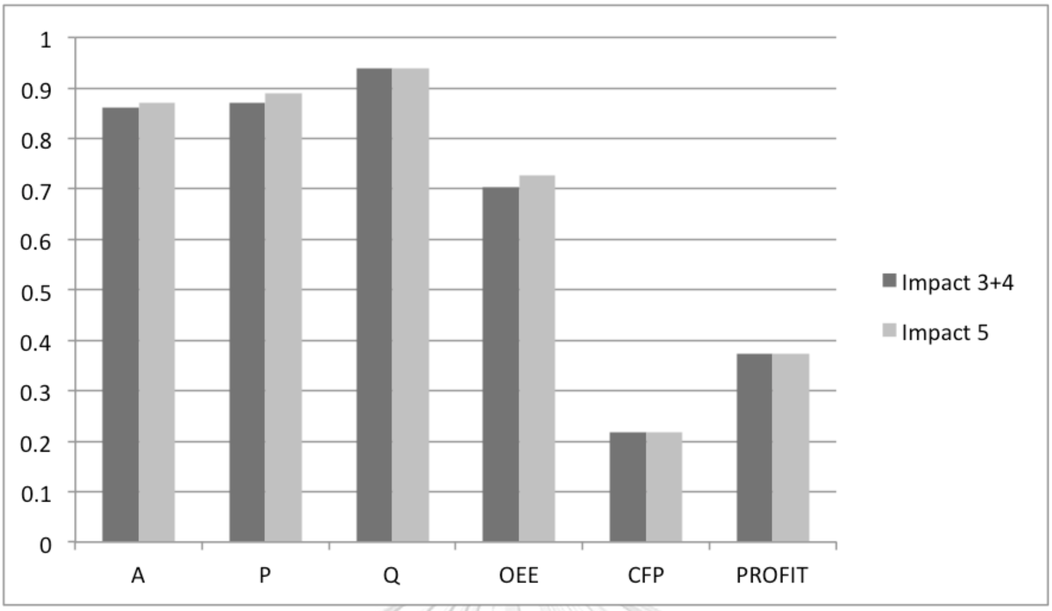

Figure 3. 18 A, P, Q, OEE, CFP and Profitability in "Impact 3+4" and "Impact 5"

Chapter 4

Prediction Model of CFP, Profitability based on OEE

4.1 Model proposal

Table 4.1 shows values of A, P, Q parameters; factors directly affecting A-Down time, P-Actual speed, Running time, Q-Reject paper and CFP values, Profitability corresponding to the five impacts.

Table 4. 1 OEE factors values in case study 1

Case 1	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5
A	0.64	0.70	0.85	0.86	0.87
Down time (minute/1000)	0.17	0.11	0.08	0.07	0.05
P	0.72	0.78	0.81	0.87	0.89
Actual speed (m/min)	10.95	11.05	11.09	11.16	11.20
Running time (minute)	289.34	312.98	356.28	397.34	401.21
Q	0.84	0.85	0.85	0.94	0.94
Reject paper (kg)	481.63	368.42	358.31	109.46	108.23
CFP	0.2456	0.2414	0.2403	0.2181	0.2176
PROFITABILITY	0.2974	0.3081	0.3104	0.3727	0.3734

Figure 4.1 indicates relationship between A, Down time and CFP, Profitability. As can be seen that A was inversely proportional to Down time; CFP was inversely proportional to A and was proportional to the Down time. In contrast, Profitability was positively correlated to A and was inversely proportional to Down time.

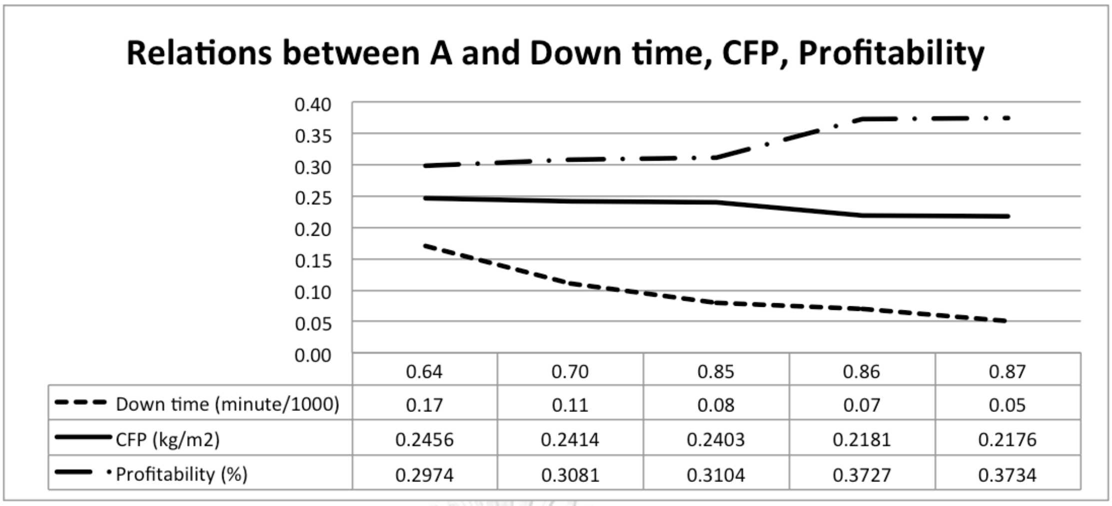

Figure 4. 1 Relations between A and Down Time, CFP, Profitability in case study 1

Figure 4.2 presents relationships between P, Actual speed, Running time and CFP, Profitability of both cases. P was proportional to Running time and inversely proportional to Actual speed; CFP negatively correlated to P, Running time, and Actual speed. However, Profitability was proportional to P, Running time and inversely proportional to Actual speed.

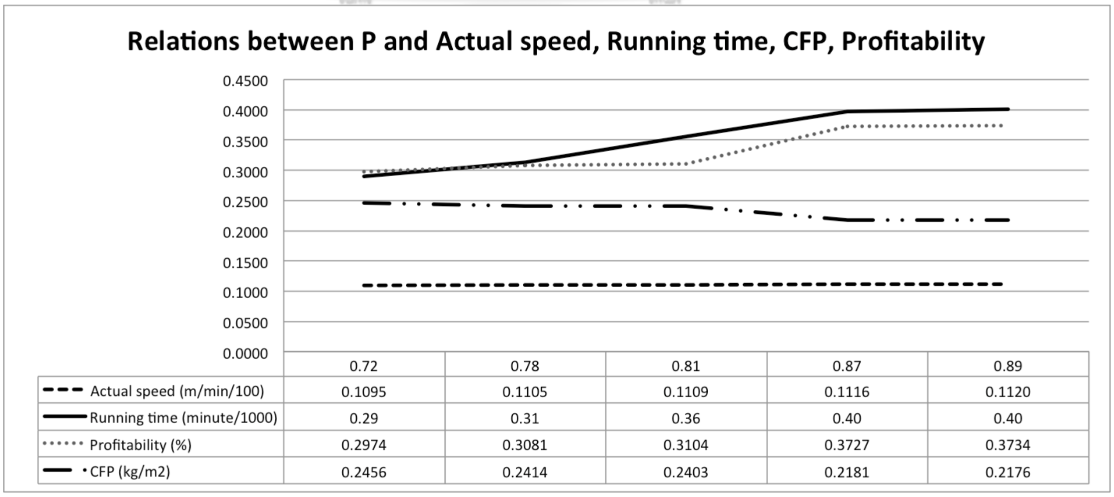

Figure 4. 2 Relations between P and Actual speed, Running time, CFP, Profitability in case study 1.

Relationships between Q, Reject paper and CFP, Profitability are shown in Figure 4.3. The graph presented that Q was inversely proportional to Reject paper; CFP was well positively correlated to Reject paper and inversely proportional to Q, whereas Profitability was positively correlated to Q and inversely proportional to Reject paper.

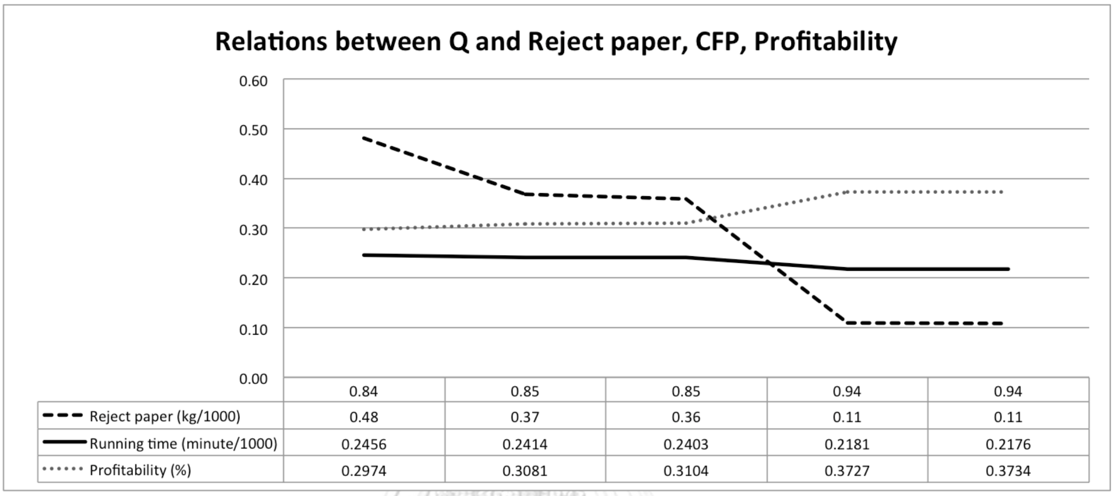

Figure 4. 3 Relations between Q and Reject paper, CFP, Profitability in case study 1.

Factors of A, P, and Q were calculated during five stages. A - factor is highly dependent on "down time", P - factor counts on "actual speed" and "running time", while Q - factor is closely related to "reject paper". These factors influenced directly to the electricity usage, the paper consumption, simultaneously, they impacted obliquely to CFP and Profitability. The averaged values of these factors are shown in Table 4.1 and Figure 4.1, Figure 4.2, Figure 4.3 which demonstrated the mutual relations of these factors. The higher the improvement of A factor is, the lesser the "down time" becomes (Figure 4.1). Similarly, the better improvement of P factor makes both "actual speed" and "running time" increase (Figure 4.2); the increase of Q factor resulted in lowering the "reject paper" (Figure 4.3). CFP decrease and Profitability increase are the common tendency in all six graphs. Conclusively, there are the relations between A factor and "down time", P factor and "actual speed" and "running time", Q factor and "reject paper", all of which influence CFP and Profitability.

Consequently, electricity consumption demand directly influences CFP and Profitability, whereas the operation speed of the machine and quality of finished paper product show influence on Performance. Similarly, impact on time for shifting orders could result in OEE change, particularly shifting A which could subsequently influence on electricity demand, thus changing CFP and Profitability. From the impacts on the manufacturing process of corrugated paper and from the aforementioned calculation equations, relation between CFP and Profitability and OEE was proposed.

Availability factor – A:

$$[\text{Down time}]_{after} = \frac{1 - A_{after}}{1 - A_{before}} \times [\text{Down time}]_{before} \qquad \textit{(Equation 4. 1)}$$

Down time decrease related to operating time, thus influencing on electricity use. CFP and Profitability were recalculated based on Equation 4.1. This could mean that CFP and Profitability were calculated based on actual amount of electricity consumed once down time was different.

CFP ~ [electric usage]

Profitability ~ [electric usage]

Performance factor – P:

When the actual speed was increased, the running time was reduced leading to reduction of electricity use. Running time has a reverse relation to actual speed, the following *Equation 4.2* and *Equation 4.3* were established.

$$[\text{Running time}]_{\text{after}} = \frac{\dfrac{1}{\text{Actual speed}_{\text{after}}}}{\dfrac{1}{\text{Actual speed}_{\text{before}}}} \times [\text{Running time}]_{\text{before}}$$

(Equation 4. 2)

$$[\text{Actual speed}]_{\text{after}} = \frac{P_{\text{after}}}{P_{\text{before}}} \times [\text{Actual speed}]_{\text{before}}$$

(Equation 4. 3)

After P was improved, the amount of electricity consumed reduced, therefore, CFP and Profitability were also recalculated according to the actual amounts consumed.

CFP ~ [electric usage]

Profitability ~ [electric usage]

Quality factor – Q:

Reject paper has inverse relation to quality factor, the following equation was established *Equation 4.4.*

$$[\text{Reject paper}]_{\text{after}} = \frac{Q_{\text{before}}}{Q_{\text{after}}} \times [\text{Reject paper}]_{\text{before}}$$

(Equation 4. 4)

Total paper includes reject paper, while CFP and Profitability were calculated based on total paper used, thus CFP and Profitability were also recalculated based on total amounts that had been used.

CFP ~ [total amount of paper]

Profitability ~ [total amount of paper]

Figure 4.4 shows the prediction model of CFP base on OEE of experiment 1. The predicted minimum value of CFP is 0.216 kg/1m2 when OEE meets the world class value (0.85). This curve can predict the value of CFP base on the value of OEE. Figure also shows the decreasing trend of CFP when improving OEE.

Equation 4.5 shows the relation between CFP and OEE that can use to predict the value of CFP when OEE is determined.

CFP = -0.0833 * OEE + 0.2831 *Equation 4. 5*

$R^2 = 0.82391$

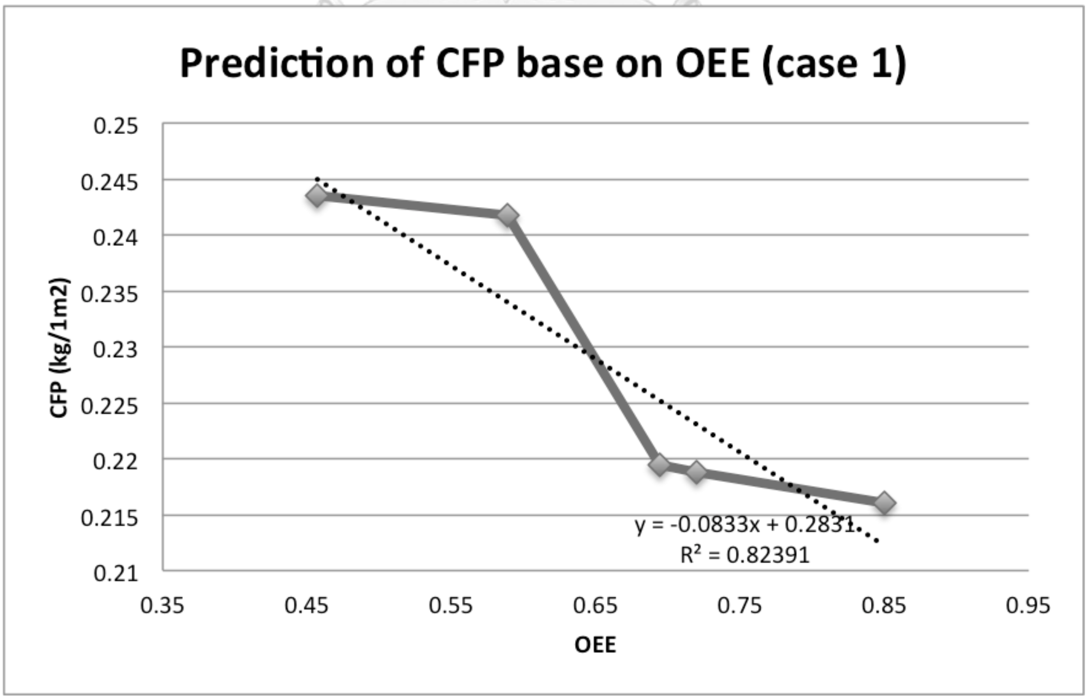

Figure 4. 4 Prediction of CFP base on OEE

Figure 4.5 shows the prediction model of Profitability base on OEE of experiment 1. The predicted maximum value of Profitability is 37.89% when OEE meets the world class value (0.85). This curve can predict the value of Profitability based on the value of OEE. Figure 4.5 also showed the increasing trend of Profitability when improving OEE.

Equation 4.6 shows the relation between Profitability and OEE that can use to predict the value of Profitability when OEE is determined.

Profiability = 0.2221 * OEE + 0.2002 *(Equation 4. 6)*

$R^2 = 0.80509$

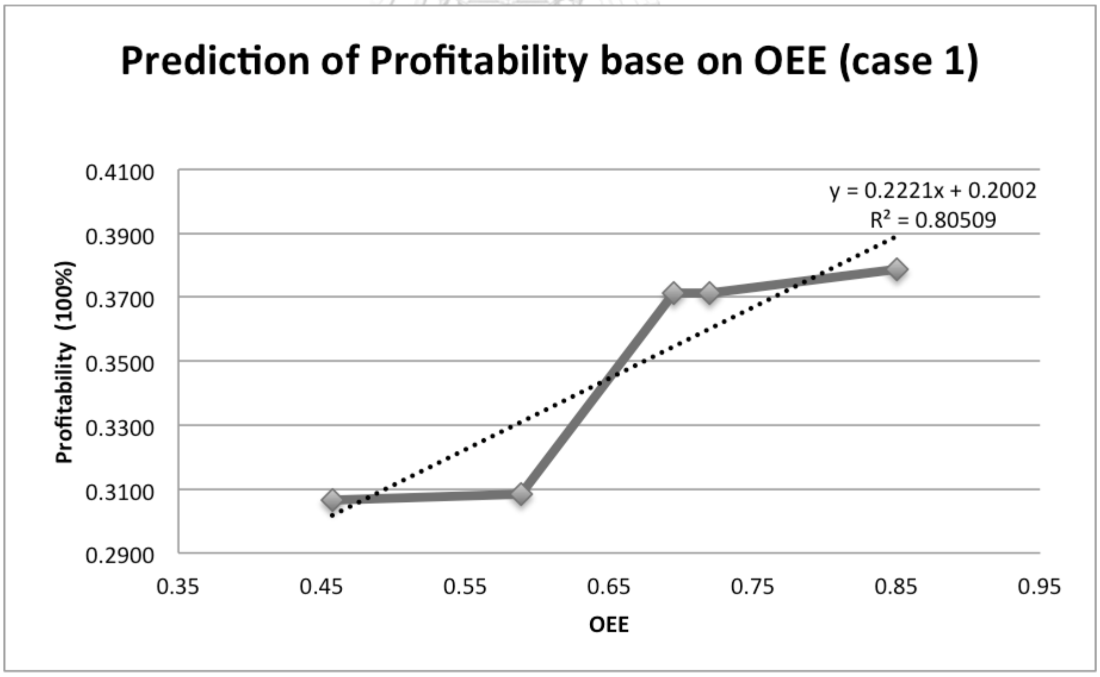

Figure 4. 5 Prediction of Profitability based on OEE

Figure 4.5 and Figure 4.5 are the curve of prediction model which can predict the value of CFP and Profitability based on OEE value. Equation 4.5, 4.6 are the prediction equation that can use to predict the value of CFP and Profitability based on OEE value.

4.2 Model application

Table 4.2 shows how the prediction model works. The value of Down time, Running time, Actual speed, Reject paper in the previous stage must be calculated. The calculation based on the 30 days of collected data of previous stage. These value were called "before" value. Equations 4.1, 4.2, 4.3, 4.4 were applied to calculate the "after" value of Down time, Running time, Actual speed, Reject paper. With these "after" value, the electric usage and the paper usage were calculated as showed in 3.1.2.2 and 3.1.2.3. And the CFP and Profitability also are calculated as showed in in 3.1.2.2 and 3.1.2.3.

Table 4. 2 Prediction calculation

Prediction calculation		
Down Time	162	Minutes
Running Time	310	Minutes
Actual Speed	11	MPM
Reject paper	389	kg
Electric usage (before)	491	kw
Electric usage (after) A	451	kw
Electric usage (after) P	439	kw
Electric usage average	445	kw
Paper usage after	2,593	kg
Good paper after	2,203	kg

Table 4.3 shows the prediction model was built in Microsoft Excel software

based on the collected data from experiment 1.

Table 4. 3 Prediction model software in Microsoft Excel

Prediction model			
	Previous stage	**Desired value**	**Prediction**
Availability	64.26%	70.00%	
Performance	73.29%	82.00%	
Quality	84.10%	90.00%	
Overall OEE	39.60%	51.66%	
CFP Per 1m2 (kgCO2e)	0.2456		0.2410
Profitability (%)	29.74		30.74

Values of CFP and Profitability are calculated by the prediction model in Microsoft Excel software as following:

1. The previous values of Down time, Running time, Actual speed, Reject paper (these values called "before" values in prediction model) are data base which could be done experiment with at least 30 days' data collection.

2. The prior values of A, P and Q (also called "before" values in prediction model) are data base which could be done experiment with at least 30 days' data collection.

3. The desired values of A, P and Q that the machine need to improve to meet (called "after" values)

4. Prediction model uses the above values to predict the value of CFP and Profitability without any new experiment to meet the desired values of OEE:

- With values of Down time, Running time, Actual speed, Reject paper of "before"; A,P, Q of "before" and A, P, Q of "after", we can apply Equation 4.1, 4.2, 4.3, 4.4 to calculate Down time, Running time, Actual speed, Reject paper of "after"
- With calculated values of Down time, Running time, Actual speed, Reject paper of "after", the values CFP and Profitability of "after" will be calculated as show in 3.1.2.2 and 3.1.2.3

In the other way, the predict values of CFP and Profitability are also able to calculate from the Equation 4.5 and Equation 4.6 based on the desired value of OEE.

Chapter 5

Applying Prediction model in experiment 2

5.1 Survey of current status

The data were collected within 30 working days (Figure 5.1 and Figure 5.2) by the machine operators. Values of OEE, CFP, and Profitability were calculated based on the software presented in 3.1.2.1, 3.1.2.2 and 3.1.2.3.

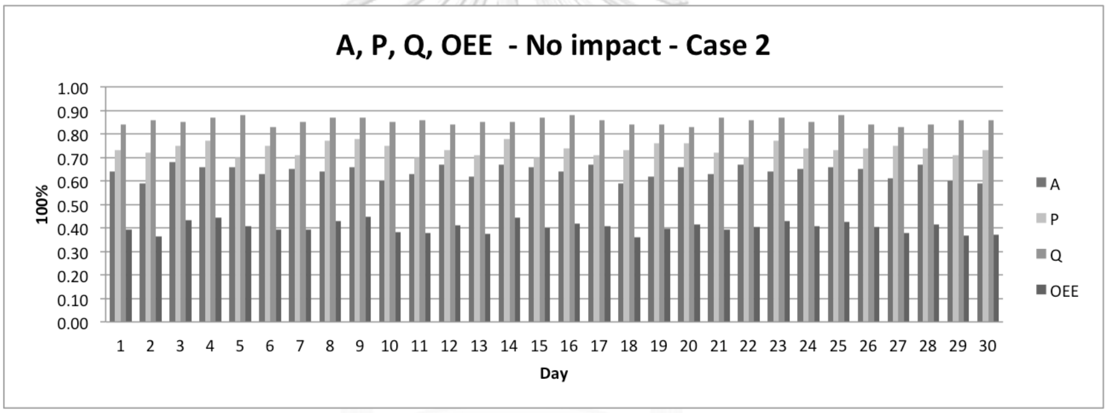

Figure 5. 1 Current status of A, P, Q, OEE in case study 2

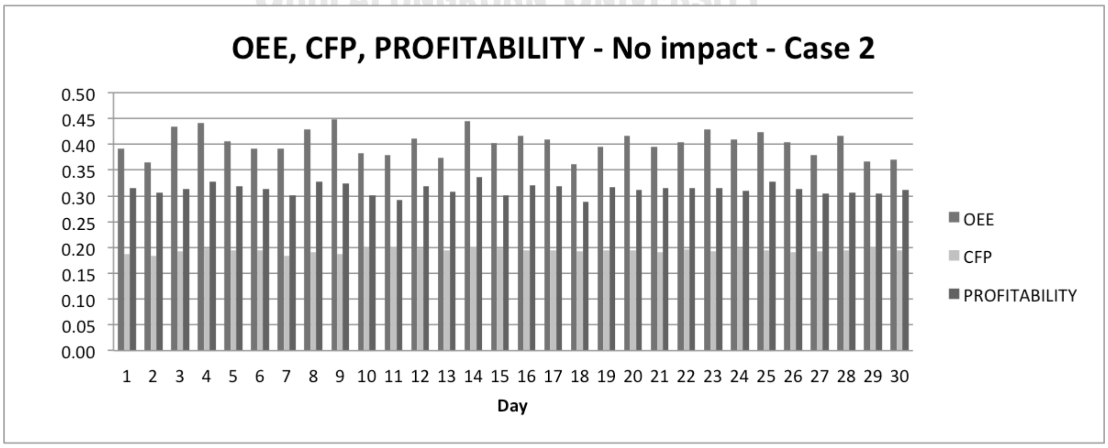

Figure 5. 2 Current status of OEE, CFP, Profitability in case study 2

5.2 Implementation of improvement of OEE

The steps of actual operation, data collection and analysis were repeatedly carried out at the place of corrugated paper production using identical technology and scale as in the case study 1.

TQM has a corresponding technique that solves each problem. TQM techniques (5 whys, SMED, SOP, 5S) were used to improve the causes (poor standard of operation, improper procedure, untidy work area, lack of quick change, lack of proper training) as in case study 1.

5.3 Process and analysis of the collected data

The process of improving OEE through TQM techniques was carried out under the direct instruction of TQM expert. Five impacts were made consequently over 12 months. Data were collected continuously using structured data collection forms. The data was collected for the period of 30 days for analysis.

Figures 5.3, 5.6, 5.9, 5.12 demonstrate data of the parameters of A, P, Q, and OEE that were recorded for the period of 30 days of single impact. All of the values of these days are lower than the value of World Class values of A, P, Q and OEE. It means that the OEE still can improve by improving A, P, Q respectively.

Figures 5.4, 5.7, 5.10, 5.13 indicate values of OEE, CFP, and PRO calculated on a daily basis for every impact. All of these Figures show the relations among OEE, CFP and Profitability. All the days of all impacts show that the highest value is OEE, the lowest value is CFP and the medium value is Profitability. It means that when improving OEE, the changing trend of values of CFP and Profitability in every day is stable.

Figures 5.5, 5.8, 5.11, 5.14 depicte change of the parameters of the two consecutive impacts. All parameters were changed after being impacted by one TQM technique, but this change was not the same for all impacts. Figure 5.5 shows the most improving of P when applying “5 whys” technique and the lowest increasing is A. Figure 5.8 shows the highest increasing of A when applying “SMED” and the lowest increasing is Q. Figure 5.11 shows the most increasing of P when applying “SOP” technique and the lowest improving is Q. Figure 5.14 shows the lowest increasing of P and a very low improving of A and Q when applying “5S” technique.

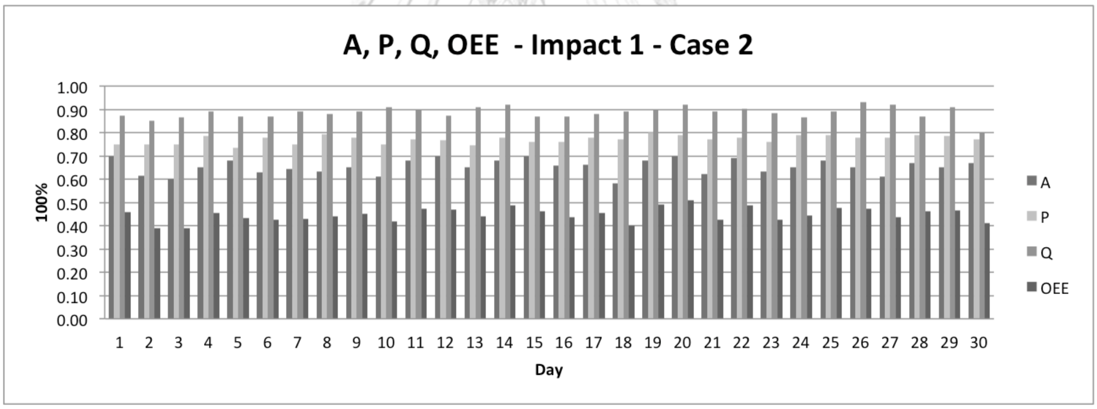

Figure 5. 3 A, P, Q, OEE under impact 1 – case study 2

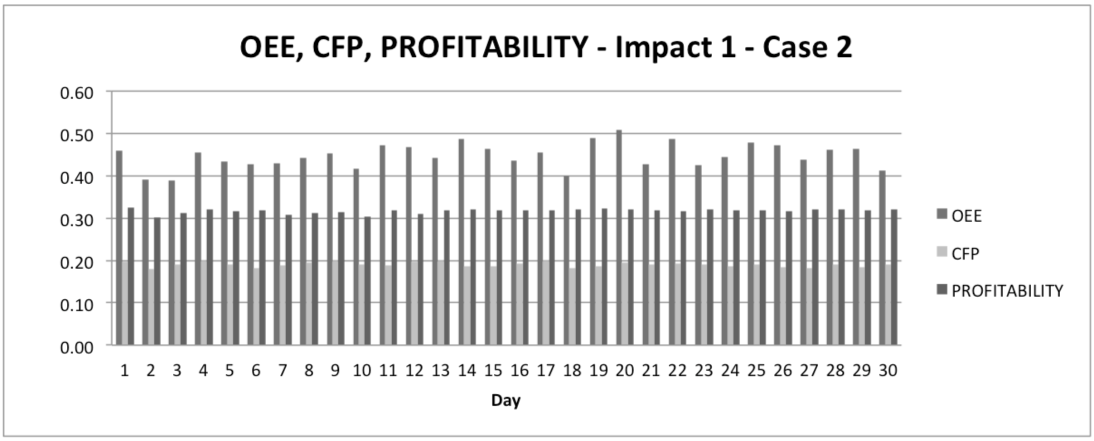

Figure 5. 4 OEE, CFP, Profitability under impact 1 – case study 2

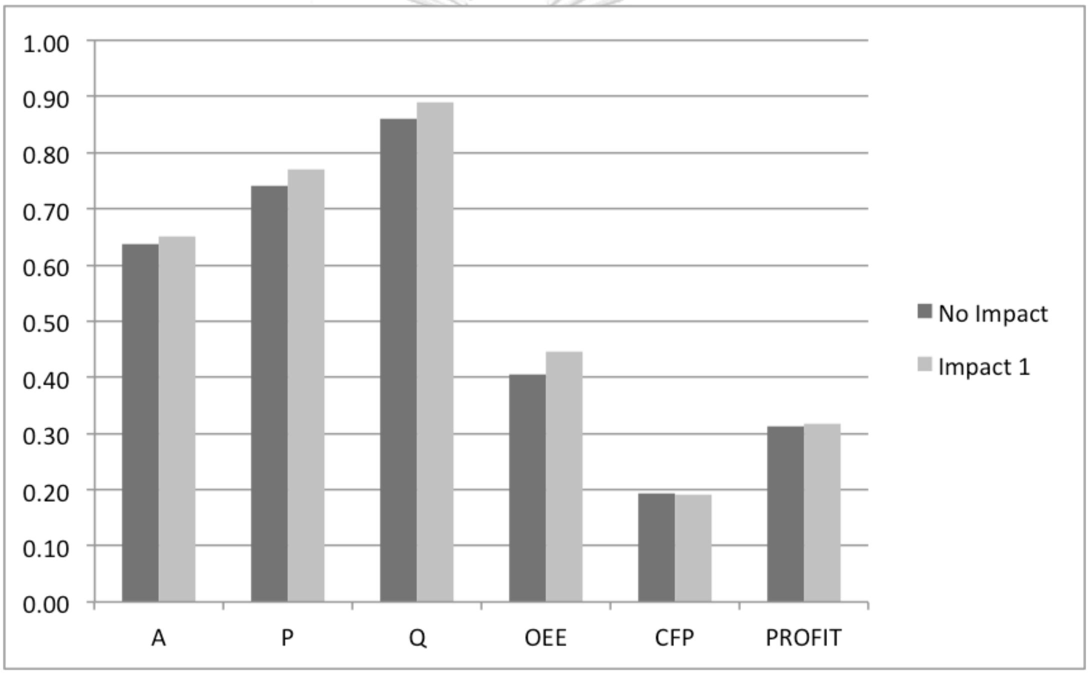

Figure 5. 5 A, P, Q, OEE, CFP and Profitability in “No impact” and “Impact 1” – case study 2

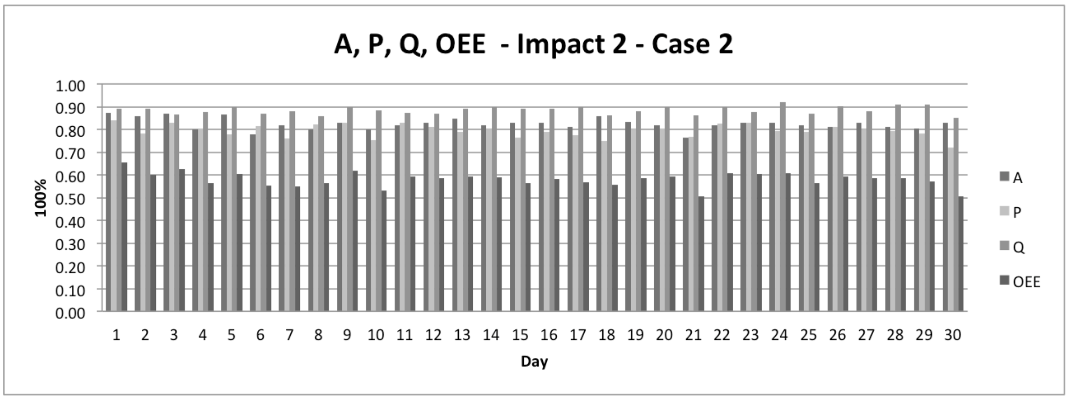

Figure 5. 6 A, P, Q, OEE under impact 2 – case study 2

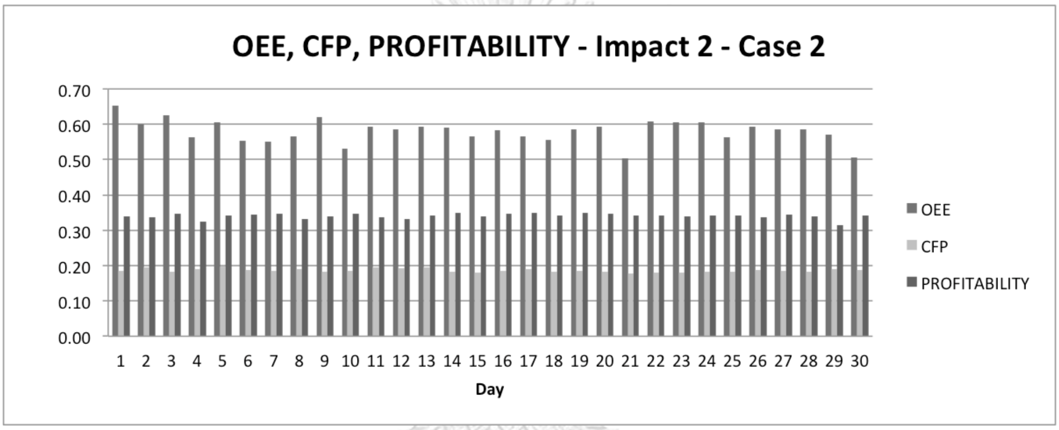

Figure 5. 7 OEE, CFP, Profitability under impact 2 – case study 2

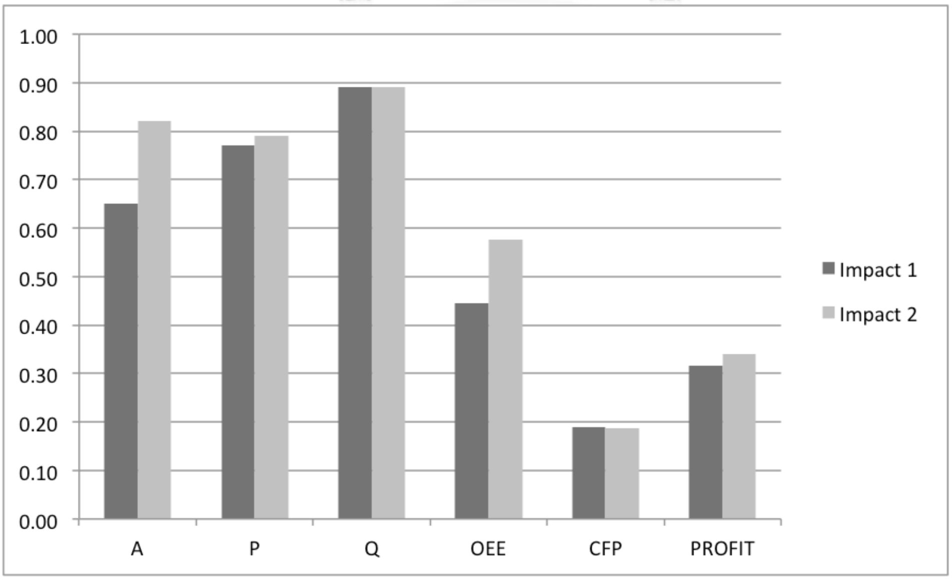

Figure 5. 8 A, P, Q, OEE, CFP and Profitability in "Impact 1" and "Impact 2" – case study 2

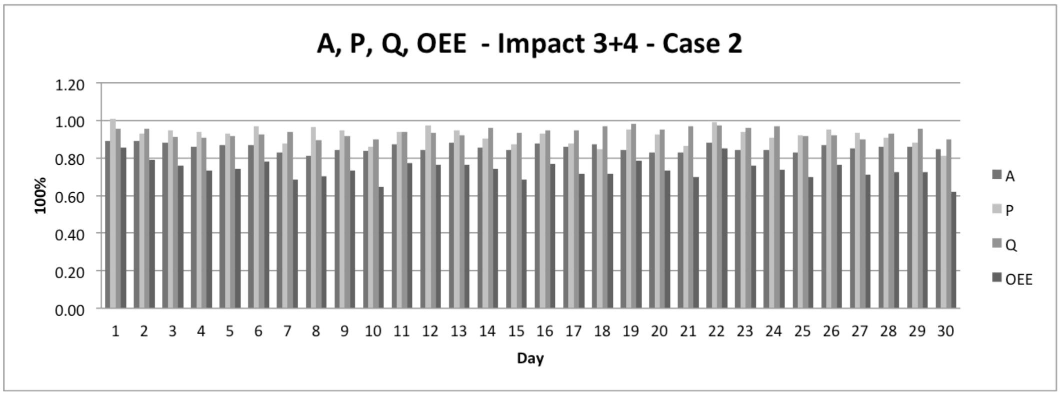

Figure 5. 9 A, P, Q, OEE under impact 3+4 – case study 2

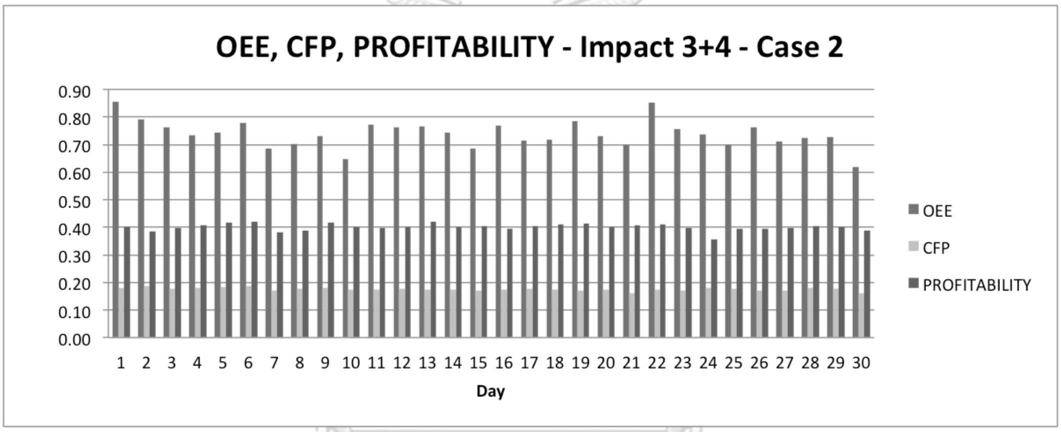

Figure 5. 10 OEE, CFP, Profitability under impact 3+4 – case study 2

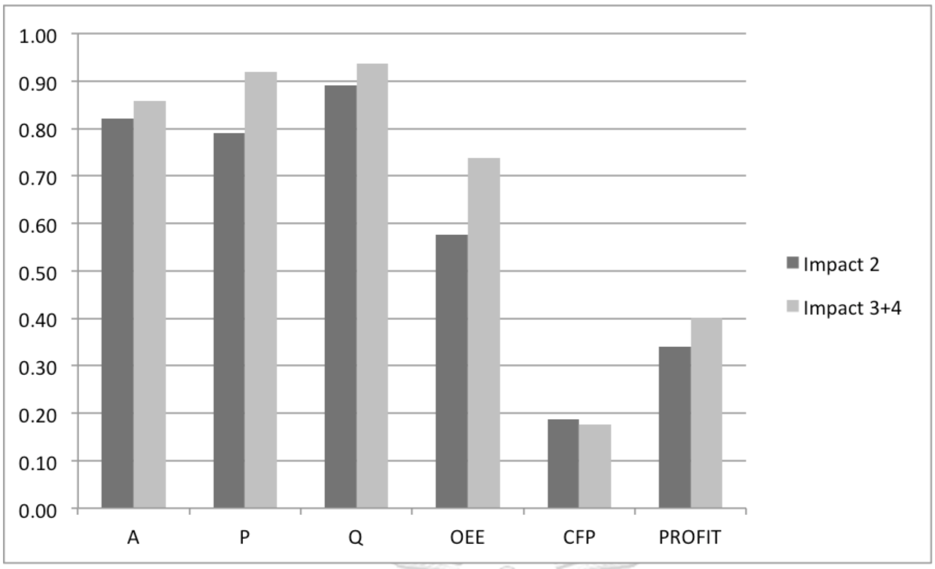

Figure 5. 11 A, P, Q, OEE, CFP and Profitability in "Impact 2" and "Impact 3+4" – case study 2

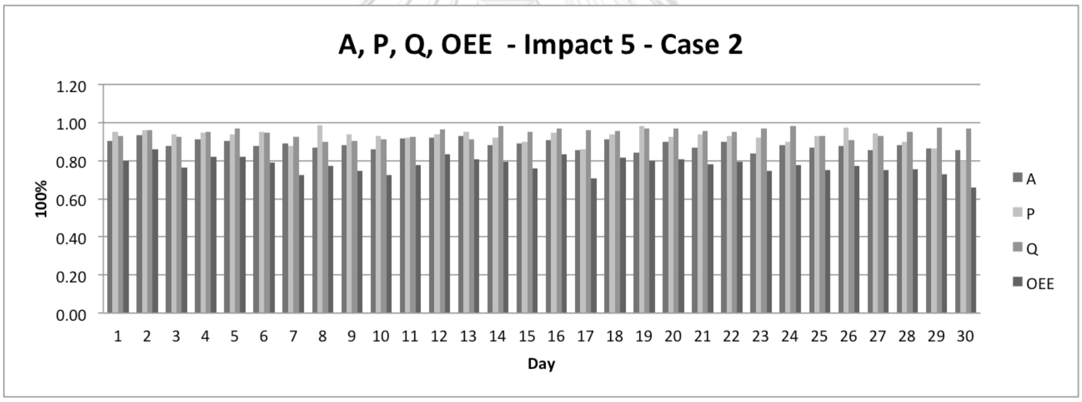

Figure 5. 12 A, P, Q, OEE under impact 5 – case study 2

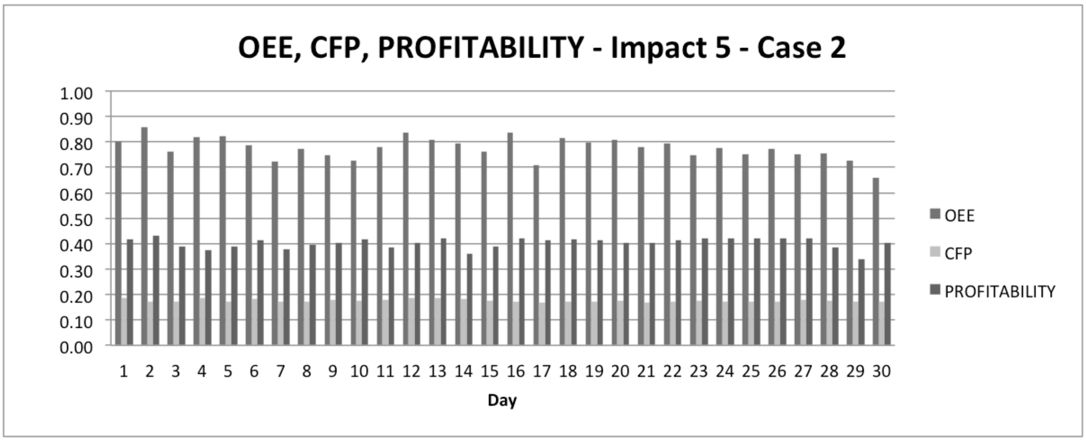

Figure 5. 13 OEE, CFP, Profitability under impact 5 – case study 2

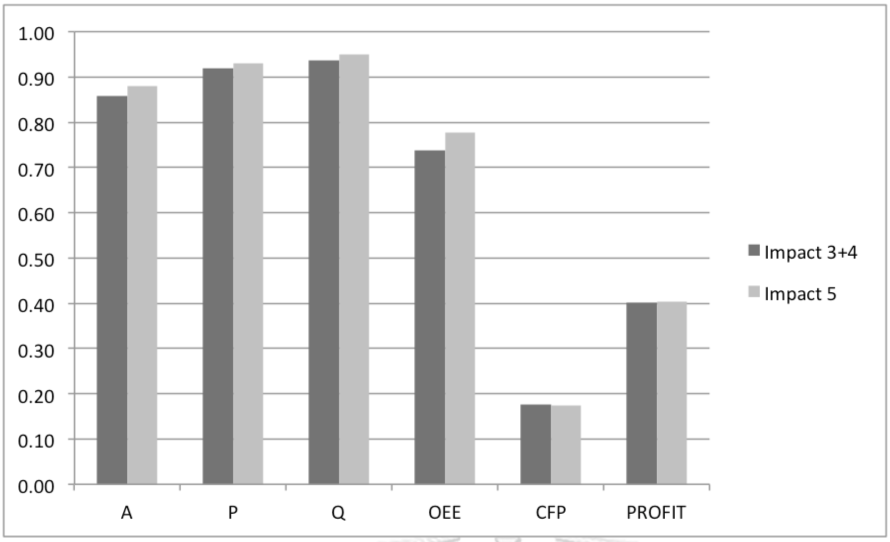

Figure 5. 14A, P, Q, OEE, CFP and Profitability in "Impact 3+4" and "Impact 5" – case study 2

Table 5.1 presents the collected data after the impact of the 5 TQM techniques resulting in changing in OEE, CFP, and PRO after each impact compared to the previous impact.

Table 5. 1 A, P, Q, OEE, CFP and Profitability during 5 impacts

	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5
A	0.64	0.65	0.82	0.86	0.88
P	0.74	0.77	0.79	0.92	0.93
Q	0.86	0.89	0.89	0.94	0.95
OEE	0.405811067	0.445445	0.576542	0.738056776	0.77748
CFP	0.1938	0.1904	0.1863	0.1754	0.1751
PROFITABILITY	0.3128	0.3169	0.3403	0.4005	0.4028

5.5 Prediction model application

Table 5.2 shows the values of CFP and Profitability from prediction model and from the practical. The differences between the prediction and practical are also shown in this table, all of the differences are less than 2%. The last column of this table also show the minimum value of CFP, 0.1750 kg/1m^2, and the maximum value of Profitability, 40.13% if the machine can meet the World Class of OEE.

Table 5. 2 Prediction of CFP and Profitability using the proposal model

Case 2	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5	**World Class**
A	0.64	0.65	0.82	0.86	0.88	0.90
P	0.74	0.77	0.79	0.92	0.93	0.95
Q	0.86	0.89	0.89	0.94	0.95	0.99
OEE	0.41	0.45	0.58	0.74	0.78	0.85
CFP	0.1938	0.1904	0.1863	0.1754	0.1751	
PROFITABILITY	0.3128	0.3169	0.3403	0.4005	0.4028	
Prediction of CFP		0.1938	0.1888	0.1787	0.1785	0.1757
Prediction of PRO		0.3116	0.3361	0.3950	0.3952	0.4013
Difference of CFP		1.77%	1.33%	1.87%	1.92%	
Difference of PRO		1.69%	1.24%	1.39%	1.92%	

Chapter 6

Results and discussion

6.1 OEE and CFP

Figure 6.1 clearly shows relationships between OEE and CFP, OEE and CFP parameters were inversely proportional. As OEE index improved, CFP was always down.

In Table 6.1, in the experiment 1, once the impact 1 was implemented, OEE increased from 0.39 to 0.46 (18.69%), while CFP index decreased from 0.2456 to 0.2414 (-1.73%). In the impact 2,3 and 4, OEE raised by 28.77%, 17.99%, and 3.62%, respectively, whereas CFP decreased -0.45%, -9.23%, and -0.24%, respectively. The correspondingly increased in OEE and CFP showed that when OEE increased, CFP was certainly decreased, but CFP was not decreased as much as the increase in OEE. For the impact 2, OEE was the highest increase (28.77%), whereas CFP was decreased by 0.45%. For the impact 3 + 4, CFP declined up to 9.23% whereas OEE only increased by 17.99%.

Table 6. 1 OEE, CFP and Profitability in case study 1

Case 1	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5
A	0.64	0.70	0.85	0.86	0.87
P	0.72	0.78	0.81	0.87	0.89
Q	0.84	0.85	0.85	0.94	0.94
OEE	0.39	0.46	0.59	0.69	0.72
CFP	0.2456	0.2414	0.2403	0.2181	0.2176
PROFITABILITY	0.2974	0.3081	0.3104	0.3727	0.3734
% OEE		18.69%	28.77%	17.99%	3.62%
% CFP		-1.73%	-0.45%	-9.23%	-0.24%
% PRO		3.63%	0.74%	20.05%	0.19%

In the second experiment (Table 6.2), the values of OEE in the impact 1, 2, 3, and 4 increased by 9.77%, 29.43%, 28.01%, and 5.34%, respectively, whereas CFP fell by -1.75%, -2.15%, -5.85%, and -0.17%, respectively. The OEE and CFP were still inversely proportional and there was a difference in increase or decrease when any impact was made. The OEE value showed the highest increase (29.43%) in the impact 2 while CFP was largely decreased in the impact 3 + 4 (-5.85%).

Table 6. 2 OEE, CFP and Profitability in case study 2.

Case 2	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5
A	0.64	0.65	0.82	0.86	0.88
P	0.74	0.77	0.79	0.92	0.93
Q	0.86	0.89	0.89	0.94	0.95
OEE	0.41	0.45	0.58	0.74	0.78
CFP	0.1938	0.1904	0.1863	0.1754	0.1751
PROFITABILITY	0.3128	0.3169	0.3403	0.4005	0.4028
% OEE		9.77%	29.43%	28.01%	5.34%
% CFP		-1.75%	-2.15%	-5.85%	-0.17%
% PROFITABILITY		1.31%	7.38%	17.69%	0.57%

The values of OEE improved significantly by 28.77% and 29.43%, respectively in the two experiments when the impact 2 was applied whereas the CFP indexes were lowered by -9.23% and -5.85%, respectively when the impact 3 and 4 were implemented. Apparently, with respect to 1 impact, the OEE and CFP would vary and that impact would have the same influence on the two experiments. The impact 2 employed the SMED technique, which directly influenced A and was the impact leading to increase of A resulting in OEE. This did not result in the decrease of CFP in all impacts. For the impact 3 and 4, when applying SOP, P and Q increased slightly, resulting in increased OEE but not the highest increase in all impacts, but the impact 3 and 4 significantly reduced CFP the two experiments. Similarly, the impact 5 employing the 5S technique, OEE showed the least increase and CFP exhibited the least decrease in the two experiments.

It can be concluded that OEE and CFP were inversely related to each other and the impact of OEE and CFP was heterogeneous.

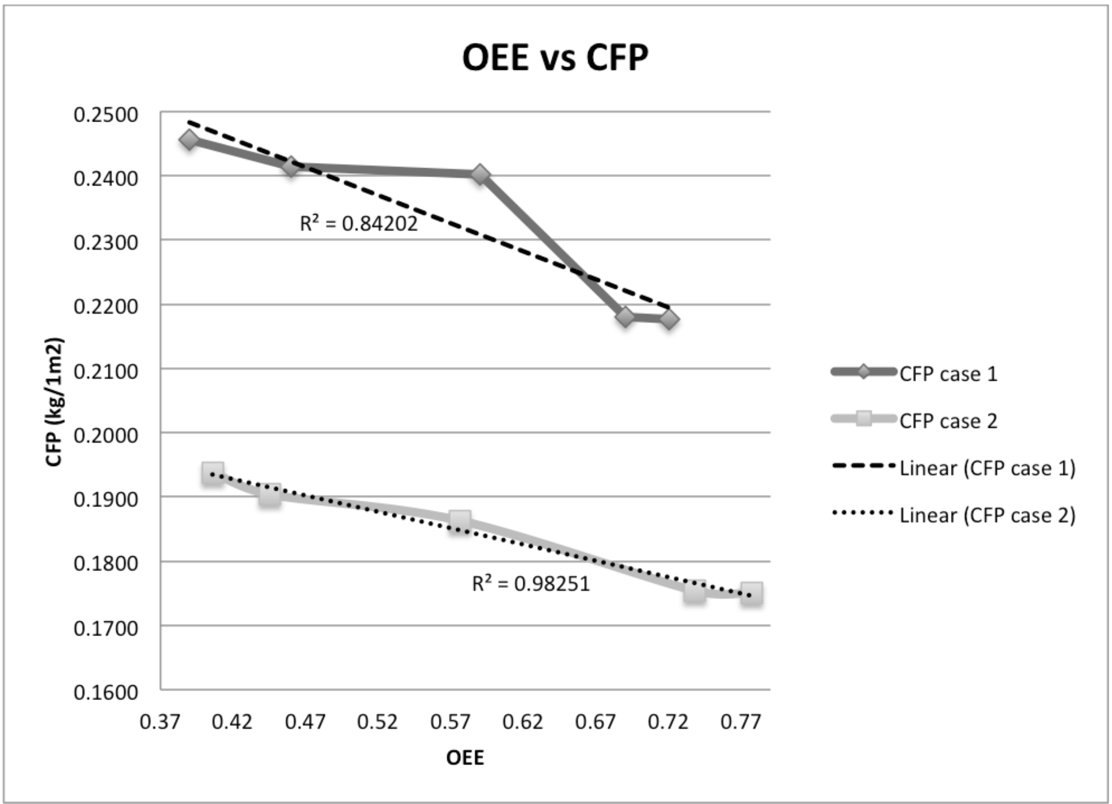

Figure 6. 1 Relations of OEE and CFP in case study 1 and case study 2.

Figure 6.1 shows the relations of OEE and CFP in case study 1 and case study 2. The differences come from the differences of worker cooperations, the maximmum speed of corrugating machine, the volume of orders, the management ways.

6.2 OEE and Profitability

Figure 6.2 clearly indicates that OEE and Profitability were positive correlation. As OEE was improved, Profitability was always increased.

In the first experiment, when the impact 1 was implemented, OEE increased from 0.39 to 0.46 (18.69%), while Profitability increased from 0.2974 to 0.3081 (3.36%). In the impact 1, 2, and 3, the values of OEE increased by 28.77%, 17.99%, and 3.62%, respectively, whereas values of profitability increased by 0.74%, 20.05%, and 0.19%, respectively. The correspondingly decreased in OEE and Profitability showed that when Profitability OEE increased, Profitability was certainly increased but it was not decreased as much as the increase in OEE. For the impact 2, OEE was the highest increase (28.77%), whereas Profitability was decreased by only 0.74%. For the impact 3 + 4, Profitability increased up to 20.05% whereas OEE only increased by 17.99%.

In the second experiment, the OEE index increased under the influence of the impact 1, 2, 3, and 4 by 9.77%, 29.43%, 28.01%, and 5.34%, respectively, while profitability increased by 1.31%, 7.38%, 17.69%, and 0.57%, respectively. OEE and Profitability were proportional and they were changed when one of the impacts was made. It was clearly showed that OEE was the highest increase (29.43%) in the impact 2 while Profitability was the highest increase in the impact 3+4 (17.69%).

In the two experiments, OEE improved by 28.77% and 29.43%, respectively, when the impact 2 was made whereas the Profitability were highly increased by 20.05% and 17.69% when the impact 3 + 4 were applied. Apparently, with respect to 1 impact, the OEE and Profitability index would change and the impact would have the same effect on the two experiments. The impact 2 employing the SMED technique, which directly influenced on A and was the most likely cause for the increase of A, leading to the highest increase in OEE and this did not maximize Profitability in all impacts. In the impact 3 and 4, when applying SOP, P and Q increased slightly resulting in increased OEE, but it was not the highest increase in all impacts. However, the impact 3 and 4 were the impacts to significantly increase Profitability in the two experiments. Similarly, in the impact 5 applying 5S technique, OEE and Profitability showed the least increase both cases.

Thus, OEE and Profitability were proportional to one another, but OEE and Profitability were changed differently as one of the impacts was applied.

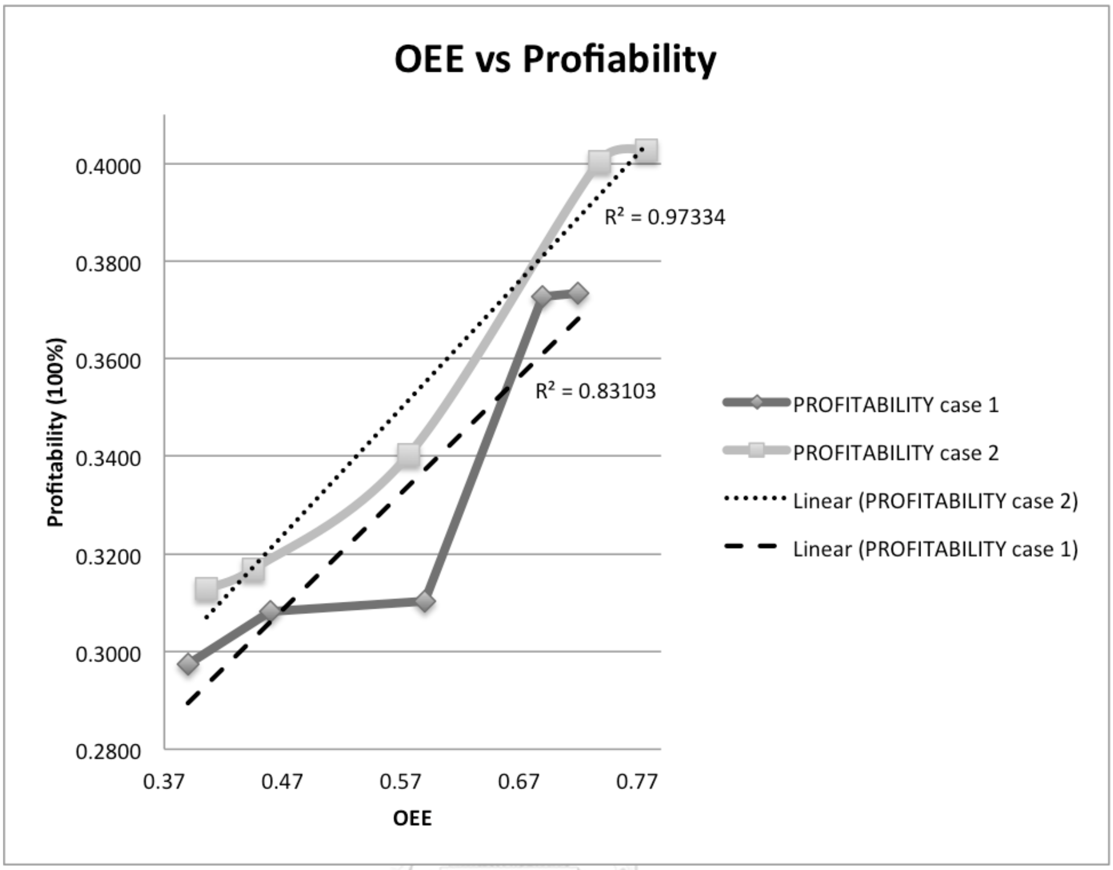

Figure 6. 2 Relation of OEE and Profitability in case study 1 and case study 2.

Figure 6.2 shows the relations of OEE and Profitability in case study 1 and case study 2. The differences come from the differences of worker cooperations, the maximmum speed of corrugating machine, the volume of orders, the management ways.

6.3 CFP and Profitability

Figure 6.3 clearly indicated that CFP and Profitability were positive correlation. As CFP was decreased, Profitability was always increased. In other words, when environmental parameter was improved leading to improvement of Profitability increased. This could mean that CFP and Profitability were proportional.

In the first experiment, when the impact 1 was implemented, CFP decreased from 0.2456 to 0.2414 (-1.73%), while Profitability increased from 0.2974 to 0.3081 (3.36%). In the impact 1, 2, and 3, the values of CFP declined by -0.45%, -9.23%, and -0.24%, respectively, whereas values of Profitability increased by 0.74%, 20.05%, and 0.19%, respectively. The correspondingly changed in CFP and Profitability showed that when Profitability CFP decreased, Profitability was certainly increased but it was corresponded to the decline of CFP. For the impact 3 + 4, Profitability increased up to 20.05% whereas CFP declined the highest by -9.23%. For the impact 5, CFP decreased by -0.24% (the lowest) while Profitability increased only by 0.19% (the lowest).

In the second experiment, the CFP index decreased when influenced by the impact 1, 2, 3, and 4 by -1.75%, -2.15%, -5.85%, and -0.17%, respectively, while Profitability increased by 1.31%, 7.38%, 17.69%, and 0.57%, respectively. CFP and Profitability were inversely proportional and they were changed when one of the impacts was made. It was clearly showed that CFP was the highest decrease (-5.58%) in the impact 3 and 4 whereas values of Profitability were also the highest increase in the impact 3 and 4 (17.69%).

In the two experiments, CFP were significantly declined by -9.23% and -5.85%, respectively when the impact 3 and 4 was made in the both experiments, whereas the Profitability were highly increased by 20.05% and 17.69% when the impact 3 + 4 were applied. Apparently, corresponding to the change of one impact, the CFP and Profitability parameters would change and the impact would have the same influence on the two experiments. The impact 3+4 employing the SOP technique, CFP declined dramatically and Profitability increased significantly in the both cases. Similarly, in the impact 5 applying 5S technique, CFP and Profitability showed the least increases the two experiments.

Thus, CFP and Profitability were negatively correlated and they changed similarly for every impact.

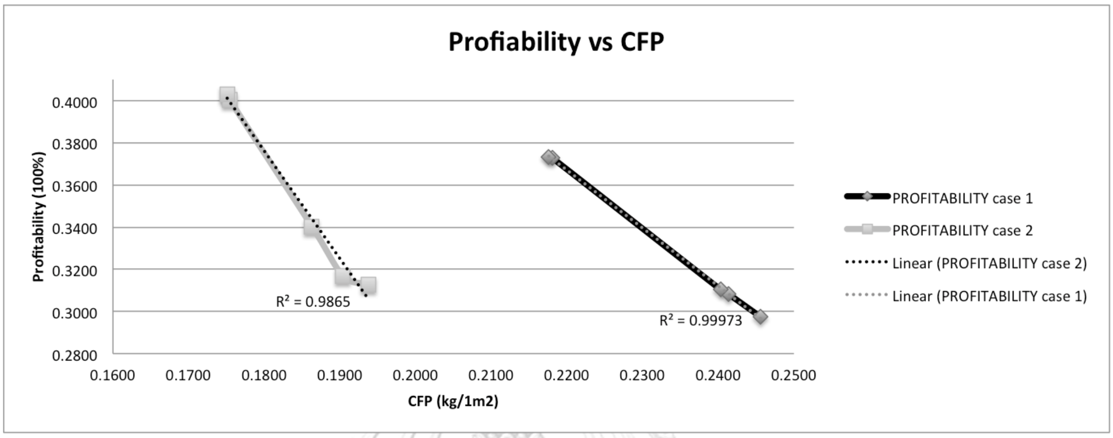

Figure 6. 3 Relation of Profitability and CFP in case study 1 and 2.

Figure 6.3 shows the relations of Profitability and CFP in case study 1 and case study 2. The differences come from the differences of worker cooperations, the maximmum speed of corrugating machine, the volume of orders, the management ways.

6.4 OEE, CFP and Profitability

Sustainable development is the destination of the industrial activities which can be obviously observed through reducing CFP. The main concern for the manufacturers when implementing environmental improvement is the negative effect on their profitability. The results from this study confirmed that by improving OEE, mitigation of environmental impact through reducing CFP in the production of corrugated paper could be achieved while the Profitability was increased.

In all impacts, as the OEE improved, CFP was always decreased and Profitability was always increased. In the experiment 1, OEE increased by 18.69%, 28.77%, 17.99% and 3.62%, respectively, CFP decreased by -1.73%, -0.45%, -9.23% and -0.24%, respectively, and Profitability increased at the rates of 3.63%, 0.74%, 20.05% and 0.19%. The tendency of OEE, CFP and Profitability was found similar in the second experiment.

In the experiment 1, OEE peaked at the impact 2 (28.77%) while CFP and Profitability significantly decreased and increased in the impact 3 + 4 (-9.23% and 20.05%, respectively). OEE only slightly increased in the impact 5, while CFP only slightly decreased, and Profitability slightly increased in the same impact 5. It was clearly indicated that the increase of OEE would cause the decline of CFP and the increase of Profitability. However, the level of increase and decrease of OEE, CFP and Profitability were not fully consistent, meaning that when OEE was the highest increase it was not necessarily CFP would significantly decrease and Profitability would significantly increase much. The same results were found in the experiment 2.

6.5 Prediction model

Table 6.6 shows the difference of CFP between the predicted values and practical values. The predicted values are higher than practical values in this case and the differences are less than 2%

Table 6. 3 Prediction and practical of CFP and its difference

Case 2			
OEE	CFP	Prediction of CFP	Difference
0.45	0.1904	0.1938	1.80%
0.58	0.1863	0.1888	1.35%
0.74	0.1754	0.1787	1.90%
0.78	0.1751	0.1785	1.95%

Table 6.7 shows the difference of Profitability between the predicted values and practical values. The predicted values are lower than practical values in this case and the differences are less than 2%.

Table 6. 4 Prediction and practical of Profitability and its difference

Case 2			
OEE	PROFITABILITY	Prediction of Pro	Difference
0.45	0.3169	0.3116	1.69%
0.58	0.3403	0.3361	1.24%
0.74	0.4005	0.3950	1.39%
0.78	0.4028	0.3952	1.92%

The figure 6.4 shows the difference of CFP between the prediction and practical in experiment 2. The prediction values are always higher than the practical values. The minimum value of CFP will be (0.1750 +/- 2%) $kg/1m^2$ when the machine can meet the World Class of OEE (85%).

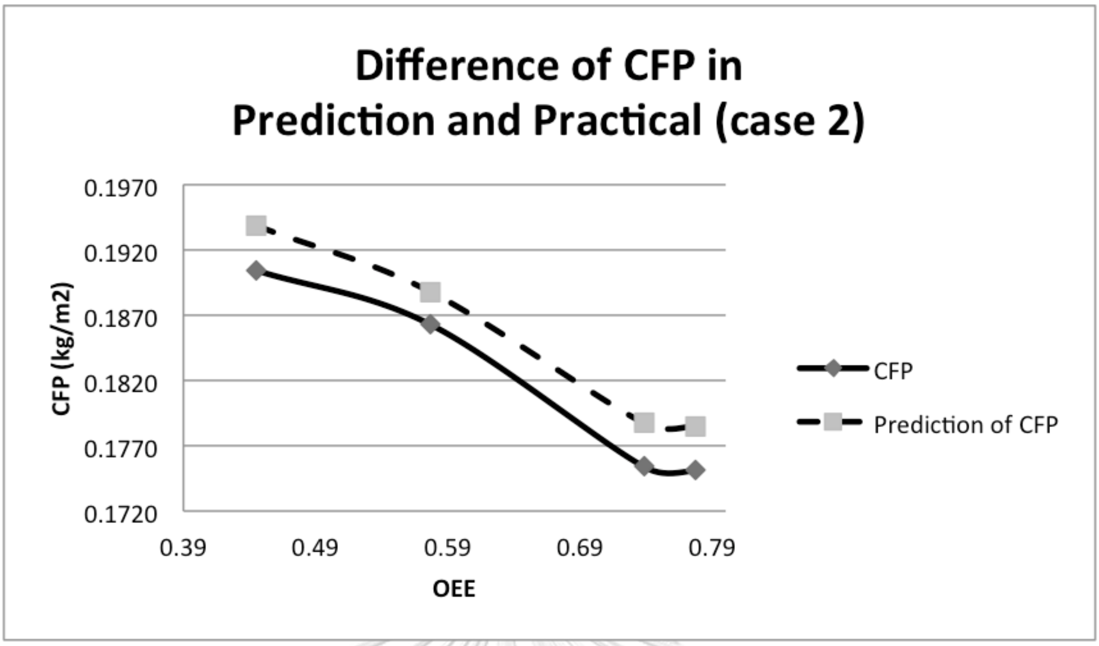

Figure 6. 4 Difference of CFP in prediction and practical

Figure 6.5 shows the difference of Profitability between the prediction and practical in experiment 2. The prediction values are lower than the practical values. The maximum value of Profitab ility will be (40.13 +/-2)% if the machine can meet the World Class of OEE (85%).

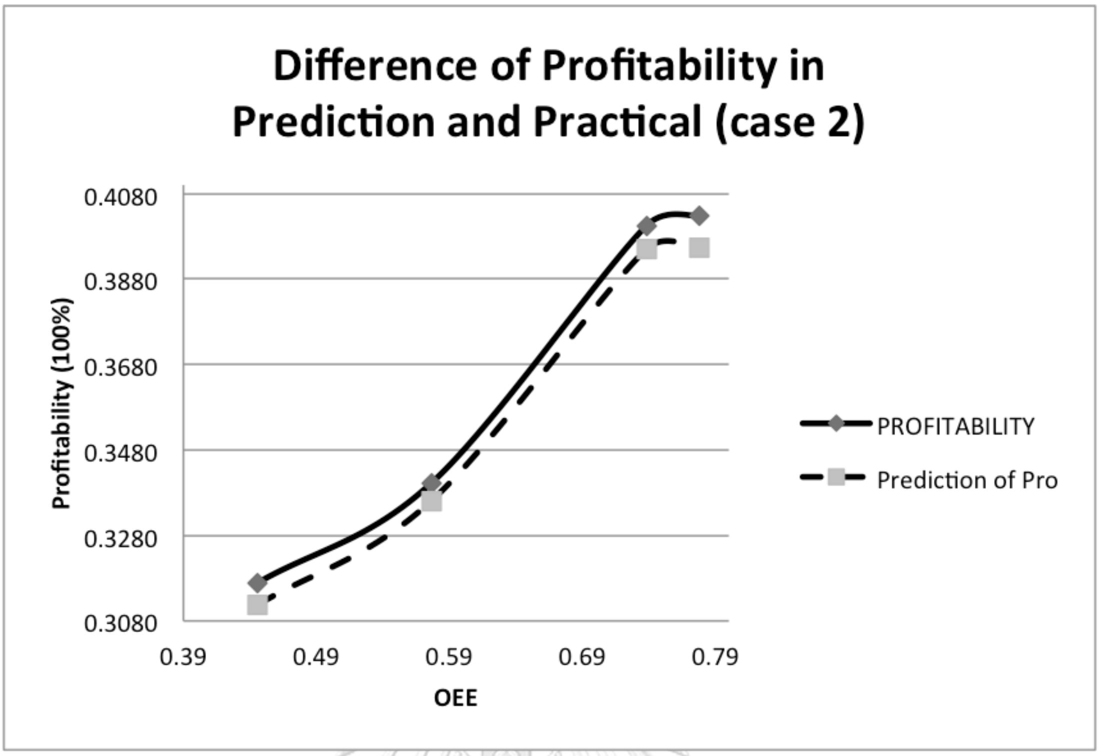

Figure 6. 5 Difference of Profitability in prediction and practical

The proposal prediction model was applied in experiment 2 to evaluate how the model is. With less than 2% differences, experiment 2 presented that the proposal prediction model could be applied to predict the value of CFP and Profitability when improving OEE.

It is obvious that when OEE was improved with a TQM technique, CFP and Profitability values were fully predictable, which is the basis for selecting the appropriate TQM technique to improve OEE, and to obtain the expected values of CFP and Profitability.

Chapter 7

Conclusions and recommendations

7.1 Conclusions

Conclusion 1: The OEE was inversely proportional to CFP, when OEE was improved, CFP was decreased. As a result, corrugated paperboard may think of improving the environment by improvement of equipment efficiency. At present, improving environment is one of the issues that are of great concern, and corrugated paper production is not out of the trend. Typically, environmental improvement in corrugated paper production involved the use of environmentally friendly materials or a change of equipment or part of the production process to minimize electricity use. These activities cost huge amount of time and money to implement and directly affect all corrugated production processes and that why the companies do not want to implement the environmental friendly processes. Improvement of OEE using TQM techniques as tested in the present study asserting that only require the contribution of workers, CFP would be minimized.

Conclusion 2: OEE was proportional to Profitability, and Profitability was improved as OEE improved. Increasing profits is always the ultimate goal of manufacturing companies which is possible when production costs and labor are cut, or cheaper materials are found. As a result of this study, corrugated paper companies have more option to increase their profitability by using TQM techniques to improve OEE. The higher the OEE, the higher the profitability. The efficiency of equipment is proportional to the efficiency of production, but improving the efficiency of the equipment through the application of TQM techniques is one of the ways to improve OEE. It is the least cost and this is what contributes to the increase in profitability. It was clearly showed that the increase in profitability of corrugated paper companies added a number of ways to implement, for example the application of TQM techniques to simultaneously improve OEE and Profitability.

Conclusion 3: When the parameter which causes harm to the environment decrease, the profitability of the corrugated paper increases. The CFP was inversely proportional to the Profitability when applying TQM techniques to improve OEE. This is a significant result that brings dual benefits for the manufacturers. Environmental issues are always required to be improved and the cost of the improvement is a concern. To minimize the CFP, a manufacturer must invest in one more equipment or change technology to achieve the ultimate goal. This would negatively affect the profitability of the producers. By using TQM techniques, not costly, mainly using employee resources, the findings have shown that when CFP decreases, Profitability did not decrease but increased proportionally.

Conclusion 4: Prediction model predicts values for CFP and profitability achieved when improving the factors including A, P, Q of OEE is an effective application in deciding which factor should be focused for the improvement. The research has shown that when applying an impact of TQM technique, the OEE would change but one of the three factors would be most affected and this factor would determine the level of increase and decrease of CFP and profitability. Corrugated paper manufacturers could apply the prediction model to evaluate the effectiveness of applying a TQM technique, in particular, to anticipate a reduction in CFP and a rise in profitability with a margin of error of less than 2%. This is the solid basis for the manufacturers to make decision when applying TQM to improve the OEE without concern on affecting environment and profitability of corrugated paper producers.

Conclusion 5: The study clearly demonstrated the relationships between OEE and CFP and Profitability of corrugated paper producers: when improving OEE, CFP would decrease and Profitability would increase. The TQM techniques used in the present study were one of the suggestions for improving OEE. In response to a TQM technique, a factor of OEE significantly improved. The values of CFP and Profitability would be affected by this factor. Prediction model was a useful tool in predicting CFP and Profitability when improving OEE.

7.2 Recommendations

The TQM techniques used in this study have brought about the improvements in the OEE and, in turn, reduced the CFP, resulting in increased profitability. TQM techniques could be considered as a set of techniques to improve OEE effectively for all three factors of OEE comprising A, P, and Q. Depending on the current state and applicability of the manufacturers, the OEE value would change more or less. This technique has been applied in two corrugated paper producers resulting in improving A, P and Q (of OEE), CFP has always decreased and Profitability has always increased. Future research should focus on finding relationship between a technique applied and the increase of one of the three factors of A, P, Q. This information will be very useful in making decision on selecting which method to be used to improve OEE more clearly and effectively.

As a result of the present study, the relationship between OEE and CFP and Profitability was nonlinear. The studies on the variations of relationships of OEE and CFP, OEE and Profitability, CFP and Profitability are among the important research topic to consider in evaluating the effect of OEE improvement on corrugating machine using TQM on CFP of corrugated board.

The prediction model needs to improve to reach the margin of error less than 1% instead of 2% as in present study.

Further research should not just focus on "corrugated board" production but should extend to "corrugated box", thus evaluating more fully the impact of improving OEE on CFP as well as Profitability.

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APPENDIX

APPENDIX

No Impact - Case 1						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.58	0.69	0.79	0.32	0.2151	0.2773
2	0.62	0.72	0.84	0.37	0.2453	0.3002
3	0.56	0.6	0.83	0.28	0.2008	0.2469
4	0.65	0.68	0.85	0.38	0.2327	0.2902
5	0.65	0.75	0.83	0.40	0.2565	0.3140
6	0.64	0.69	0.84	0.37	0.2340	0.2949
7	0.62	0.73	0.8	0.36	0.2437	0.2848
8	0.67	0.75	0.85	0.43	0.2535	0.3161
9	0.63	0.73	0.87	0.40	0.2557	0.2995
10	0.69	0.75	0.89	0.46	0.2710	0.3197
11	0.58	0.74	0.78	0.33	0.2337	0.2713
12	0.57	0.66	0.86	0.32	0.2185	0.2835
13	0.63	0.72	0.84	0.38	0.2503	0.3047
14	0.61	0.75	0.81	0.37	0.2417	0.3026
15	0.68	0.69	0.79	0.37	0.2512	0.2775
16	0.68	0.76	0.89	0.46	0.2734	0.3307
17	0.69	0.7	0.87	0.42	0.2644	0.3159
18	0.65	0.73	0.86	0.41	0.2525	0.2973
19	0.64	0.64	0.81	0.33	0.2316	0.2741
20	0.67	0.76	0.84	0.43	0.2678	0.3102
21	0.66	0.76	0.86	0.43	0.2699	0.3071
22	0.63	0.73	0.81	0.37	0.2497	0.3003
23	0.65	0.72	0.79	0.37	0.2481	0.2784
24	0.64	0.74	0.81	0.38	0.2496	0.2898
25	0.68	0.72	0.85	0.42	0.2390	0.3052
26	0.67	0.74	0.81	0.40	0.2497	0.3033
27	0.63	0.75	0.87	0.41	0.2478	0.3081
28	0.62	0.75	0.8	0.37	0.2433	0.2871
29	0.65	0.75	0.87	0.42	0.2411	0.3209
30	0.59	0.75	0.86	0.38	0.2364	0.3113

Impact 1 - Case 1						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.70	0.73	0.88	0.45	0.2366	0.3119
2	0.69	0.80	0.85	0.47	0.2491	0.3192
3	0.60	0.75	0.77	0.34	0.2081	0.2621
4	0.69	0.74	0.89	0.46	0.2422	0.3065
5	0.72	0.84	0.88	0.53	0.2650	0.3459
6	0.69	0.77	0.83	0.44	0.2296	0.3046
7	0.66	0.79	0.85	0.44	0.2383	0.3012
8	0.71	0.83	0.88	0.52	0.2622	0.3235
9	0.67	0.74	0.80	0.40	0.2283	0.2759
10	0.75	0.80	0.88	0.53	0.2701	0.3237
11	0.68	0.74	0.83	0.42	0.2312	0.3087
12	0.74	0.74	0.88	0.48	0.2567	0.3023
13	0.71	0.81	0.85	0.49	0.2309	0.3114
14	0.68	0.75	0.83	0.42	0.2289	0.3048
15	0.70	0.74	0.80	0.41	0.2354	0.3243
16	0.75	0.84	0.87	0.55	0.2504	0.3371
17	0.63	0.78	0.81	0.40	0.2276	0.3192
18	0.69	0.77	0.89	0.48	0.2488	0.3053
19	0.73	0.80	0.82	0.48	0.2570	0.3011
20	0.75	0.75	0.84	0.47	0.2420	0.3104
21	0.70	0.81	0.82	0.46	0.2412	0.3102
22	0.72	0.79	0.91	0.52	0.2306	0.3172
23	0.69	0.72	0.86	0.43	0.2347	0.3109
24	0.72	0.79	0.89	0.51	0.2447	0.3137
25	0.68	0.79	0.83	0.45	0.2441	0.3085
26	0.71	0.73	0.83	0.43	0.2393	0.2907
27	0.68	0.82	0.80	0.44	0.2463	0.3027
28	0.67	0.72	0.87	0.42	0.2478	0.3107
29	0.71	0.79	0.83	0.46	0.2415	0.2968
30	0.67	0.77	0.80	0.41	0.2326	0.2836

Impact 2 - Case 1						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.83	0.84	0.87	0.61	0.2514	0.3163
2	0.86	0.85	0.89	0.65	0.2594	0.3291
3	0.87	0.83	0.77	0.55	0.2620	0.2910
4	0.85	0.88	0.87	0.64	0.2622	0.3226
5	0.87	0.87	0.87	0.66	0.2658	0.3380
6	0.82	0.82	0.87	0.58	0.2465	0.3187
7	0.85	0.83	0.88	0.62	0.2496	0.3188
8	0.84	0.87	0.80	0.58	0.2494	0.3295
9	0.88	0.83	0.85	0.62	0.2401	0.3135
10	0.80	0.75	0.84	0.50	0.2408	0.2839
11	0.80	0.83	0.80	0.53	0.2353	0.2892
12	0.85	0.80	0.83	0.56	0.2379	0.3021
13	0.82	0.85	0.83	0.58	0.2475	0.3197
14	0.81	0.83	0.87	0.59	0.2456	0.3026
15	0.89	0.82	0.87	0.64	0.2451	0.3166
16	0.89	0.88	0.89	0.70	0.2408	0.3027
17	0.87	0.77	0.85	0.57	0.2462	0.3082
18	0.86	0.81	0.84	0.58	0.2371	0.3045
19	0.80	0.76	0.85	0.51	0.2205	0.3089
20	0.87	0.75	0.85	0.55	0.2335	0.3025
21	0.77	0.80	0.86	0.53	0.2181	0.3153
22	0.89	0.84	0.87	0.65	0.2251	0.3099
23	0.89	0.83	0.86	0.63	0.2245	0.3122
24	0.83	0.70	0.86	0.50	0.2216	0.3160
25	0.88	0.82	0.87	0.63	0.2427	0.3032
26	0.87	0.81	0.87	0.62	0.2594	0.3058
27	0.87	0.85	0.88	0.65	0.2406	0.3108
28	0.85	0.81	0.87	0.60	0.2271	0.3089
29	0.84	0.79	0.86	0.57	0.2261	0.2929
30	0.74	0.72	0.85	0.45	0.2069	0.3197

Impact 3+4 - Case 1						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.83	0.93	0.94	0.73	0.2295	0.3789
2	0.86	0.93	0.93	0.75	0.2322	0.3708
3	0.87	0.83	0.90	0.65	0.2492	0.3451
4	0.83	0.94	0.94	0.74	0.2189	0.3618
5	0.89	0.96	0.94	0.80	0.2168	0.3904
6	0.81	0.89	0.94	0.68	0.2047	0.3792
7	0.85	0.88	0.93	0.69	0.2130	0.3673
8	0.82	0.94	0.95	0.74	0.2288	0.3643
9	0.88	0.83	0.92	0.67	0.2053	0.3345
10	0.80	0.79	0.93	0.59	0.2169	0.3692
11	0.83	0.83	0.94	0.65	0.2101	0.3824
12	0.85	0.88	0.94	0.70	0.2056	0.3790
13	0.86	0.94	0.95	0.76	0.2187	0.3730
14	0.82	0.83	0.96	0.65	0.2123	0.3790
15	0.89	0.86	0.96	0.74	0.2451	0.3729
16	0.89	0.96	0.94	0.80	0.2156	0.3704
17	0.87	0.80	0.93	0.65	0.2099	0.3802
18	0.86	0.83	0.92	0.66	0.2073	0.3752
19	0.85	0.83	0.94	0.66	0.2095	0.3378
20	0.87	0.81	0.92	0.65	0.2103	0.3891
21	0.87	0.88	0.93	0.71	0.2056	0.3793
22	0.89	0.87	0.95	0.74	0.2251	0.3829
23	0.89	0.85	0.94	0.71	0.2245	0.3795
24	0.86	0.73	0.95	0.60	0.2019	0.3804
25	0.88	0.88	0.93	0.72	0.2165	0.3862
26	0.87	0.84	0.94	0.68	0.2173	0.3821
27	0.87	0.91	0.93	0.74	0.2234	0.3737
28	0.85	0.85	0.94	0.68	0.2271	0.3756
29	0.84	0.82	0.92	0.63	0.2261	0.3724
30	0.87	0.83	0.93	0.67	0.2166	0.3680

Impact 5 - Case 1						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.83	0.98	0.96	0.78	0.2103	0.4092
2	0.86	0.97	0.93	0.78	0.2056	0.3999
3	0.87	0.83	0.90	0.65	0.2047	0.3394
4	0.81	0.96	0.93	0.73	0.2259	0.3565
5	0.91	1.01	0.91	0.84	0.2035	0.3965
6	0.80	0.93	0.94	0.70	0.2465	0.3825
7	0.85	0.89	0.93	0.70	0.2496	0.3642
8	0.81	0.97	0.95	0.75	0.2254	0.3768
9	0.88	0.83	0.92	0.67	0.2401	0.3284
10	0.80	0.79	0.94	0.60	0.2135	0.2966
11	0.88	0.83	0.94	0.69	0.2136	0.3471
12	0.85	0.93	0.94	0.74	0.2224	0.3857
13	0.89	0.99	0.95	0.84	0.2157	0.3869
14	0.89	0.83	0.96	0.71	0.2189	0.3879
15	0.91	0.87	0.96	0.75	0.2079	0.3696
16	0.89	0.99	0.94	0.83	0.2158	0.3846
17	0.87	0.79	0.93	0.64	0.2462	0.3893
18	0.86	0.83	0.92	0.66	0.2371	0.3880
19	0.89	0.86	0.94	0.72	0.2108	0.3889
20	0.87	0.81	0.92	0.65	0.2052	0.3857
21	0.87	0.88	0.93	0.71	0.2088	0.3958
22	0.89	0.87	0.95	0.74	0.2251	0.3854
23	0.94	0.85	0.94	0.75	0.2245	0.3857
24	0.86	0.92	0.95	0.75	0.2157	0.3757
25	0.88	0.90	0.93	0.74	0.2068	0.3897
26	0.87	0.84	0.92	0.67	0.2054	0.3851
27	0.87	0.94	0.93	0.76	0.2006	0.3609
28	0.89	0.85	0.94	0.71	0.2001	0.3588
29	0.83	0.82	0.92	0.62	0.2061	0.3108
30	0.88	0.87	0.94	0.72	0.2167	0.3903

No Impact - Case 2						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.64	0.73	0.84	0.39	0.1872	0.3147
2	0.59	0.72	0.86	0.37	0.1844	0.3056
3	0.68	0.75	0.85	0.43	0.1934	0.3137
4	0.66	0.77	0.87	0.44	0.1983	0.3276
5	0.66	0.7	0.88	0.41	0.1946	0.3191
6	0.63	0.75	0.83	0.39	0.1945	0.3132
7	0.65	0.71	0.85	0.39	0.1830	0.3008
8	0.64	0.77	0.87	0.43	0.1915	0.3274
9	0.66	0.78	0.87	0.45	0.1870	0.3238
10	0.6	0.75	0.85	0.38	0.1988	0.3009
11	0.63	0.7	0.86	0.38	0.1990	0.2913
12	0.67	0.73	0.84	0.41	0.1977	0.3196
13	0.62	0.71	0.85	0.37	0.1948	0.3082
14	0.67	0.78	0.85	0.44	0.1997	0.3369
15	0.66	0.7	0.87	0.40	0.1977	0.3012
16	0.64	0.74	0.88	0.42	0.1943	0.3212
17	0.67	0.71	0.86	0.41	0.1952	0.3187
18	0.59	0.73	0.84	0.36	0.1922	0.2887
19	0.62	0.76	0.84	0.40	0.1945	0.3168
20	0.66	0.76	0.83	0.42	0.1952	0.3115
21	0.63	0.72	0.87	0.39	0.1903	0.3157
22	0.67	0.7	0.86	0.40	0.1953	0.3157
23	0.64	0.77	0.87	0.43	0.1932	0.3144
24	0.65	0.74	0.85	0.41	0.1975	0.3107
25	0.66	0.73	0.88	0.42	0.1939	0.3280
26	0.65	0.74	0.84	0.40	0.1909	0.3130
27	0.61	0.75	0.83	0.38	0.1925	0.3039
28	0.67	0.74	0.84	0.42	0.1935	0.3069
29	0.6	0.71	0.86	0.37	0.1993	0.3044
30	0.59	0.73	0.86	0.37	0.1943	0.3114

Impact 1 - Case 2						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.70	0.75	0.87	0.46	0.1975	0.3247
2	0.61	0.75	0.85	0.39	0.1808	0.3021
3	0.60	0.75	0.87	0.39	0.1904	0.3122
4	0.65	0.78	0.89	0.46	0.1992	0.3214
5	0.68	0.73	0.87	0.43	0.1907	0.3164
6	0.63	0.78	0.87	0.43	0.1828	0.3177
7	0.64	0.75	0.89	0.43	0.1894	0.3072
8	0.63	0.79	0.88	0.44	0.1938	0.3115
9	0.65	0.78	0.89	0.45	0.1982	0.3134
10	0.61	0.75	0.91	0.42	0.1902	0.3035
11	0.68	0.77	0.90	0.47	0.1884	0.3187
12	0.70	0.77	0.87	0.47	0.1978	0.3103
13	0.65	0.75	0.91	0.44	0.1987	0.3186
14	0.68	0.78	0.92	0.49	0.1873	0.3197
15	0.70	0.76	0.87	0.46	0.1869	0.3195
16	0.66	0.76	0.87	0.44	0.1934	0.3192
17	0.66	0.78	0.88	0.45	0.1996	0.3192
18	0.58	0.77	0.89	0.40	0.1827	0.3198
19	0.68	0.80	0.90	0.49	0.1864	0.3227
20	0.70	0.79	0.92	0.51	0.1947	0.3199
21	0.62	0.77	0.89	0.43	0.1913	0.3195
22	0.69	0.78	0.90	0.49	0.1923	0.3172
23	0.63	0.76	0.88	0.43	0.1907	0.3199
24	0.65	0.79	0.87	0.44	0.1862	0.3193
25	0.68	0.79	0.89	0.48	0.1907	0.3185
26	0.65	0.78	0.93	0.47	0.1842	0.3167
27	0.61	0.78	0.92	0.44	0.1830	0.3199
28	0.67	0.79	0.87	0.46	0.1902	0.3197
29	0.65	0.79	0.91	0.46	0.1845	0.3189
30	0.67	0.77	0.80	0.41	0.1914	0.3199

Impact 2 - Case 2						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.87	0.84	0.89	0.65	0.1862	0.3384
2	0.86	0.78	0.89	0.60	0.1951	0.3359
3	0.87	0.83	0.87	0.63	0.1835	0.3456
4	0.80	0.81	0.88	0.56	0.1900	0.3233
5	0.87	0.78	0.90	0.61	0.1976	0.3413
6	0.78	0.82	0.87	0.55	0.1880	0.3435
7	0.82	0.76	0.88	0.55	0.1848	0.3469
8	0.80	0.82	0.86	0.57	0.1898	0.3320
9	0.83	0.83	0.90	0.62	0.1834	0.3384
10	0.80	0.75	0.88	0.53	0.1858	0.3477
11	0.82	0.83	0.87	0.59	0.1952	0.3369
12	0.83	0.81	0.87	0.58	0.1914	0.3320
13	0.85	0.79	0.89	0.59	0.1957	0.3425
14	0.82	0.80	0.90	0.59	0.1832	0.3492
15	0.83	0.76	0.89	0.56	0.1802	0.3394
16	0.83	0.79	0.89	0.58	0.1843	0.3456
17	0.81	0.78	0.90	0.57	0.1888	0.3481
18	0.86	0.75	0.86	0.56	0.1822	0.3415
19	0.83	0.80	0.88	0.59	0.1851	0.3485
20	0.82	0.80	0.90	0.59	0.1825	0.3476
21	0.76	0.77	0.86	0.50	0.1780	0.3428
22	0.82	0.82	0.90	0.61	0.1803	0.3417
23	0.83	0.83	0.88	0.60	0.1802	0.3396
24	0.83	0.79	0.92	0.61	0.1827	0.3427
25	0.82	0.79	0.87	0.56	0.1827	0.3415
26	0.81	0.81	0.90	0.59	0.1865	0.3373
27	0.83	0.80	0.88	0.58	0.1855	0.3441
28	0.81	0.79	0.91	0.59	0.1823	0.3383
29	0.80	0.78	0.91	0.57	0.1893	0.3142
30	0.83	0.72	0.85	0.51	0.1873	0.3412

Impact 3+4 - Case 2						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.89	1.01	0.95	0.86	0.1789	0.4001
2	0.89	0.93	0.95	0.79	0.1861	0.3844
3	0.88	0.95	0.91	0.76	0.1756	0.3970
4	0.86	0.94	0.91	0.73	0.1816	0.4077
5	0.87	0.93	0.92	0.74	0.1828	0.4169
6	0.87	0.97	0.92	0.78	0.1882	0.4217
7	0.83	0.88	0.94	0.69	0.1702	0.3818
8	0.81	0.97	0.90	0.70	0.1758	0.3869
9	0.84	0.95	0.92	0.73	0.1808	0.4173
10	0.84	0.86	0.90	0.65	0.1746	0.4023
11	0.87	0.94	0.94	0.77	0.1724	0.3972
12	0.84	0.97	0.93	0.76	0.1773	0.3997
13	0.88	0.94	0.92	0.76	0.1748	0.4210
14	0.86	0.90	0.96	0.74	0.1743	0.4013
15	0.84	0.87	0.94	0.69	0.1723	0.4032
16	0.88	0.93	0.95	0.77	0.1745	0.3945
17	0.86	0.88	0.95	0.71	0.1761	0.4030
18	0.87	0.85	0.97	0.72	0.1752	0.4094
19	0.84	0.95	0.98	0.79	0.1701	0.4130
20	0.83	0.93	0.95	0.73	0.1752	0.4023
21	0.83	0.87	0.97	0.70	0.1618	0.4084
22	0.88	0.99	0.97	0.85	0.1754	0.4109
23	0.84	0.94	0.96	0.76	0.1702	0.3977
24	0.84	0.91	0.97	0.74	0.1787	0.3575
25	0.83	0.92	0.91	0.70	0.1784	0.3942
26	0.87	0.95	0.92	0.76	0.1703	0.3953
27	0.85	0.93	0.90	0.71	0.1715	0.3987
28	0.86	0.91	0.93	0.72	0.1788	0.4035
29	0.86	0.88	0.96	0.73	0.1775	0.4009
30	0.85	0.81	0.90	0.62	0.1619	0.3879

Impact 5 - Case 2						
Day	A	P	Q	OEE	CFP	PROFITABILITY
1	0.90	0.95	0.93	0.80	0.1850	0.4188
2	0.93	0.96	0.96	0.86	0.1703	0.4309
3	0.88	0.94	0.92	0.76	0.1734	0.3899
4	0.91	0.95	0.95	0.82	0.1868	0.3752
5	0.90	0.94	0.97	0.82	0.1721	0.3899
6	0.88	0.95	0.95	0.79	0.1821	0.4152
7	0.89	0.88	0.93	0.72	0.1719	0.3789
8	0.87	0.99	0.90	0.77	0.1723	0.3949
9	0.88	0.94	0.90	0.75	0.1785	0.4029
10	0.86	0.93	0.91	0.73	0.1758	0.4165
11	0.92	0.92	0.93	0.78	0.1804	0.3861
12	0.92	0.94	0.97	0.84	0.1846	0.4041
13	0.93	0.95	0.91	0.81	0.1875	0.4189
14	0.88	0.92	0.98	0.79	0.1809	0.3618
15	0.89	0.90	0.95	0.76	0.1757	0.3877
16	0.91	0.95	0.97	0.83	0.1702	0.4189
17	0.86	0.86	0.96	0.71	0.1688	0.4123
18	0.91	0.94	0.95	0.82	0.1702	0.4187
19	0.84	0.98	0.97	0.80	0.1702	0.4148
20	0.90	0.93	0.97	0.81	0.1741	0.4037
21	0.87	0.94	0.95	0.78	0.1701	0.4026
22	0.90	0.93	0.95	0.80	0.1704	0.4134
23	0.84	0.92	0.97	0.75	0.1744	0.4195
24	0.88	0.90	0.98	0.78	0.1703	0.4198
25	0.87	0.93	0.93	0.75	0.1707	0.4195
26	0.88	0.97	0.91	0.77	0.1702	0.4193
27	0.86	0.94	0.93	0.75	0.1773	0.4216
28	0.88	0.90	0.95	0.75	0.1766	0.3861
29	0.87	0.87	0.97	0.73	0.1713	0.3394
30	0.85	0.80	0.97	0.66	0.1702	0.4020

OEE OF CORRUGATING MACHINE

Date 01-Nov-16

Production Data		
Shift Length	510.00	Minutes
Breaks	30	Minutes
Down Time	75	Minutes
Ideal Run Rate	12	MPM (Meter Per Minute)
Total Paper	3,062	Kg
Reject Paper	481	Kg
Real Run Rate	10.22	MPM (Meter Per Minute)

Support Variable	Calculation	Result	
Planned Production Time	Shift Length - Breaks	480	Minutes
Operating Time	Planned Production Time - Down Time	405	Minutes
Good Paper	Total paper - Reject paper	2,581	Kg

OEE Factor	Calculation	My OEE%
Availability	Operating Time / Planned Production Time	**84.38%**
Performance	Real Run Rate / Ideal Run Rate	**85.17%**
Quality	Good Paper / Total Paper	**84.30%**
Overall OEE	Availability x Performance x Quality	**60.58%**

OEE Factor	World Class	My OEE%
Availability	90.00%	**84.38%**
Performance	95.00%	**85.17%**
Quality	99.90%	**84.30%**
Overall OEE	85.00%	**60.58%**

CFP OF CORRUGATING MACHINE

Date 01-Nov-16

Item	Amount usage	Carbon emission factor	CO2 emission (kg)	%	Total CO2 emission (kg)	%
Raw materials					3,137.00	31.33
Paper (kg)	3,062.00	1.00	3,062.00	30.58		
Glue(kg)	75.00	1.00	75.00	0.75		
Manufacture					678.14	6.77
Electricity usage (kw)	677.50	1.00	677.50	6.77		
Lighting in plant (kw)	0.64	1.00	0.64	0.01		
Recycle waste					480.83	4.80
Paper waste (kg)	480.83	1.00	480.83	4.80		
Disposal					2,581.17	25.78
Land fill (kg) - 20%	516.23	1.00	516.23	5.16		
Recycle (kg) - 70%	1,806.82	1.00	1,806.82	18.04		
Burnning (kg) - 10%	258.12	1.00	258.12	2.58		
Transportation					3,137.00	31.33
Paper	3,062.00	1.00	3,062.00	30.58		
Glue	75.00	1.00	75.00	0.75		
Tota (kgCO2e)			**10,014.14**	**100.00**	**10,014.14**	**100.00**
Per 1m2 (kgCO2e)			**0.48**		**0.48**	

PROFITABILITY OF CORRUGATING MACHINE	
Date	01-Nov-16
COST PRICE (vnd)	**31,413,076.92**
Total paper usage (kg)	3,062.00
Price of roll paper (vnd/kg)	9,000.00
Price of glue (vnd)	1,035,000.00
Price of electricity	1,897,000.00
Price of worker	923,076.92
SELLING PRICE (vnd)	**41,756,832.00**
Total corrugated board (square meter of 1 layer)	20,878.42
Price of 1 layer board paper (vnd/square meter)	2,000.00
PROFIT (vnd)	**10,343,755.08**
PERCENTAGE OF PROFIT MARGIN (%)	**24.77**
PERCENTAGE OF PROFIT MARK-UP (%)	**32.93**

PHIẾU THEO DÕI SẢN XUẤT GIẤY SÓNG

Ngày	01-Nov-16	Lệnh sản xuất	349							
Thời điểm bắt đầu (giờ:phút)	7:30	Số tấm trên chiều khổ	1							
Thời điểm kết thúc (giờ:phút)	16:00	Số lớp	5	Phẳng	B	Phẳng	C	Phẳng	None	None
Thời điểm nghỉ giải lao (g:p)	11:30	Khổ giấy cuộn (cm)		80	80	80	80	80		
Thời điểm hết nghỉ giải lao (g:p)	12:00	Định lượng giấy (g/m2)		150	110	110	110	150		
Chỉ số điện lúc bắt đầu (kw)	678	Cân nặng giấy cuộn đầu vào (kg)		600	718	640	873	607		
Chỉ số điện lúc kết thúc (kw)	870	Cân nặng giấy cuộn còn lại (kg)		"-"	"-"	184	152	40		
Bột sử dụng (kg)	75.00	Cân nặng 1 tấm (kg)	1.20	3,556.80	4,730.54	3,556.80	5,477.47	3,556.80	0.00	0.00
		Chiều dài giấy tấm (cm)	171	0.2052	0.2001384	0.15048	0.23174	0.2052	0	0
		Chiều rộng giấy tấm (cm)	80							
		Số tấm thành phẩm (tấm)	2,600							
		Thời điểm chạy giấy (giờ:phút)	8:35							
		Thời điểm ngưng chạy giấy (g:p)	15:50							

Prediction		
	Previous stage	**Prediction**
Availability	64.26%	90.00%
Performance	73.29%	95.00%
Quality	84.10%	99.90%
Overall OEE	39.60%	85.41%
CFP Per 1m2 (kgCO2e)	0.2456	0.2338
Profitability (%)	29.74	32.26

Case 1	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5	World Class
A	0.64	0.70	0.85	0.86	0.87	0.90
P	0.72	0.78	0.81	0.87	0.89	0.95
Q	0.84	0.85	0.85	0.94	0.94	0.99
OEE	0.39	0.46	0.59	0.69	0.72	0.85
CFP	0.2456	0.2414	0.2403	0.2181	0.2176	
PROFITABILITY	0.2974	0.3081	0.3104	0.3727	0.3734	
Prediction of CFP		0.2435	0.2389	0.2194	0.2178	0.2160
Prediction of PRO		0.3031	0.3118	0.3405	0.3831	0.3766
Difference of CFP		0.9913	1.0057	0.9942	0.9993	
Difference of PRO		1.0166	0.9955	1.0944	0.9746	

Case 2	No Impact	Impact 1	Impact 2	Impact 3 + 4	Impact 5	World Class
A	0.64	0.65	0.82	0.86	0.88	0.90
P	0.74	0.77	0.79	0.92	0.93	0.95
Q	0.86	0.89	0.89	0.94	0.95	0.99
OEE	0.41	0.45	0.58	0.74	0.78	0.85
CFP	0.1938	0.1904	0.1863	0.1754	0.1751	
PROFITABILITY	0.3128	0.3169	0.3403	0.4005	0.4028	
Prediction of CFP		0.2035	0.1989	0.1894	0.1878	0.2160
Prediction of PRO		0.3011	0.3118	0.3805	0.3731	0.3766
Difference of CFP		0.9356	0.9365	0.9261	0.9326	
Difference of PRO		1.0525	1.0913	1.0525	1.0795	

VITA

Nguyen Long Giang was born on 1st July 1975 in Ho Chi Minh City, Vietnam. He attended university in 1993 and earned his Bachelor degree in Printing Technology that was awarded in 1998 by the Rector of University of Technical Education Ho Chi Minh City, Ho Chi Minh city, Vietnam. From 1998 to 2013, he was a lecturer of University of Technical Education Ho Chi Minh City, Ho Chi Minh city, Vietnam.

He received a scholarship for the period from August of 2014 to July of 2017, funded by Scholarship between the 100th Anniversary Chulalongkorn University Fund for Doctoral Scholarship and Scholarship for International Graduate Students: Top-Up Scholarship (100th Ann. CU + Top-Up Scholarship) from Chulalongkorn University, for his Doctoral degree in Imaging Technology, Faculty of Science, Chulalongkorn University. He implemented his dissertation entitled "Effect of overall equipment effectiveness improvement of corrugating machine using total quality management on carbon footprint of corrugated board" to complete his doctoral degree.