A STUDY OF FABRIC LOSS DURING SPREADING

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ABSTRACT

Fabric is the core of apparel manufacturing. For this concern, many studies have been carried out with the aim to reduce fabric wastage in the production process.

Cutting room is a place where a huge amount of fabric loss is generated. Fabric loss in cutting room is mainly caused by two operations – marker making and fabric spreading. Although marker making shares a large portion of material wastage, fabric loss due to spreading is of equal importance for material utilization control.

This study focuses on the development of an appropriate method which can be used for the prediction of total fabric loss during spreading in an accurate manner. The use of it could help people to determine and evaluate the efficiency of a particular cutting lay.

Through intensive revision, Ng's theoretical model[37, 38] was considered to be the most comprehensive model, was selected as the groundwork through which a more integral and generic new equation was formulated to furnish a high precision way for total fabric loss prediction during spreading.

Apart from the factors considered by Ng's model, the new equation was formulated by the incorporation of two adjusting factors. Not only these two factors can make the equation to be better with high integrity and generality, but also they fetched it with high preciseness in the prediction of total fabric loss during spreading.

Industrial data was involved for validation and verification of the new equation. To further examine it's practicability and generality, bipolar study was used for such examination, in which two sets of data were collected from two factories producing different kinds of garment (men's shirt and pants) with an immense variation on their style and material used.

During the study, real industrial data was compared with those theoretical prediction obtained by the new equation so that the prediction error can be fully revealed. The results proved that the equation is capable of making a precise prediction of total fabric loss with only a trivial range of error (-0.08% to 0.01%) in all samples. Since two cases for verification were selected in a bipolar manner that with notable difference on the products nature, thus, it is believed that the error on predicting total fabric loss for other types of apparel product will also lie within a low level.

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CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND OF STUDY

In garment manufacturing, material utilization is an important issue in controlling the production costs. The significance of material cost in apparel production has long been recognized by the apparel manufacturers. The fabric cost alone is about 35% to 40% of the selling price of an apparel product[1]. The reduction of fabric wastage can increase the competitiveness and profitability of an apparel enterprise.

Garment production involves three major operations, which are cutting, sewing, and finishing[2]. Before performing the sewing and finishing operations, the main role of cutting process is to transform fabric rolls into garment panels prepared for the subsequent sewing operations. Spreading is the process of superimposing lengths of fabric on a spreading table, cutting table, or specially designed surface in preparation for the cutting process.

Fabric loss resulting from the cutting and spreading processes is one of the key factors in determining the fabric utilization in apparel production. Amongst the three main production processes - cutting, sewing and finishing – in apparel manufacturing, a considerable amount of fabric would be lost during the cutting and spreading processes and such loss cannot be recovered by subsequent production processes.

To control the material wastage in apparel production, one of the main concerns is marker planning. A marker is a diagram of a precise arrangement of pattern pieces for the sizes of a specific style that are to be cut from a single spread. Marker making is the process of determining the most efficient layout of pattern pieces for a specified style, fabric and distribution of sizes. Markers are made to fit the specific widths of fabric and assortments of size. Characteristics of pattern pieces may limit fabric utilization in marker planning. Generally the percentage of fabric utilization increases when a variety of garment sizes are used in the same marker and when the patterns contain both large and small pieces. One means of determining the fabric utilization in the marker planning is by comparing the total area of the marker with the perimeter area of pattern pieces. Thus, the area not used by garment parts is the marker loss[3]. The effectiveness of material utilization of a marker can be represented by marker efficiency. Marker efficiency is the percentage of marking area that is actually used in the garment parts out of the total area in marker. The marker efficiency can be determined by a planimeter or computer. Numerous researches[4, 5, 6, 7, 8, 9] including the development of advance marker-making software were focused on the marker planning for maximizing the marker efficiency.

Apart from the marker loss, a certain amount of fabric is also lost in many other areas during the cutting and spreading processes. For instance, if a marker is wider than the width of the fabric to be cut, garment parts located on the edge of the marker will not be completed. Therefore, a marker has to be narrower than the width of the fabric to be cut, and thus the unused fabric at the two edges of the fabric width will be wasted. Besides the width loss, due to the narrower width of marker, there are other types of spreading loss including the fabric loss caused by remnants, inconsistent edging, splicing, and the loss at the two ends of the cutting lay.

Many previous researches have studied the fabric usage in apparel production. The work of Cole Jr. and Sanborn[10] showed that about 94.96% of fabric is used for making up the garment as well as the marker loss. The remaining 4.64% of fabric is lost in the cutting and spreading processes. The result was further supported by another study which carried out by Clothing Industry Productivity Association (CLIPA) and National Productivity Institute in 1989[11]. The findings showed that the garment itself and the marker loss cover about 94.9% of fabric usage. About 5.1% of fabrics belong to the areas of fabric loss in spreading. Trautman's survey[12] also assessed that about 4.4% of fabrics is used on the width loss, remnants, splice loss and end loss. Even though the fabric loss in spreading is only about 5% of the total fabric usage in production, it is a considerable amount of fabric that can be significantly affected the total production cost in apparel manufacturing. Over these years, many research works focused on the area of marker planning, there is no study specially concern on the fabric loss caused by spreading process.

In spreading, one cutting order may require several markers to achieve optimum material utilization as well as production efficiency. Cut order planning determines how many markers are needed, how many of each garment size should be in each marker(i.e. the marker length), and the number of ply that will be cut from each marker. A cutting lay is a stack of fabric plies that have been prepared for cutting. The actual process of spreading involves laying out fabric in the desired number of layers, and the fabric must be kept flat, smooth, and tension-free on the spreading surface. Such processes may be done manually or by spreading machines. A spread or lay may consist of a single ply or multiple plies of fabric that is the total amount of fabric prepared for a single marker. The height of a spread or lay is limited by the vertical capacity of the spreading equipment, cutting method, fabric characteristics, and the size of the order to be cut. Another main consideration in the spreading process is the spreading mode, that is the manner in which fabric plies are laid out for cutting. In most cases, fabric is laid out continuously as the spreader moves up and down the spreading table, thus the fabric roll tuned at the end of each ply. Sometimes, the fabric roll must be cut at each end of the spread and the new end repositioned. The spreading modes relate to the fabric structure, prints, color shade and the direction of fabric "nap".

Besides, lay planning is critical in affecting the fabric loss in spreading processes. It is associated with the cutting order, size of marker, dimensions of the cutting table, type of cutting equipment, and the length of fabric rolls to be spread. Traditionally, lay planning is performed by the subjective judgement of the operatives in cutting room. There is no systematic approach to handle the lay planning process. The fabric wastage of each cutting lay is estimated based on the historical record of previous orders and by the experience of the cutting room managerial staff. Material usage planning is regarded as the foremost step to achieve an efficient use of material. Since different lay plans of various length of marker, spreading modes, the height of a cutting lay, and the length of fabric rolls may lead to different amounts of fabric loss, it is difficult for apparel manufacturer to determine which lay planning is the most economical one for fabric savings. If there is a systematic method for predicting the fabric loss before production, and if such method could integrate various types of fabric loss, the manufacturer would be able to select the most appropriate cut order plan for production. Thus, the apparel enterprise could maximize its resources utilization through effective planning and control on material.

1.2 OBJECTIVES

The objectives of this work were to study and develop an appropriate method for predicting the total fabric loss in the spreading process of apparel production in an accurate manner. Through a field study in apparel industry, the proposed methods for the prediction of total fabric loss during spreading were recommended. The accuracy and reliability of the prediction of fabric loss during cutting and spreading processes could be improved. The outcome of this research work can help the garment manufacturer to establish a systematic method for selecting the most appropriate lay plan in order to minimize the fabric loss.

1.3 SCOPE OF STUDY

This study focused on manufacturing of the ready-to-wear apparel products made from plain fabric with no checks or stripes pattern. Therefore, pattern matching is unnecessary in the cutting and spreading process. The fabric used in the study was assumed with no flaws. Even if flaws exist in the material, the flaws will not be cut away immediately during the spreading process. The method of flaws management is to replace the garment parts with flaws after the cutting lay has been cut.

Even though marker efficiency is a crucial element of material utilization, the marker planning was of no account in this study. The marker loss was determined by the marker efficiency that was determined by a computerized marker maker. As this research work focused on the lay planning of fabric in apparel production, the data would be more representative when a larger number of fabric rolls are used in a cutting lay, thus the minimum yardage of cutting lay selected for the study was 1500 meters. Such amount of yardage is about 10 to 15 fabric rolls.

1.4 METHODOLOGY

Subsequent to literature review on material utilization in apparel industry, the inadequacy of the existing methods for predicting total fabric loss in apparel production was discussed. Amongst these existing methods, a theoretical model was adopted as the framework of this study. Through a field study as well as the statistical analysis (e.g., descriptive statistic, linear regression and ANOVA), an appropriate method for prediction of total fabric loss during spreading was proposed. In order to evaluate the effectiveness of such method for its application in apparel industry, the results predicted by the new equation of the proposed method were compared with a set of data collected from a local apparel factory, and such method was discussed with the domain experts in apparel manufacturing.

CHAPTER 2 : LITERATURE REVIEW

2.1 TYPES OF FABRIC LOSS IN CUTTING ROOM

As described in the previous chapter, a piece of fabric may be consumed in many areas during the spreading and cutting process. Not only the garment itself, but also there are many kinds of source for fabric consumption. In this section, each type of fabric loss in the cutting room is introduced and classified according to its source of formation.

Generally, there is no mutual agreement for the classification of fabric loss in the cutting room. Based on individual experience and knowledge, different people may have their own way to classify the types of fabric loss in spreading process. Many previous researches have their own definitions on the classification of fabric loss in spreading. For instances, in the works of Carr H. C.[13], he suggested that the term spreading loss is referring to the losses incurred during spreading. Spreading losses include end waste, edge control (width loss) and splices. Thereafter, in Ronald M. Kallman's study[14], provided that the term spreading losses really refers to the losses which the spreaders are responsible for. Only end loss and splice lap loss were classified as spreading losses in his study.

Through the review of previous literature on cutting room losses, by capturing and combining of their main ideas, in this project, all the losses in cutting room are classified into three groups as marking loss, spreading loss and other indirect losses as discussed in the following sub-sections.

2.1.1 *Marking Loss*

Marker implies a large sheet of paper on which were drawn the edges of all the pattern pieces, this is only appropriate when cutting is by manually controlled knife and a line must be provided for the cutting operator to follow. Where a paper marker is used, it is normally placed on the top ply of the cutting lay by stapling or by ironing so that an adhesive backing on the paper may lightly stick to the surface of the fabric. Then, the paper marker is cut along with the fabric plies, and thus destroyed.[15]

Marker is the basic element in cutting process, it provides an accurate and essential indication for spreading and cutting. Without the marker, the required garment panels cannot be formed for the later stages of production. Not only is the marker as the basic and vital element in production, but it is also dominant the largest portion of fabric wastage, which is known as marking loss or marker fallout. In practice, the value of marker efficiency is commonly used to indicate the effectiveness of a particular marker on fabric utilization.

According to Ruth E. Glock and Grace I. Kunz in 1990[3], one measure of marker efficiency is the percentage of fabric utilization. Fabric utilization is the percentage of fabric actually used in garment pieces. One means of determining fabric utilization is by comparing the total area of the marker with the perimeter area of pattern pieces. Hence, the area not used by garment pieces is **waste** (sometimes termed marking loss or marker fallout).

In actual operation, marker efficiency is governed by many factors and marking restrictions. Those factors are described as follows:

a. *Fabric restrictions*

Since the fabric properties such as the appearance, extensibility and shrinkage are different in warpwise and weftwise direction, each pattern block is designed with a predetermined grain line. In the process of marker planning, the placing of pattern blocks on the marker is restricted by their grain lines. It is impossible to place the pattern blocks in any direction on the marker even though such arrangement can provide better marker efficiency [12].

b. The garment patterns

The shape of each garment panel, location and number of seams have a large influence on marker efficiency. The seams affect not only the number of pattern pieces, but also can determine the area that is used by each panel. Shifting of a seam for some parts can bring an extra space thus gained for placing one additional large part across the width of the marker. In addition to seam location, the number of seams directly affects the shape of the patterns, which can determine material usage. For example, in men's shirts, the one-piece back can be transformed into two-pieces by adding an extra seam at the centre back in order to have more flexibility in marking.

Besides, adding a seam can also change the shape of patterns, which if used appropriately, by interlocking the pattern parts and filling the gaps between patterns, can lead to increased marker efficiency[12].

c. Marking skill

The variability of marking skill is well known. Depending on the marker maker himself, different marker makers will have their own skill, method and experience for marking. Moreover, different aptitudes and personality characteristics are other factors that influence the learning and marking ability of a person. Some of these characteristics included; mathematical ability and numerical reasoning; spatial visualisation; the ability to integrate elements of patterns; short term memory [16].

d. *Marker width*

Marker width is one of the major constraints in marking, it governs the flexibility for the marker maker to place pattern panels within the marking area. Actually, marker width is determined by fabric width and it cannot generate a marker wider than the fabric. As a result, fabric becomes the major constraint in marker planning.

e. *Number of garments*

In most cases, increasing the number of pieces, which are available for interlocking, allows a higher maker efficiency to be achieved. In addition, with a large number of small parts, the marker maker can have more options to explore. Also, the small parts can be used to fill the gaps or intervals between the large panels. Although the marker efficiency can increase by adding the number of garments marked, the rate of saving still depends on the product itself.

f. Size combinations

Besides the number of sizes to be marked, size's combination is another factor that is closely related to marker efficiency. If the number of sizes to be put into a marker is fixed, a question may arise to what sizes of the garments should be chosen to mark on this marker. For example, is it better to make a two-size markers of 36-42(92-108) and 40-44(100-112) or 36-40 (92-100) and 42-44 (108-112)? In general, there can often be 0.5% to 1% difference between the good and bad combinations[13].

g. Pattern engineering

It can be defined as pattern changes that do not affect the finished quality, appearance, fit, or saleability of a garment. There are several techniques employed in pattern engineering. For examples, seam shifting, shirttail reshaping, component reshaping etc. Pattern engineering could help to reduce the area that exist between the pattern panels, therefore, to increase marker efficiency. [12].

h. Patterned fabric

The marking and cutting of patterned fabric become as the last manually-intensive practices in the cutting room. Placing pattern pieces accurately on the fabric imposes numerous problems on cutting room personnel, which despite many years of endeavor, automation has failed to solve. Selection of pattern repeat distances and modification of the location of the predominant stripe are two common ways to minimize waste for marking patterned fabric. There is great potential for patterned fabric to reduce marker utilization and it is important that every aspect of manufacture is scrutinized carefully[17].

i. Die-cut allowance

In areas where cutting accuracy is considered to be critical and when the volume of cut order can justify the expense, parts are blocked out and die cut. The most common allowance in die cutting is 1/4" between die-cut parts or 1/8" perimeter allowance built into them. When die-cutting is used, the edge allowance of each garment part would be increased, and thus the marker efficiency would become lowered.

2.1.2 *Spreading Loss*

The main function of spreading is to place the number of plies of fabric that the production planning process has dictated, to the length of the marker plan, in the colors required, correctly aligned as to length and width, and without tension. It is inevitable that fabric loss will be formed in the spreading process. In this project, spreading loss is referring to the losses incurred during spreading. These are categorized as end loss, width loss, splice loss and remnant loss.

2.1.2.1 End loss

In the expression of D. J. Tyler[18], due to the spreading skills, limpness and extensibility, and machinery capability, an extra allowance must dispense at the ends of the cutting lay to ensure the panels will be cut out completely. The amount of end allowance is mainly dependent on fabric's physical characteristics.

In Trauman's study[12], end loss can be determined by the following factors:

a. The length of the spreads:- The percentage of material loss represented by the two ends in excess of the marker length by a consistent amount will vary inversely with the spread length.

b. The fabrics being spread, the spreading method (one way or two way spreading), and the types of end devices used (catchers, bars, weights etc.). The amount of stretch or tension in the fabric, in combination with the spreading method and equipment used, will play an important part in the determination of end loss.

c. The care exercised by the spreaders:- Regardless of the care taken to reduce the loss, there will still be some degree of human fallibility causing end losses. Therefore, a standard should be established and spreaders' performance should be monitored on a sampling basis.

2.1.2.2 Width loss

It is usual for the width of a marker to be drafted less than the edge-to-edge width of the fabric. The marker is said to be made to the usable width of the fabric. The usable width is dependent on the quality of the selvedge, the consistency of fabric width, and also on the precision of edge control during spreading. Hence, width loss is the difference in width between the width of the marker and the width of the material laid upon the table.

Trauman's work[12] also showed that width loss is mainly governed by the following factors:

(i) The maximum marker width is limited by the narrowest fabric piece of a spread. If a cutting lay involves fabric rolls of different widths, the width loss of the spread will be increased.

(ii) In general, a percentage increase in marker width can be translated into a corresponding percentage decrease in marker length, therefore, the wider the marker, the lower the fabric loss because the width loss is reduced and the length of the cutting lay is shorter.

(iii) The fabrics of poor dimensional stability (e.g. woolens and knit power net) will have great variations on the fabric width. The spreading of such kinds of material must be careful and the width loss of the spread certainly will be much higher.

2.1.2.3 *Remnant loss*

Remnant lengths are produced whenever companies separate different shades of fabric pieces and lay up only complete plies. All part-ply lengths are put to one side and cut separately. Remnant lengths may also be generated when short lengths of material are left over after the completion of a lay, and are returned to store. Other marker or markers may be marked additionally for these lengths. The remnants left over after cutting a remnant lay should be very short and , if they are not usable, would be regarded as remnant loss[18].

2.1.2.4 *Splice loss*

Splicing refers to the joining of fabric plies in a spread. The reasons for splicing may due to; first, the used up fabric piece, it is therefore, another fabric piece is needed to splice for continuing the spreading process; and second, the removal of fabric flaws during spreading, it implies the cutting out of damaged or stained part within a fabric piece so that the fabric flaws will not appear in cut garment panels[19].

In practical, splicing cannot take place everywhere along the length of marker, the splice position is controlled by the predetermined splice lines which are located according to the layout of patterns in the marker. There are two kinds of splice line, known as straight-line splice and interlock splice[20]. Practically, the decision for type, number and position of splice line in a marker depends mainly on the pattern's layout and the judgement made by the management or the spreader themselves. The main function of splice line is to protect the crucial or the large pattern panels in marker. Once the crucial pattern panels have been defined, the splice lines will be set as a reference to save such panels during the splicing of fabric rolls.

It is inevitable, during the splicing of fabric rolls, a certain length of fabric may be consumed in the overlapping area in order to protect the crucial pattern panels. This overlapping length of fabric will eventually be wasted and thus regarded as splice loss.

2.1.3 Other Indirect Losses

2.1.3.1 *Loss due to marker planning*

The job of marker planning is to determine the most efficient combination of style numbers, sizes, and colours for each marker to obtain the best of equipment and material usage. Loss on marker planning occurs when the most cost saving marker or the higher efficiency marker is not used for cutting. Obviously, the cost for choosing an unsuitable marker is the addition of fabric losses. Although the company is suffering a loss due to the inappropriate marker, it may be forced to do so because of the need for quick response to customer requirements and production pressures

Quick response to the customer is essential in a highly competitive apparel industry. To fulfil the customers priority orders, a marker may be made only subject to the time constraint. The additional loss of material is a common practice if the marker maker has not enough time to generate a good marker.

The sewing room is effectively the customer of the cutting room, and the activities of the sewing room must govern the work of cutting. Although the sewing room's customer can constrain its activities, similar effects can occur for internal reasons. Machine failure and disruptions within the sewing department are causes for modifying the cutting targets, and it may be necessary to create some appropriate new markers. Also, this is a way to create losses owing to the time pressure.

2.1.3.2 Ticket length loss

Woven fabrics and some knitted fabrics are purchased by length. Measurement of piece lengths is undertaken by the fabric supplier who attaches a ticket to each piece indicating the length for which the customer will be invoiced. Generally, gross length is recorded, which is the distance between the ends, and also a net length, which is the distance for which the charge is made. The difference between the two figures arises because the supplier credits the purchaser with an agreed length of fabric for each strung fault[18].

2.1.3.3 Loss at beginning of rolls

The beginning of a roll of fabric is never perfectly straight and square with the selvage. It is necessary to straighten the end of each new roll when laying up. Additionally, it is usual for an indelible identification or trademark to be stamped at the end of every roll, and normally this is also cut off. In several instances, it was found that patterns had been cut out indiscriminately by the clothing manufacturer for such purposes as stock recording and identification. In some cases, it was observed that two patterns had been cut alongside each other at one selvage; making it necessary to waste twice as much fabric as would have been the case had the second pattern also been cut at the end of the roll[11].

2.2 MATERIAL UTILIZATION CONTROL IN CUTTING ROOM

As described, there is no doubt on the importance of fabric in garment production. Any saving on fabric utilization, more or less, could help to improve the profitability of a company in the long run. This is why many production professionals devoted themselves to explore those latent areas for material saving. With the objectives of this project for the topic material utilization, previous researches and projects in this field were closely examined.

Early in 1982, J. Magowan[21], an outerwear manufacturer, did a project for optimizing material utilization in the cutting room. He pointed out that the term material utilization does not mean the minimum amount of cloth required to clothe the human body, it means the most effective use of fabric and trim that goes into a garment.

His study suggested four steps to achieve the aim for material saving. The program starts on fabric receiving. It is recommended that the manufacturer should check 100% on the width, 10% on length, 10% on quality, 10% on flaws and 10% on unstrung of all incoming fabric so that to ensure they get what they ordered.

Having received the fabric according to the purchase order, the next step would be focused on how to make efficient use of the material. The factors involved are end loss, width loss, flaws, remnants and marker fallout. The recommendations are given as below:

a. *End loss*

End cutter should be used to cut the fabric ply at each end of the lay to gain a maximum of 1 cm saving per ply.

b. *Width loss*

For width loss, all the fabric after inspection should be grouped and used in spreading according to their width in such a way that markers can be produced at the optimum width of each batch.

c. *Flaws Management*

Small flaws would probably fall in the marker fallout or it could be undertaken in the machine room, therefore, small flaws are not necessary to cut out during spreading. If major flaws are encountered and have to be cut out, then, the overlapping length in fabric splicing should be kept to minimum by using accurate splice marks which should be made before the spreading process.

d. *Remnant*

Scrap marker should be used to make full use of those small remnants. The garments from this scrap marker may be shaded but are generally salable at full factory cost.

Apart from those recommendations, Magowan also suggested that a proper control procedures should be established to secure the benefits from material utilization program. Thus, a standard must be prepared for cloth consumption. Actual consumption is measured, and compared with the budget standard. In addition, any variance should be traced back to its causes and action taken to prevent a recurrence.

Later, in 1989, the Clothing Industry Productivity Association (CLIPA) and National Productivity Institute carried out a joint project[11, 22-24] for a comprehensive study on the aspects of material utilization in cutting room operation. The study was divided into four parts from data collection, analysis and suggestions, and, ended with the recommended action plans for small, medium and large garment manufacturing companies.

Based on the survey from over one thousand companies, the study adopted the cost benefit analysis on six key control areas in apparel production. The six control areas for the preparation of fabric utilization improvement plan are:

1. Check width of rolls of fabric on receipt.
2. Check length of selected rolls of fabric on receipt.
3. Improve marker utilization and cut order planning.
4. Reduction of end loss.
5. Reduction of width loss.
6. Control of discrepancies.

This study showed that an improvement on fabric inspection equipment and grouping could help to minimize the fabric deliveries variance. Apart from this, some standards, simple estimation techniques and methods were suggested to deal with end losses, width losses and cutting room discrepancies. In addition, some special alternatives were suggested to make full use of all remnants in order to obtain further improvement on material utilization.

And, for marker making, some instances such as pattern engineering, computerized marker making and pre-cut planning were proposed for dealing with low marker utilization. It is natural that the improvement will vary according to different garment products. To sum up, computer-aided marker making can certainly contribute to achieving fabric savings, especially in ladies wear and other fashion wear.

Although there are many key points suggested, only a successful implementation of them can bring benefits to the company. Concerning this aspect, the final part of this study outlined three action plans for implementing the material utilization program for small, medium and large company respectively. By prioritizing, companies of different sizes should put their attention to those areas for improvement according to the extent of contribution. Resources and efforts should be re-allocated for implementation. Finally, revision should be made to monitor the material utilization program and to reveal if there is any possible area for amendment.

Thereafter, in 1990, Norton Eberly[25], carried out a study entitled Additional Material Utilization Benefits Through Synergism. Synergism means as the cooperative action of two agencies such that the total effect is greater than the sum of the parts. In his case, the two agencies being the garment and textile industries.

His study pointed out that fabric quality is a vital factors for achieving a successful material utilization control. With the supply of better quality fabric, new opportunities for better material utilization have become available. Three cases have been studied from various manufacturers of basic pants and shirts.

In this study, the importance of three factors on fabric have been identified. They are roll length, fabric quality and fabric carrying cost as described below:

a. *Roll length*

The longer roll length the fewer would be the frequent stop/load/restart occurrences. Findings on this factor were illustrated in two charts to show the relationship between the cost per yard and roll length. The relationship between cost per yard to yards per cuttable shade was also shown.

b. *Fabric quality*

This takes into consideration of the number of flaws which appear in a fabric piece. The findings were plotted to show the cost per yard with respect to various flaw management practices.

c. *Fabric carrying cost*

For fabric storage, this study estimates the carrying cost of one week's inventory versus raw material cost. Theoretically, shorter lead time can reduce the risk of fabric obsolescence.

Taking altogether the above factors, three scenarios, which were worst, typical and ideal had been used to show the fabric cost per yard in each case. Ideally, longer roll length, continuous piece length and more yards per cuttable shade will bring higher benefits. With the cooperation between apparel and textile industries, additional benefits will be brought by supplying better quality fabric pieces. The results showed that there should be 1.5% to 7% savings in raw material cost by improving the worst case to typical case, or, from typical case to ideal case.

2.3 SUMMARY

An intensive examination and review on previous literature gives many important implications for this study. Over these years, many apparel manufacturers have become aware of the importance of material utilization in apparel production. This stimulated many studies[1, 10, 26-35] to explore the significance of material usage as well as the cost benefit analysis[11, 22-24] of material utilization. The outcome of most of these studies provide only the suggestions and recommendations on the procedures, methods, or techniques in the cutting operations for material saving. For instance, suggestions for the use of end cutter were advised in some studies[22, 10, 21] in order to reduce end waste. Undeniable, practical guidelines are vital for front-end operations as it involves the actual material consumption. Such suggestions and guidelines would help management to set standards for controlling the cutting performance.

To achieve good control of material utilization, management needs to have some tools for predicting the material wastage before production so that a proper material control plan can be established for minimizing the material loss. Some theoretical works have attempted to predict fabric loss in the cutting and spreading processes; which will be discussed in the next chapter.

CHAPTER 3 : THEORETICAL ASPECTS

3.1 INTRODUCTION

Besides the previous studies on material utilization as described in Chapter 2, some researchers attempted the development of theoretical models for the prediction of fabric loss during spreading. The purpose of theoretical models is to help cutting-room management to forecast the performance of a particular cutting lay, and thus pre-cut planning can be formed to reduce or even to eliminate any unnecessary material wastage. Furthermore, mathematical calculation and prediction on fabric loss during spreading can provide an understanding of material utilization when different combinations of fabric pieces or marker are used. Hence, decisions can be made to select the most effective pre-cut planning. The two typical models are the Milokhina's regression model[36] and the Ng's theoretical model[37, 38].

3.2 THE REGRESSION MODEL FOR CALCULATION OF FABRIC LOSS

In 1986, Milokhina, Burlakin and Skututa[36] used a regression model to compute fabric loss along the spread. This study suggested that the amount of fabric loss is generally affected by seven factors (level of mechanization, additional works, qualification and experience of worker, length of spread, elongation of fabric, tangential resistance and linear density). According to this work, all of the factors mentioned are of the same importance in the calculation of fabric loss of a cutting lay.

To formulate a regression model for this concern, Milokhina et. al. claimed that there is a need for a large amount of data for the regression analysis. In fact, it was impractical or even impossible to hold an active experiment to collect such a huge amount of data from a production environment for study purposes. To cope with this constraint, a statistical model was used for formulation of the model. The development of their regression model focused only on the fabric properties such as fabric elongation, fabric tangential resistance and fabric linear density, and, the length of marker. A computer system (EC–1050) was employed to simulate the real production environment in order to generate the required data for the regression analysis.

By regression, an equation was derived for the calculation of fabric loss of a cutting lay as follows:

$$Y = 0.7400X_1 + 0.10976X_2 - 0.6080X_3 - 0.1096X_4 + 157.981$$

Where:

Y is total fabric loss

X_1 is length of the spread

X_2 is the elongation of fabric

X_3 is the tangential resistance

X_4 is the fabric's linear density

In examination of the derived equation, a conspicuous discrepancy was found between its outcome and the real value of fabric loss. Milokhina et. al. believed that such discrepancy may probably due to the exclusion of other important factors known as level of mechanization, additional works, and qualification and experience of workers. However, insufficient information and quantifying technique on these factors were the major difficulties to incorporate them into the model. In order to increase the precision of their model, Milokhina et. al. suggested that all these factors should be included in the model.

3.3 A THEORETICAL MODEL ON FABRIC LOSS DURING SPREADING

In 1996, a linear equation was derived mathematically by Ng et. al.[37, 38] to portray the whole spreading process for the prediction of total fabric loss in the spreading process. In this theoretical model, the spreading process is broken down into different components. Each component is represented by a specific notation as illustrated below:

m	Marker length
w	Marker width
n	No. of splicing interval
i	No. of fabric roll ranges from 1 to a positive integer
j	No. of splicing interval ranges from 1 to a positive integer
S_n	Length of the n^{th} splicing interval
T_j	Length of marker from left to right end of the j^{th} splicing interval
T_j'	Length of marker from right to left end of the j^{th} splicing interval
L_i	Length of the i^{th} fabric roll
W	Width of fabric roll
h	Length of overlap during spreading
p_i	No. of complete plies laid by the i^{th} fabric roll
R_i	Length of remnant laid by the i^{th} fabric roll
V_i	Distance from the end of the marker to the cut edge laid by the i^{th} fabric roll

x_i Cut off length of the i^{th} fabric roll

g Length of allowance made for the fabric in turn between one ply and the next ply

N_i Total no. of turns from the 1^{st} fabric roll to the i^{th} fabric roll

λ_k Proportion of the fabric loss in the k^{th} splicing interval

B_i Total length of "Internal" loss from the 1^{st} fabric roll to the i^{th} fabric roll

A_i Area of fabric loss in the i^{th} roll

A_w Total area of fabric loss for all fabric rolls

a_t Proportion of fabric loss for all fabric roll

P Number of rolls

L_t Total length of fabric rolls being laid

The following explains the mathematical model for calculating fabric loss during spreading. Suppose a marker is drafted with a length *m* and width *w*, and, *m* is separated into *n* splice intervals from S_1 to S_n by the splice lines as stated in figure 3.1. The notation T_j is used to describe the partial sum of the length of splice intervals S_1 to S_j from left to right.

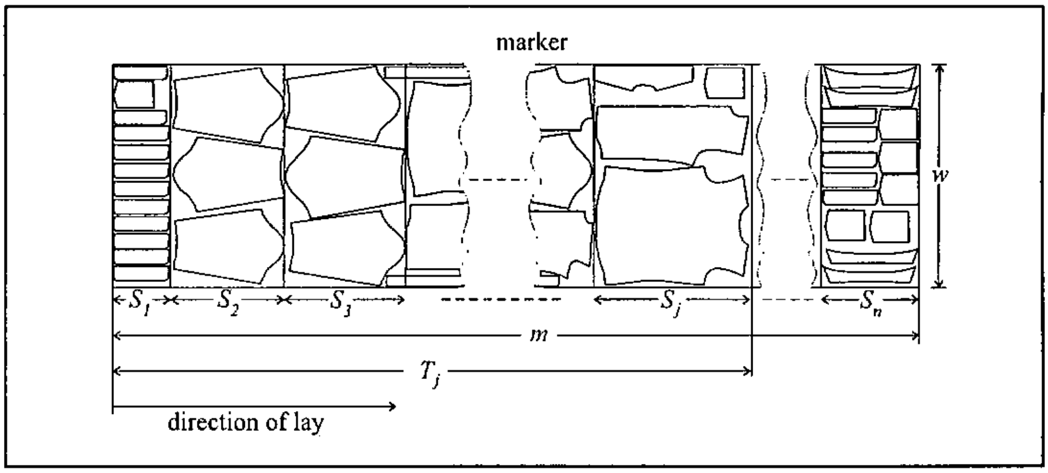


Figure 3.1 A theoretical analysis of marker (when fabric laid from left to right)

Conversely, figure 3.2 used the same marker as shown in figure 3.1, but, the fabric is laying in the direction from right to left. Therefore, *m* is equal to the sum of S'_1 *to* $S'_{n'}$ and T'_j is the partial sum of splice interval S'_1 *to* S'_j from right to left.

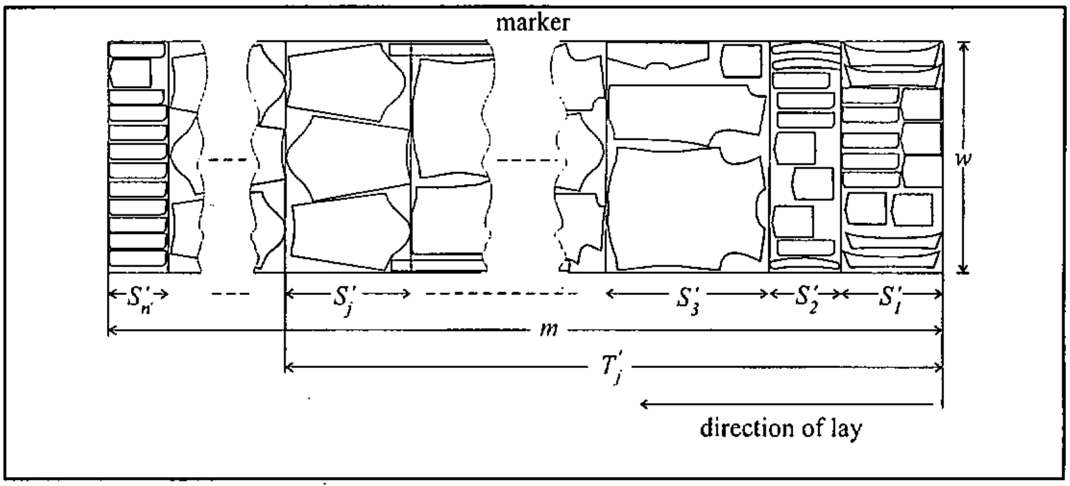


Figure 3.2 A theoretical analysis of marker (when fabric laid from left to right)

In this mathematical model, fabric loss due to spreading generally derived from two sources: "Internal" and "External" waste.

The "External" waste is referring to the fabric loss due to laying up fabrics. In figure 3.3, the i^{th} fabric roll, of length L_i and width $W(\geq w)$ has been laid down. This roll starts at the end of one of the splicing intervals V_{i-1} with an allowance h which is used for fabric alignment since it is difficult to align the roll exactly to the splice line. Being laid the first ply (possibly incomplete), the i^{th} roll can spread for a certain number of complete plies p_i and leave a remnant length equal to R_i. To continue spreading, R_i will be spliced according to the splice position, which depends on where R_i is lying within $(j+1)^{th}$ splicing interval. The length between the neighbouring splice line to end of the remnant is x_i, which cannot be used (termed splice loss).

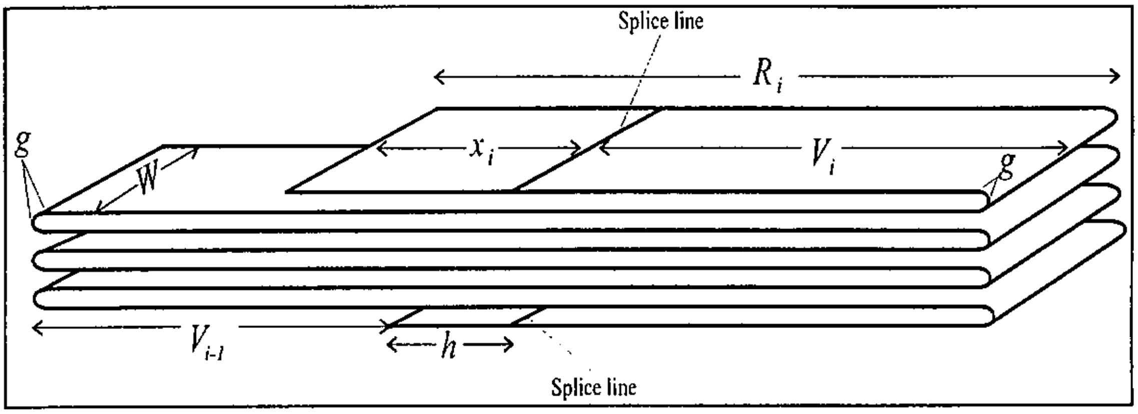


Figure 3.3 A theoretical analysis of "External" waste

For remnant laid from left to right, it results:

$$T_j \le R_i \le T_{j+1} \tag{1(a)}$$

And, if it is laid from right to left, then:

$$T'_j \le R_i \le T'_{j+1} \tag{1(b)}$$

Whether the i^{th} remnant is being laid from left to right or from right to left depends on the total number of turns that have been made in laying up the i^{th} roll. Assuming, without loss of generality, that the start of the first roll is at the left and assume V_{i-1} is not equal to zero, the total number of turns is:

$$N_i = \sum_{k=1}^{i} (1 + p_k) \tag{2}$$

and if this is an even number the i^{th} remnant is being laid from left to right; if it is an odd number it is being laid from right to left. Let $J=j(i)$ be the value of j for which the appropriate condition, 1(a) or 1(b), is satisfied. Then:

$$\left.\begin{aligned} R_i &= T_{j(i)} \text{ if } N_i \text{ is even} \\ &= T'_{j(i)} \text{ if } N_i \text{ is odd} \end{aligned}\right\} \quad (3)$$

As illustrated in figure 3.3, in computing the "External" waste of the i^{th} fabric roll, a strip of length L_i with width equal to $(W\text{-}w)$ will be removed as width loss. Besides, the extra allowance g represents the turns at ends of the cutting lay. The area of each turn is equal to the length of g multiply w, and, totally there are $(1+p_i)gw$ of them. This is known as the end loss in spreading. Another waste is the length of allowance h, which area equals to hw. Finally, the area of splice loss of length x_i and width w is wasted and termed as splice loss. Gathering all these wastages together, the area of "external" waste of the i^{th} fabric roll is:

$$L_i(W - w) + (1+p_i)gw + hw + x_iw \quad (4)$$

The "Internal" waste refers to the wastage arises within each splice interval. During the marker making process, it is inevitable for gaps and other fallout areas to exist between garment panels. This is known as marking loss. If a marker is divided into a certain number of splicing intervals, then, "Internal" waste is referred to the fallout area of each interval. Let λ_k be the proportion of waste fabric in the k^{th} interval. The internal waste in the first ply of the i^{th} roll is equal to that in the intervals $J_{(i-1)}+1$ *to* n, i.e.

$$\sum_{k=J_{(i-1)}+1}^{n} \lambda_k S_k w \qquad (5)$$

Similarly, the "internal" waste in the final ply is equal to that in the first $J_{(i)}$ intervals, or

$$\sum_{k=1}^{J(i)} \lambda_k S_k w \qquad (6)$$

Finally, the waste in each of the p_i complete plies is:

$$\sum_{k=1}^{n} \lambda_k S_k w \qquad (7)$$

Hence the total area of internal waste is:

$$w\left\{ \sum_{k=J_{(i-1)}+1}^{n} \lambda_k S_k + p_i \sum_{k=1}^{n} \lambda_k S_k + \sum_{k=1}^{J_{(i)}} \lambda_k S_k \right\} = wB_i, \text{ say} \qquad (8)$$

The final expression for the area of waste in the i^{th} roll is therefore:

$$A_i = L_i (W-w) + (1+p_i)gw + hw + x_i w + B_i w \qquad (9)$$

If there are P rolls altogether, the total waste area over all pieces is:

$$A_w = \sum_{i=1}^{P} A_i$$

$$= (W - w)\sum_{i=1}^{P} L_i + gw\sum_{i=1}^{P}(1 + p_i) + Phw + w\sum_{i=1}^{P} x_i + w\sum_{i=1}^{P} B_i \quad (10)$$

As the total area of fabric is $A=WL_t$, the final expression for proportion of waste area over all rolls is:

$$a_t = \frac{A_w}{A} = 1 - \frac{w}{WL_t}\left\{m\sum_{i=1}^{P}(1 + p_i) + V_P - \sum_{i=1}^{P} B_i\right\} \quad (11)$$

3.4 INADEQUACY OF THE EXISTING THEORETICAL MODELS

In revision of the theoretical model of Ng et. al.[37, 38] and the regression model of Milokhina et. al.[36], they were with the similar objective to obtain a prediction of total fabric loss in the spread (or termed the cutting lay). However, some inadequacies were found in their models. There were no validation and verification work provided for either models. For this reason, the accuracy and reliability in calculating and predicting fabric loss using either model is doubtful.

3.4.1 The Regression Model

The regression model of Milokhina et. al.[36] is considered to have too much emphasis on the effect of fabric properties like fabric elongation, linear density and tangential resistance. Fabric properties may be one of the factors in affecting total fabric loss during spreading. However, they may not be the major factors and their effects on total fabric loss in spreading may be trivial. Therefore, estimation of total fabric loss in spreading relies mainly on fabric properties regarded as unquantifiable.

Moreover, the model cannot treat the infeasible solution, for example, if all input variables are set to zero, the total fabric loss predicted by the model is still in a positive value (157.981), thus the reliability of the model is ambiguous.

Indeed, some important factors for prediction of fabric loss during spreading are missing in the model except one component - marker length. The factors such as end loss, width loss, splice loss, fabric roll length and marker width were all beyond the consideration in their model. In fact, it has been widely recognized that these factors are the key concerns for fabric loss during spreading. By neglecting these factors and without any real data support their exclusion in the model, it is believed that a significant value of discrepancy will inevitably be present in the model.

3.4.2 *The Ng's Theoretical Model*

The Ng's theoretical model of predicting fabric loss during spreading is estimated merely by theoretical calculation. It may not be able to reflect the exact amount of material wastage in production environment. It is inevitable that deviations exist between the theoretical calculation and real production performance. The deviations may be caused by many uncontrollable factors, for examples, type of fabric and spreader's handling skill in spreading. Before the estimation and prediction of material utilization, it is vital to have a clear understanding of the level of accuracy of the theoretical calculation. Inaccurate material prediction will lead to a poor pre-cutting planning that will subsequently increase the fabric loss in cutting and spreading processes.

This is not saying that the theoretical model developed by Ng et. al.[37, 38] is not applicable to real situations. It becomes necessary to carry out a verification and validation of the model before using it for industrial purposes.

Their model has used an experimental case to demonstrate how it could help to determine the fabric wastage during spreading. But many assumptions defined by the model are considered not applicable to the real production environment. Such discrepancies are addressed as below:

a. *Fabric flaws*

In the mathematical model, it is assumed that there are no fabric flaws and all fabric pieces are in prefect condition. In fact, fabric pieces without flaws is nearly impossible in real situations. The methods in handling and dealing with fabric flaws may influence the outcome of total fabric waste.

b. *Irregular end loss and width loss for each fabric ply*

In spreading, due to the limpness and extensibility of fabric's physical properties, end loss and width loss at each ply may differ according to the extent of stress and tension at each ply. This is also an important factor to be validated as the model assuming that the measurements of end loss and width loss at each ply are exactly the same.

c. *Type of garment*

The pattern's layout, spreading method and material used may vary according to different kinds of garment. Such differences may affect the final outcome of material wastage. Since the theoretical model was designed generically, therefore, it is important and necessary to verify on the model's compatibility for various garment types and materials.

d. Human factors

Human error is also a factor which could alter the amount of fabric waste. Spreaders with different skills and experiences may affect their performance in spreading. Therefore, given the same spreading condition, the outcome of material wastage may vary due to different spreaders' own performance. This is also a factor which should be examined to divulge it's effect on the model's accuracy.

The neglect of the above factors in the theoretical model may cause a certain extent of discrepancy in estimating the amount of fabric loss. Therefore, the actual cutting performance cannot be fully reflected or the result may be misleading.

3.5 DISCUSSION

In the present day, cutting room management should have more concern on cutting performance and lay planning in order to minimize the fabric loss in apparel production. In order to achieve better control over lay planning in the cutting room, two theoretical models have been developed for predicting fabric loss in a systematic manner. If the theoretical calculation can provide an understanding of material utilization of a cutting lay under different spreading conditions (for examples, different marker length, different number of fabric rolls or different number of fabric plies in the cutting lay), the cutting room management would be able to select the most effective cutting plan, and thus the fabric loss could be minimized.

The existing theoretical models[36-38] have already attempted to consider various factors that may affect the fabric loss in the spreading process. For this study, an efficient and effective way to develop an appropriate method for predicting the fabric loss during spreading was to select one of the existing theoretical models as the backbone for development. Among two existing models, the Ng's theoretical model covers all the "internal" and "external" fabric wastage of a cutting lay. It provides a means to merge the actual and theoretical phenomenon together so that the amount of total fabric wastage of a cutting lay during spreading can be estimated in a systematic manner.

In order to improve the accuracy in prediction of fabric loss in spreading, the design of the experimental study was to examine the existence of prediction error in the Ng's theoretical model with industrial data. If the prediction error exists, it is necessary to evaluate the major determinants in affecting the prediction error so that an appropriate method can be developed for the precise prediction of fabric loss. The field study was essential for the development of a precise method in the prediction of fabric loss. Details of the field study are described in Chapter 4.

CHAPTER 4 : FIELD STUDY

4.1 INTRODUCTION

As explained in the previous chapter, the Ng's theoretical model was selected as a backbone for the design of this field study. Before building an appropriate method for the prediction of total fabric loss in spreading, various types of fabric wastage caused by the spreading process in apparel production should be identified and quantified by reference to the real production environment. For capturing the required data from the real production environment, a method was firstly designed to measure various types of fabric loss (e.g. end loss, width loss, remnant, splice loss etc.,) that occur in the spreading process.

4.2 THE FIELD STUDY

4.2.1 *Factory Selection*

In order to ensure that the measurements taken are representable, the factory selected for data collection should fulfill some pre-defined requirements as following:

(i) Style Change

In marker making, garment style has a great impact in affecting the marker efficiency, length and splice line position. An ever changing garment style in the study would cause great variation to the measurement outcomes. To simplify the study, it is better to minimize the change of garment style.

(ii) Production Capacity

The production capacity of the selected factory should be large enough (at least 1500 meters of fabric for each selected cutting lay). Such amount of fabric consumption normally involves 10 to 15 fabric rolls, and thus possible to reveal clearly on each type of fabric loss in the cutting lay during spreading. If the fabric yardage for each cutting lay is too small, some parameters such as remnant or splice loss may be missed.

(iii) *Equipment and Management*

The cutting room itself should be well established in terms of its equipment and management. It is a common practice that a cutting room may contain more than one cutting table in a medium or large size garment manufacturing company. In order to keep a consistent spreading quality among all cutting tables, it is necessary to choose a well managed cutting room that is equipped with the same kind of spreading machine as well as a set of comprehensive instructions for the spreaders to follow. Hence, the influence on total fabric loss resulting from machinery and human error due to unclear instruction can be minimized.

(iv) *Skill of spreader*

The skill of the spreader plays an important role in affecting the amount of fabric loss. The spreaders should be well trained so that the spreading skills among them are similar, thus, the effect on human error can be kept consistent at all sample cutting lays.

Based on the consideration of the above requirements, a leading men's shirt manufacturing factory in Hong Kong was chosen. This is because men's shirt is a kind of basic staple garment that experiences only little change in styling. The same style of men's shirt made of the same fabric and color could be stocked year around due to the low demand for fashion change and seasonal influence.

Here is a description of the factory. In the factory, there are six cutting tables in the cutting room at the highest floor. Each cutting table is managed by an experienced spreader. Every spreader has a minimum of five years working experience in fabric spreading. Generally speaking, the spreading skill among the spreaders is similar, or in other words, it has no significant difference of their handling skill in fabric spreading.

Although the spreaders skill level is highly consistent in the factory, it is believed that a random sampling method can further reduce the deviation caused by human skill among samples, therefore, the data were measured on a random basis. For sample selection, data collection work could not be carried out on one particular cutting table even all cutting orders for such table were qualified for measurement, thus, the cutting lays on the six cutting tables were measured sequentially.

4.2.2 *Types of Data Collected*

For each sample cutting lay, a set of data and information were recorded based on three categories: *General Information*, *Marker Information* and *Actual Measurements* as stated in table 4.1.

Table 4.1 Types of information collected from the sample cutting lay

General Information	Marker Information	Actual Measurements
1. Spreader & cutting lay number.	1. Number of garments in marker	1. Total number of fabric rolls used in spreading
2. Order number	2. Marker width	2. Length of each fabric roll in cutting lay
3. Total number of garments to be cut	3. Marker length	3. Number of complete plies laid by each fabric roll
4. Spreading method (one way or two way)	4. Marker efficiency	4. Length of splice loss and allowance at every splice position
5. Fabric type and color	5. Splice line position	5. Length of end loss
-	-	6. Length of width loss
-	-	7. Length of remnant of each fabric roll used

The *general information* was recorded for each sample cutting lay with reference to the purchase order. This included fabric type, spreading method, and the total number of garment to be cut for each order. In facilitating and referencing cutting lay identification, the particulars of the cutting order were provided in the above *general information.*

The *Marker Information* is vital for fabric loss calculation. Such information included the number of garments and their sizes in the marker. All these are the key factors for the determination of marker length and marker efficiency. Marker efficiency can indicate the amount of fabric loss incurred within the marker and thus the amount of fabric required by the marker can be estimated. The number and position of splice lines were used as a reference to determine the amount of splice loss and splice allowance of each sample cutting lay (see figure 4.1 for the graphical illustration of splice loss and allowance measurement).

The *Actual measurements* were the main concern of this study. For determining the total fabric loss during spreading, it is necessary to obtain and quantify all kinds of fabric loss involved in the spreading process. Thus, the total amount of fabric loss during spreading of each sample cutting lay was obtained for further analysis.

4.2.3 Measurement of Fabric Loss During Spreading

Figure 4.1 illustrates all kinds of fabric loss incurred during spreading. The procedures for measuring the various kinds of fabric loss for the field study are described briefly as follows:

a. Splice loss, splice allowance and remnant measurements

Here is an explanation of the spreading process in the factory as well as the ways for taking splice loss, splice allowance and remnant measurements. When the spreading process begins, fabric rolls will be loaded onto the spreading machine and spreading is started at one extreme end of the cutting table. Then, the spreading process continues by superimposing the fabric plies onto the previous one. The number of fabric plies which can completely cover the whole marker length (named as complete ply or plies) in each fabric roll was recorded. Due to the limited length of each fabric roll, after spreading for a number of complete plies, the fabric will be used up and leaves a remnant somewhere along the marker length. To continue spreading, a new fabric roll must be used. Meanwhile, fabric splicing will take place between the ends of the original fabric roll and the new fabric roll at the nearest splice line's position. During splicing, the length of remnant, splice loss and splice allowance were measured by means of a measuring tape. This measuring work will persist until the end of the spreading process. Upon the completion of spreading, the remaining length of fabric (known as remnant) left by the last fabric roll was measured.

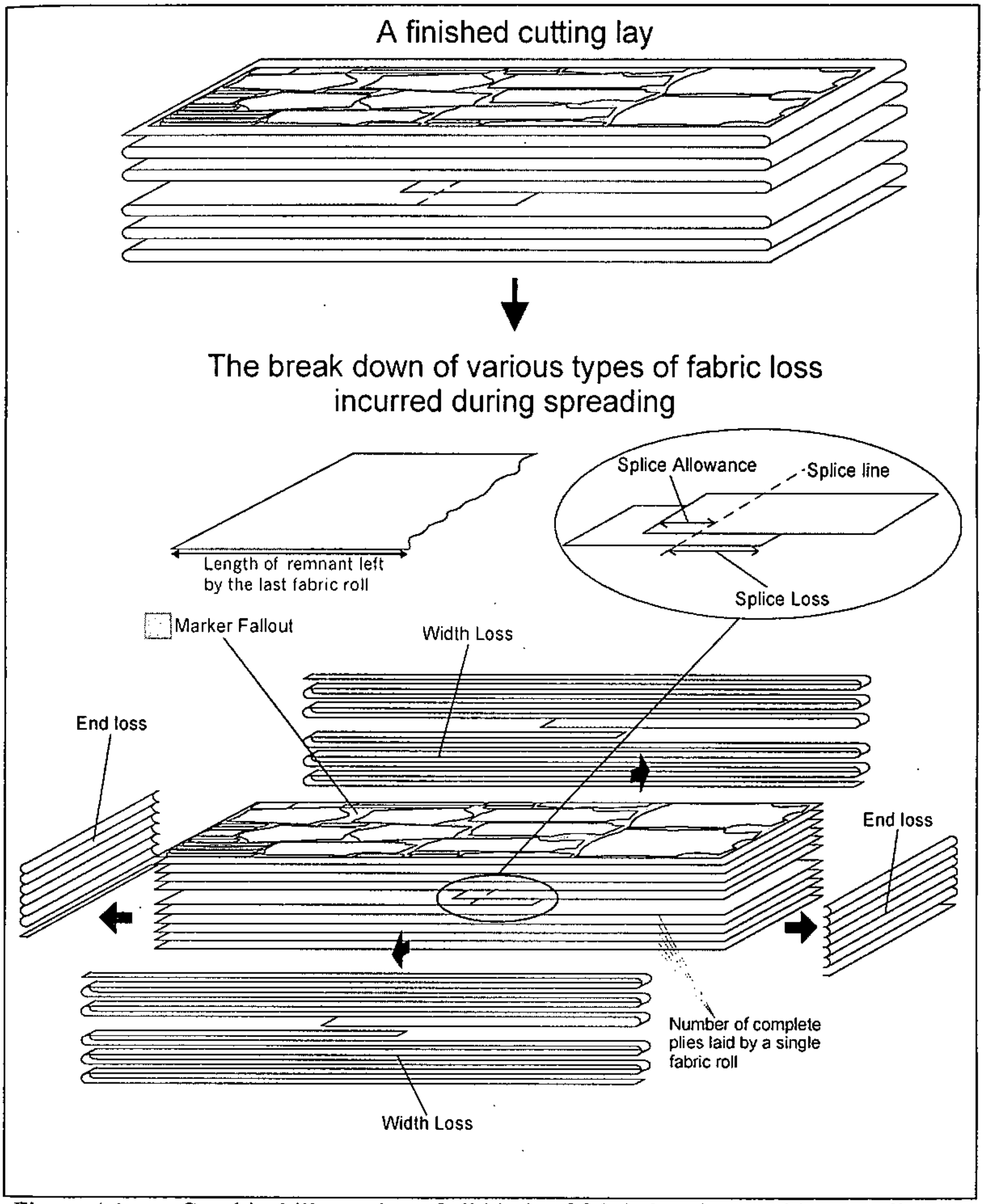


Figure 4.1 Graphical illustration of all kinds of fabric loss incurred in spreading

b. End loss and width loss measurements

The lengths of end loss and width loss are two elements which were measured at completion of the spreading process. Due to the limpness and extensibility of the fabric's physical properties, the length of end loss and width loss are difficult to measure accurately at each fabric ply. Besides, if these two types of loss have to be measured during the spreading process, it will cause an immense interference to the spreading process, in the extreme, the process has to be halted for taking each measurement. Such interference is not allowed by the manufacturing company in this study. To cope with this constraint, a hybrid method which incorporates the measurement of fabric weight and length was adopted. Therefore, end loss and width loss can be worked out by a simple computation based on the measurement of their weight and length.

Measurement of end loss

End loss occurs when the spreader reaches the end of the marker and the fabric must be cut from the roll or folded back for the return lap. In practice, the operator in the cutting room does not remove the end loss individually from the cutting lay, therefore it is difficult to distinguish the fabric loss at the two ends of the marker from marking loss to end loss. For this study, the total end loss was calculated from a small portion by simple proportion. For taking this measurement, a small portion of end loss (in width 10cm) was cut from the two ends of the cutting lay as illustrated in figure 4.2 and described as below.

The procedures for measuring the end loss are illustrated as below:

1. A piece of fabric (10cm X 10cm) was cut from the cutting lay.

2. Using an electronic balance, the weight of cut fabric in grams *g* was measured under standard atmospheric conditions.

3. A portion of fabric of 10cm width was cut from each end of the cutting lay and weighed to obtain its weight in grams *k* as illustrated in figure 4.2.

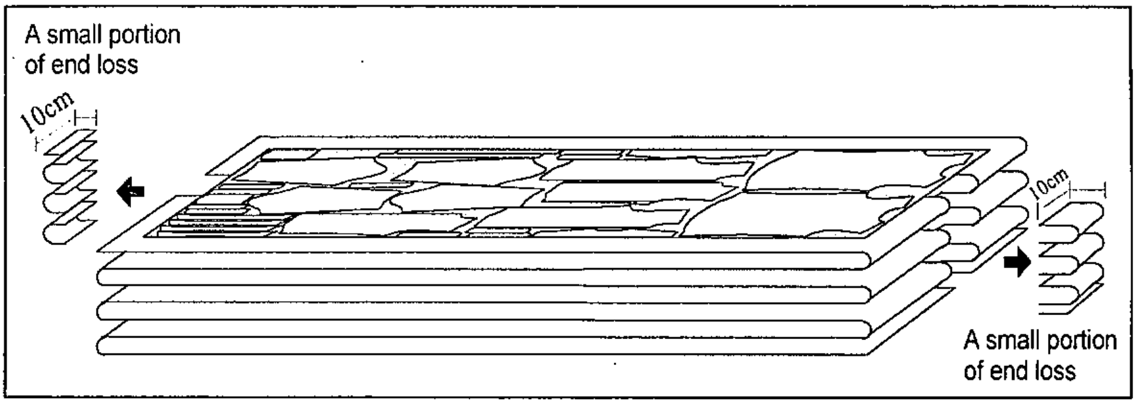


Figure 4.2 The measurement of end loss

4. Measured the width of marker *w*.

5. After the above measurements had been taken, the total area of end loss was worked out as follows:

Let g - be the weight of the small piece of fabric (10cm x 10cm) in grams that cut from the lay and g occupies an area of 100 cm^2 fabric;

k - be the weight of the small portion of fabric (with a 10cm width), cut from two extreme ends of the lay, in grams;

w - be the measurement of marker width.

In computation:

A gram of material occupies an area of $100/g$ cm^2 and 1 cm end loss weighs $k/10$ gram, thus, the area of end loss with w cm of marker width is

$$\frac{100}{g}(\text{cm}^2/\text{gram}) \bullet \frac{k}{10}(\text{gram/cm}) \bullet w(\text{cm}) = \frac{10wk}{g}(\text{cm}^2).$$

Measurement of width loss

The width of marker has to be drafted narrower than the actual width of the fabric, width loss is the amount of fabric wastage which lies between the selvedge edges of the fabric roll and the edges of the marker.

Similar to the measuring method for end loss as mentioned in the previous section, the measurement of width loss was carried out after the completion of spreading. Again, only a small portion of width loss (in width of 10cm) was taken from the cutting lay. The procedures for measuring width loss are as following:

1. A piece of fabric (10cm X 10cm) was cut from the cutting lay.
2. Using an electronic balance, the weight of cut fabric in grams g was measured under standard atmospheric conditions.
3. A portion of fabric of 10cm width was cut from each edge of the cutting lay and weighed to obtain its weight in grams k as illustrated in figure 4.3.
4. Measured the total length of fabric used l in the cutting lay.
5. After the above measurements had been taken, the total area of width loss was worked out as follows:

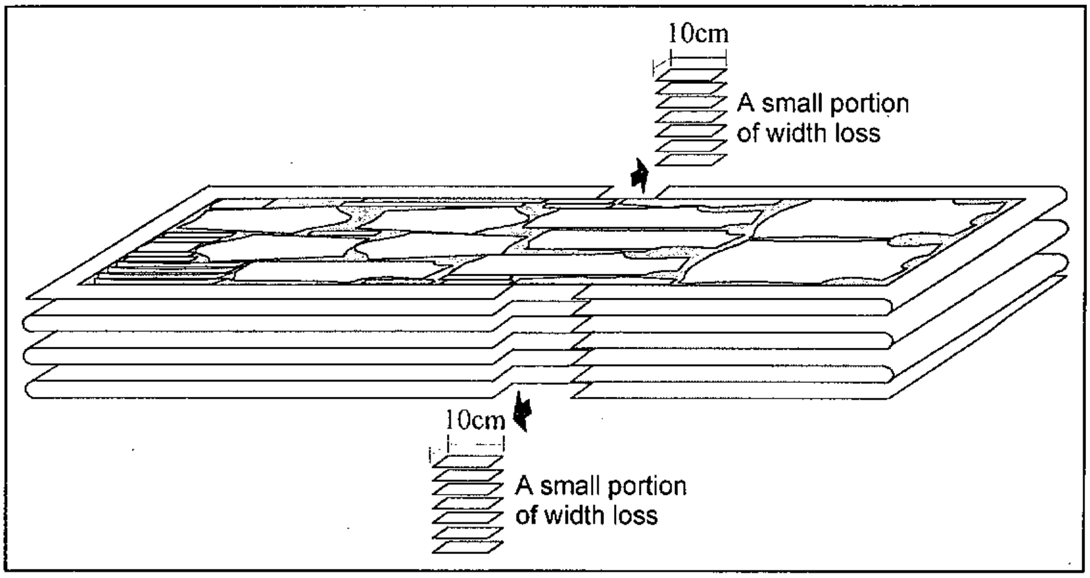


Figure 4.3 The measurement of width loss

Let g - be the weight of the small piece of fabric (10cm x 10cm) cut from the lay and g occupies an area of 100 cm^2 fabric;

k - be the weight of the small portion of fabric (with a 10cm width) cut from two edges of the lay;

l - be the total length of fabric in the cutting lay

In computation:

A gram of material occupies an area of $100/g$ cm^2 and 1 cm width loss weighs $k/10$ gram, thus, the area of width loss with the total length of fabric l is $\frac{100}{g}\left(\text{cm}^2/\text{gram}\right)\bullet\frac{k}{10}\left(\text{gram/cm}\right)\bullet l(\text{cm})=\frac{10lk}{g}(\text{cm}^2)$.

c. Marker loss measurement

Marker loss describes the proportion of fabric layout which has been wasted when all pattern blocks are placed into the marking area of each cutting lay. This is another essential measurement in data collection. As the percentage of marker utilization could be provided by the computerized marker making system which is used by the factory, so that, the marker efficiency of each selected cutting lay was obtained from the record of that marker making system.

4.3 DATA ANALYSIS

The theoretical model developed by Ng et. al.[37, 38] can be served as a basic framework and reference for data analysis. Although Ng's theoretical model had been built by concerning many kinds of fabric loss during spreading, it is believed that there are still some factors neglected by that model and such negligence will eventually cause a certain extent of error in predicting and calculating the total fabric loss. In order to evaluate the degree of accuracy of prediction by that selected theoretical model, the differences between the theoretical calculation and actual measurements taken from the field study were determined by means of comparative approach.

By the field study, actual measurements of total fabric loss that belong to 30 sample cutting lays were taken. For comparison, the actual amount of total fabric loss during spreading was expressed in percentage. The collected data on total fabric loss during spreading was firstly compared with the theoretical calculation (refer to equation (11) in Chapter 2). The input variables of each sample cutting lay for theoretical computation are listed in Table 4.2.

Table 4.2 The actual measurements of all input variables used for theoretical calculation

Sample	Marker width (*w*) in meter	Total area of fabric used in spreading (*WLt*) in Sqm.	Marker length (*m*) in meter	No. of complete fabric plies in cutting lay	Length of remnant (V_p) in meter	Total area of marker loss of all fabric plies (*wBj*) in Sqm.
1	1.467	1864.403	19.978	60	28.5	198.9
2	1.455	1847.247	20.205	61	0	244.793
3	1.124	2065.389	23.013	78	14.813	171.054
4	1.48	2373.12	20.977	73	15.877	193.085
5	1.118	2121.479	34.868	52	11.27	210.184
6	1.118	1418.535	23.853	51	7.132	185.844
7	1.118	1858.701	23.269	68	18.4	169.66
8	1.473	1889.008	25.872	48	0	164.832
9	1.118	2184.459	29.573	60	92	207.78
10	1.124	1861.822	30.25	50	86	143.85
11	1.118	1687.412	28.417	49	56.1	155.036
12	1.118	1530.673	33.174	39	18.474	154.011
13	1.422	2632.818	26.516	64	67.448	295.168
14	1.422	2184.05	23.186	64	0	250.816
15	1.422	2427.48	22.616	73	4.066	249.806
16	1.422	1580.252	16.863	63	6.563	173.124
17	1.441	2485.232	16.628	100	0.828	274.4
18	1.118	2221.538	28.505	67	12.8	203.412
19	1.48	3416.652	25.094	89	3.994	329.834
20	1.48	3437.706	25.094	89	16.494	329.834
21	1.48	2616.663	25.094	66	73	244.596
22	1.486	2152.939	25.669	55	2.919	194.7
23	1.102	1529.583	16.91	78	19.5	144.924
24	1.134	1727.558	11.793	119	89	158.627
25	1.467	2018.74	19.978	65	36.3	215.475
26	1.118	1806.591	34.868	44	10.568	177.848
27	1.118	1340.566	14.469	79	4.769	116.288
28	1.473	2191.799	25.872	51	126	175.134
29	1.118	1476.67	33.174	38	8.05	150.062
30	1.486	2193.953	25.669	56	0	198.24

Based on the data as shown in table 4.2, the total fabric loss during spreading was worked out by theoretical calculation. The results of the comparison between the actual total fabric loss and the theoretical calculation are tabulated in table 4.3. The detail breakdowns of total fabric loss in each sample cutting lay are shown in Appendix A.

Table 4.3 Comparison results of total fabric loss between actual measurements and theoretical calculations

Sample	Percentage of total fabric loss from actual measurement in factory (A)	Percentage of total fabric loss obtained by theoretical calculation (B)	Error (A) - (B)
1	14.38%	14.11%	0.27%
2	16.17%	16.17%	0.00%
3	9.87%	9.79%	0.08%
4	11.74%	11.65%	0.09%
5	13.83%	13.76%	0.07%
6	16.74%	16.66%	0.08%
7	12.96%	12.85%	0.11%
8	11.89%	11.89%	0.00%
9	14.51%	13.99%	0.52%
10	11.74%	11.22%	0.52%
11	13.62%	13.21%	0.41%
12	14.37%	14.21%	0.16%
13	16.39%	15.91%	0.48%
14	14.87%	14.87%	0.00%
15	13.37%	13.34%	0.03%
16	14.84%	14.77%	0.07%
17	14.59%	14.58%	0.01%
18	12.46%	12.40%	0.06%
19	12.76%	12.74%	0.02%
20	12.81%	12.73%	0.08%
21	11.99%	11.54%	0.45%
22	11.42%	11.40%	0.02%
23	13.19%	13.04%	0.15%
24	11.84%	11.22%	0.62%
25	13.99%	13.67%	0.32%
26	14.32%	14.25%	0.07%
27	12.99%	12.95%	0.04%
28	11.66%	10.85%	0.81%
29	14.18%	14.11%	0.07%
30	11.67%	11.67%	0.00%

Referring to the result presented in table 4.3, it is demonstrated that a noticeable error actually exists in the theoretical calculation of total fabric loss during spreading ranged from 0 to 0.81%. The results also show that the theoretical calculation usually underestimated the amount of total fabric loss thus providing positive value of deviation at 26 samples as illustrated in table 4.3.

From the comparison results, they implied that there is an error existed in the prediction of total fabric loss by Ng's theoretical model. As discussed in Chapter 2, it reveals that some missing factors in the theoretical model may affect its accuracy for the prediction of total fabric loss during spreading.

Up to this stage, it was suggested that a new component namely ε, which represents as the error, should be added in the equation for the prediction of total fabric loss during spreading. Consequently, the new equation for predicting total fabric loss becomes:

$$a_t = \frac{A_w}{A} + \varepsilon = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) + V_p - \sum_{i=1}^{P}B_i\} + \varepsilon \qquad (12)$$

Based on the data collected from the men's shirt manufacturing company, the error ε is ranged from 0% to 0.81%. It is believed that such error may be caused by human error during the process, the kind of material used and the type of garment. Detail investigation for the cause of such prediction error and the improvement work of the existing equation are presented in next chapter.

4.4 DISCUSSION

In the design of this field study, there arose some difficulties and restrictions for the data collection work in the real production environment. For measuring fabric loss, direct weighing of all residual fabrics after cutting is the most effective way for measuring fabric loss in spreading. Although this method is the most direct way for fabric loss measurement, it is unable to measure each type of fabric loss separately, thus, only the total amount of fabric loss can be obtained. It would become a very tedious task to separate the fabric residues if this method is employed to measure various kinds of fabric loss individually. More importantly, measuring fabric loss by weighting will cause a great interference on the production process, sometimes, the cutting operation has to be stopped due to the measurement of fabric loss. It is impractical to make substantial interference on the factory's operation.

To cope with such constraints, a method was proposed for measuring fabric loss in the real environment with higher efficiency and with less interference to the normal spreading process. This is a hybrid measurement method which incorporates different measures of fabric weight and length and uses the approximation to calculate the end loss and width loss as described in the previous sections.

Using the proposed method for data collection, the measurements were carried out effectively with only trivial interference to the factory's cutting operation. In addition, this method also facilitated the measurement work in some other ways.

Firstly, it has a high efficiency in measuring, therefore, time and human effort can be saved. Normally, a single recorder is enough for taking those measurements. Secondly, it is a good approximation to the measurements obtained by direct weighing. Using the same principle as fabric weighing, direct measurements of fabric weight and length are involved in the measuring work, therefore, the outcomes obtained would be very close to that by weighing alone. Finally, the work on classifying total fabric loss is eliminated since those fabric losses are measured separately.

To sum up, the proposed method for fabric loss measurement could be considered as an cost effective and practical way in measuring various kinds of fabric loss in a real production environment. This method could be adopted in the real production environment with only trivial interference. Also, the method is compatible for measuring fabric loss for other apparel products and factories. Furthermore, in comparison to direct weighing, the proposed method provides dramatic reduction for the cost and effort in measuring fabric loss during spreading.

CHAPTER 5 : PREDICTION IMPROVEMENT

5.1 REGRESSION ANALYSIS

Thereafter the comparison work as presented in the previous chapter, the error ε is necessary to be concerned. If the error could be minimized, it means that the accuracy in the prediction of fabric loss could be improved. In order to understand the relationship of the error ε with all input variables in the theoretical model, regression analysis was used to determine the coefficient of correlation (R Square) between all input variables and the error ε.. Such variables in the theoretical model include marker width, marker length, number of fabric plies in a cutting lay, total area of fabric used in a cutting lay, length of remnant, and the total area of marker loss. By graphical expression, the X-Y plots of each variable with ε were plotted as shown in figure 5.1 to 5.6. The summary of the regression analysis of each variable in terms of coefficient of correlation (R Square) is illustrated in Table 5.1. Details of the regression analysis are shown in Appendix B.

Table 5.1 Summary of the regression analysis

	Factors Studied by Regression Analysis	Value of R Square
Main variables of the theoretical model	Marker width w	0.00771
	Total area of fabric used in cutting lay WL_t	0.000275
	Marker length m	0.000193
	Number of fabric plies in cutting lay p_i	0.000303
	Length of remnant V_p	0.9772
	Total area of marker loss wB_i	0.0222

Figure 5.1 X-Y Plot of Error (ε) Percentage Against Marker Width(w)

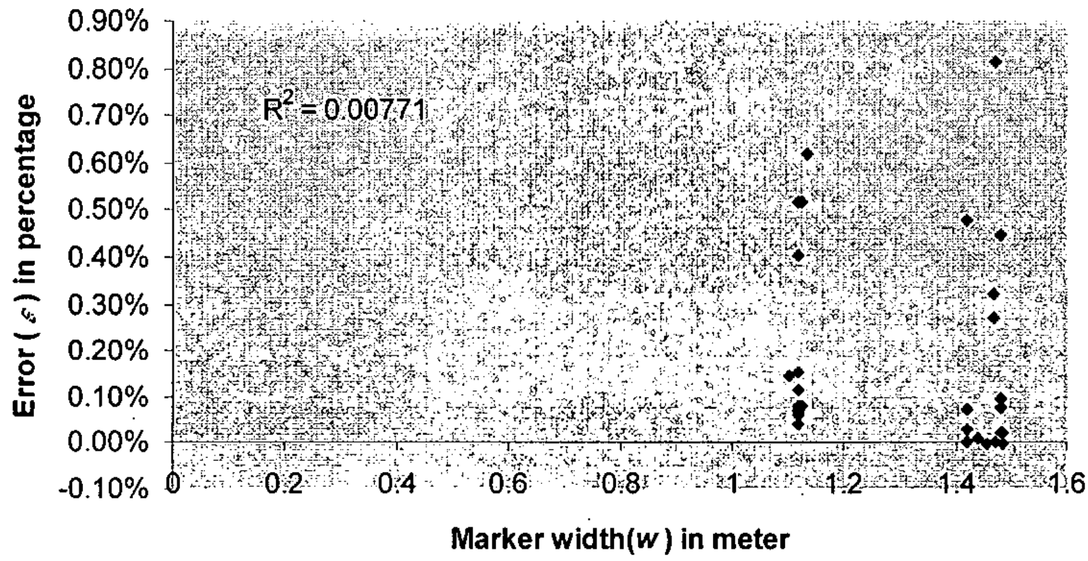


Figure 5.2 X-Y Plot of Error (ε) Percentage Against Total Area of Fabric Used in Cutting Lay(WL_t)

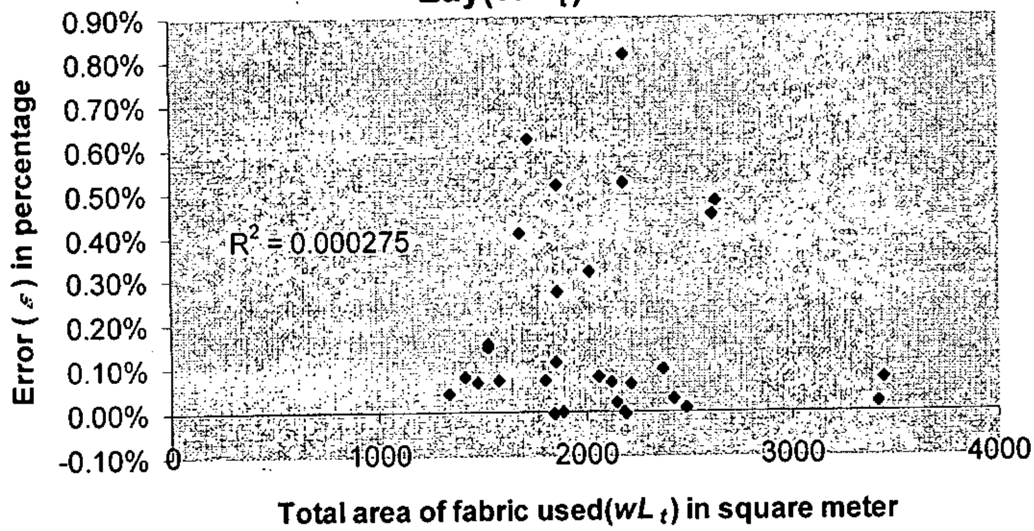


Figure 5.3 X-Y Plot of Error (ε) Percentage Against Marker Length(m)

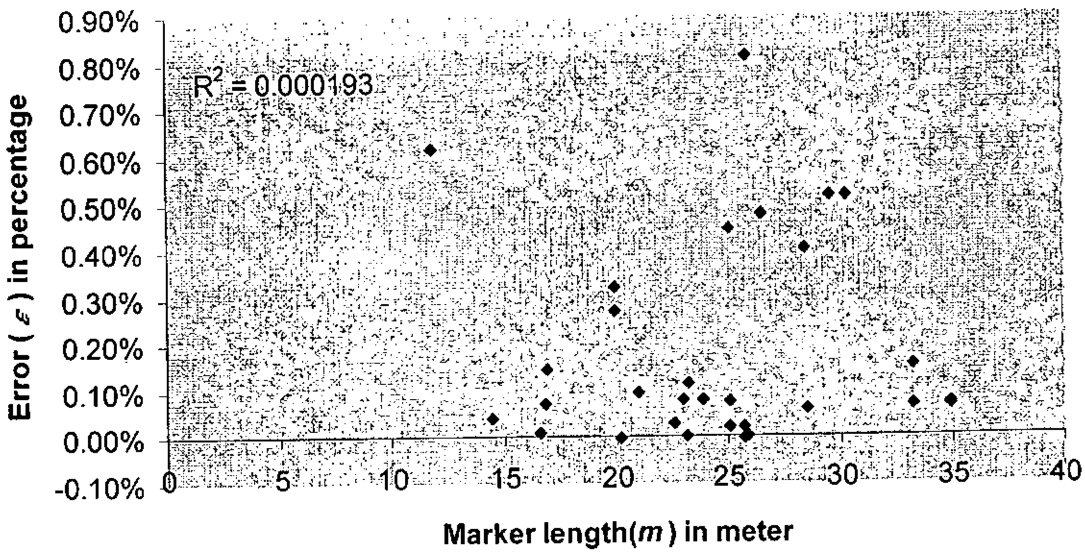


Figure 5.4 X-Y Plot of Error (ε) Percentage Against Total Number of Fabric Plies(*P*) in Cutting Lay

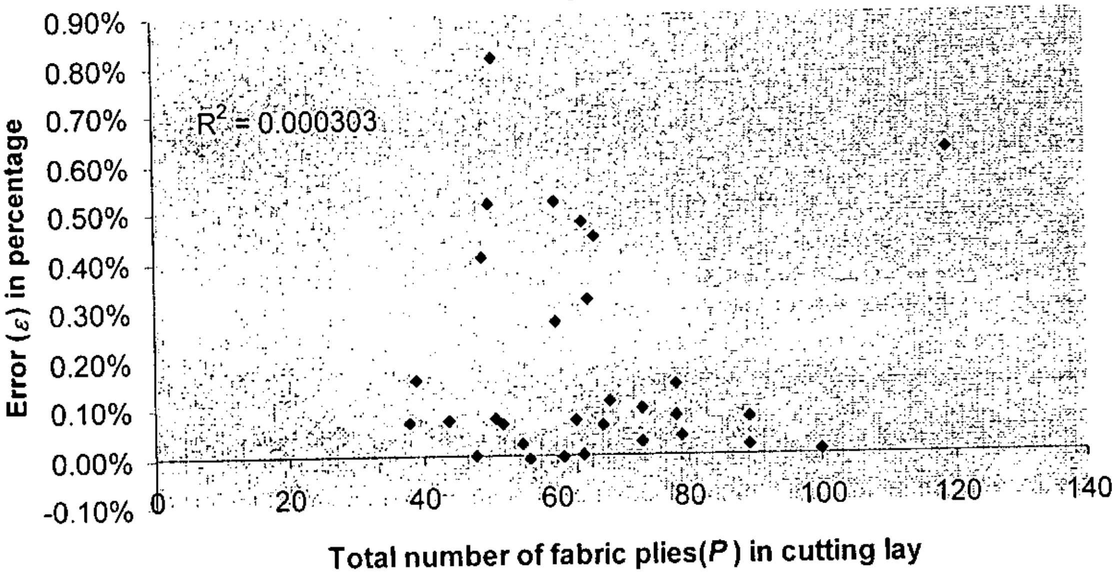


Figure 5.5 X-Y Plot of Error (ε) Percentage Against Length of Remnant(V_p) in Cutting Lay

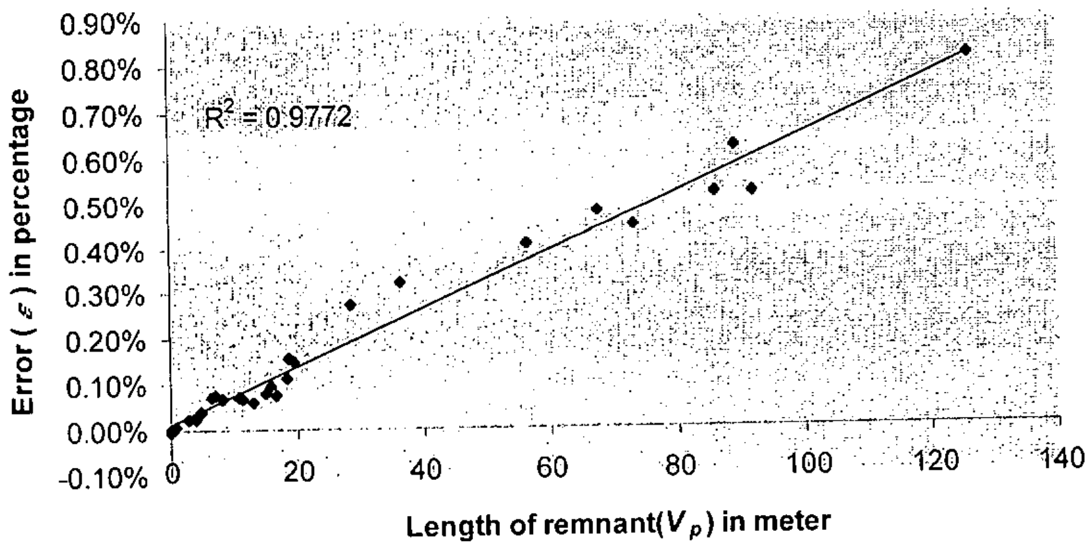
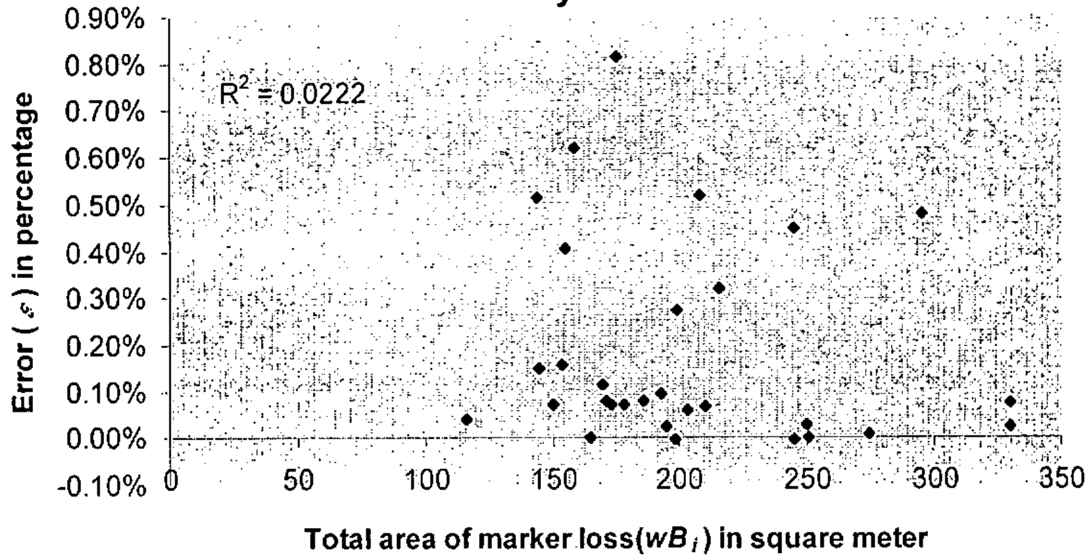


Figure 5.6 X-Y Plot of Error (ε) Percentage Against Total Area of Marker Loss(wB_i) in Cutting Lay



From the X-Y plots and values of the R Square, it was observed that most of the variables in the theoretical model presented no correlation with the ε except one variable - remnant length V_p. Other variables including marker width, total area of fabric used, marker length, number of fabric plies and marker loss, were explicated a near zero value of R Square (ranged from 0.000193 to 0.0222). From the X-Y plots (see figure 5.1 to 4 and 5.6) of these variables, it revealed that the dots spread evenly over the plotting area. Hence, the correlation of these variables with the ε is difficult to identify, or in other words, there has no observable relationship between them and the error ε.

On the contrary, in figure 5.5, it can be observed that the remnant length V_p has a very high positive linear relationship to the ε ($R^2 = 0.9772$). Each point locates nearly at two sides of the trend line, thus, an increasing length of remnant implies an increasing value of error. From this analysis, the variable V_p can be used to predict the value of ε in the linear form. (i.e. $\varepsilon = a + bV_p$)

5.2 SIGNIFICANCE OF THE VARIABLE - V_p IN THE PREDICTION MODEL

By regression, the variable remnant length V_p was found that it has a positive linear relationship with the prediction error ε in Ng's theoretical model. It is necessary to study the variable V_p for its nature and effect on total fabric loss so that improvement could be made on the existing model.

In Ng's theoretical model, the input variable V_p is referring to the remnant length of the last fabric roll, or in other words, V_p is the length of fabric left after spreading. In fact, V_p is not just simply as an input value which merely relies on the last fabric, but, it is affected by many factors incurred during spreading. In order to illustrate the actual meaning of remnant length V_p in this model, figure.5.7 is shown.

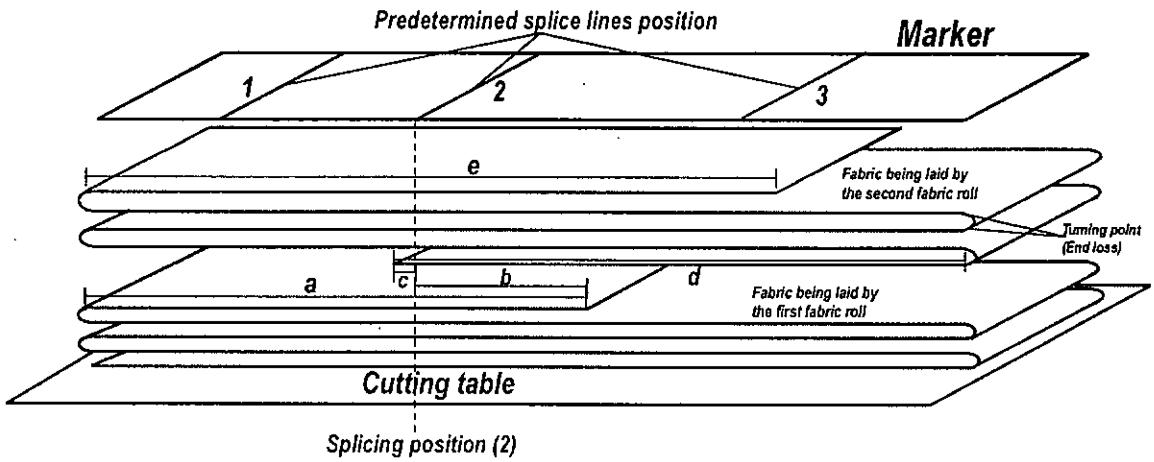


Figure 5.7 A cutting lay contains two fabric rolls

In figure 5.7, it is a graphical illustration of a finished cutting lay which contains two fabric rolls being laid onto the cutting table. The distance *a* is the length of remnant left by the first fabric roll. To continue spreading, a new fabric roll is introduced. As indicated by the dotted line, which is the nearest predetermined position (splice position (2)) for splicing, therefore, splicing takes place at that location. During splicing, distance *b* of the first fabric roll is regarded as splice loss. While, in the second fabric roll, distance *c* is the extra tolerance provided for splicing. Where the distance *d* in the second fabric roll is the length of fabric used to compensate the incomplete ply left by the first fabric roll. Upon the completion of spreading, distance *e* is regarded as remnant length left by the last fabric roll in the cutting lay. Referring to Ng's theoretical model (see equation (11) in Chapter 3) for the prediction of total fabric loss, the fabric length *e* would be equated to the input value of remnant length V_p for calculation.

Actually, the remnant length V_p is built in with many parameters incurred during spreading. Now, with four different cases, we can examine on how some major factors which can affect the remnant length V_p in the cutting lay illustrated.

Case One The change on fabric roll length

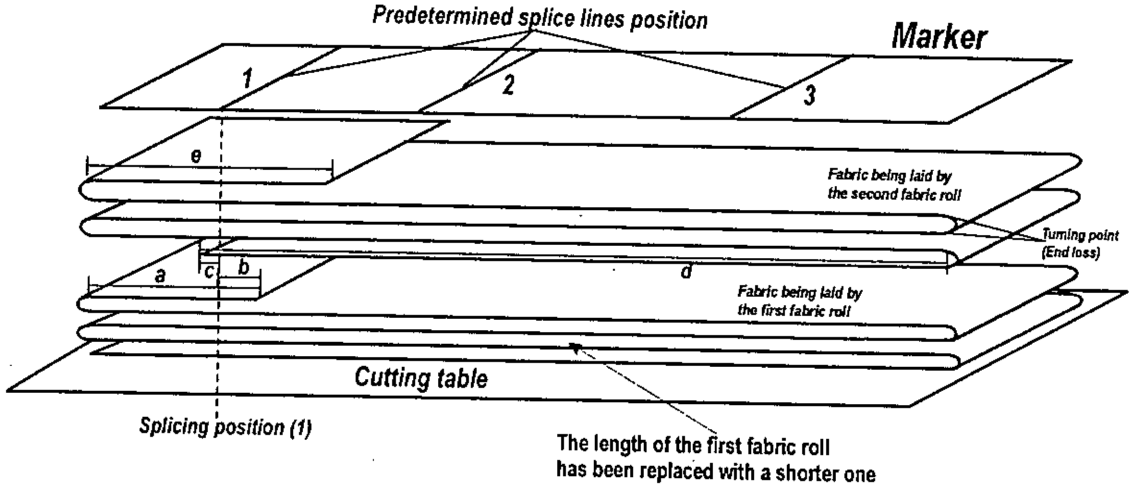


Figure 5.8 The cutting lay begins with a shorter fabric roll

In the first case, as illustrated in figure 5.8, given that all the factors are remained the same in the cutting lay except the first fabric roll has been changed to a shorter one. With a shorter fabric roll, the remnant length *a* left will become shorter. Hence, the nearest predetermined splice position must be changed. In this case, the splice position (1) should be used as the position for splicing. Consequently, the length *d* of the second fabric roll will be longer to compensate for the shortened length *a*. As a result, the remnant length *e* left by the last fabric roll will be shorter, hence, the input value of V_p for theoretical computation will become smaller.

Case Two The change of number of splice line in marker

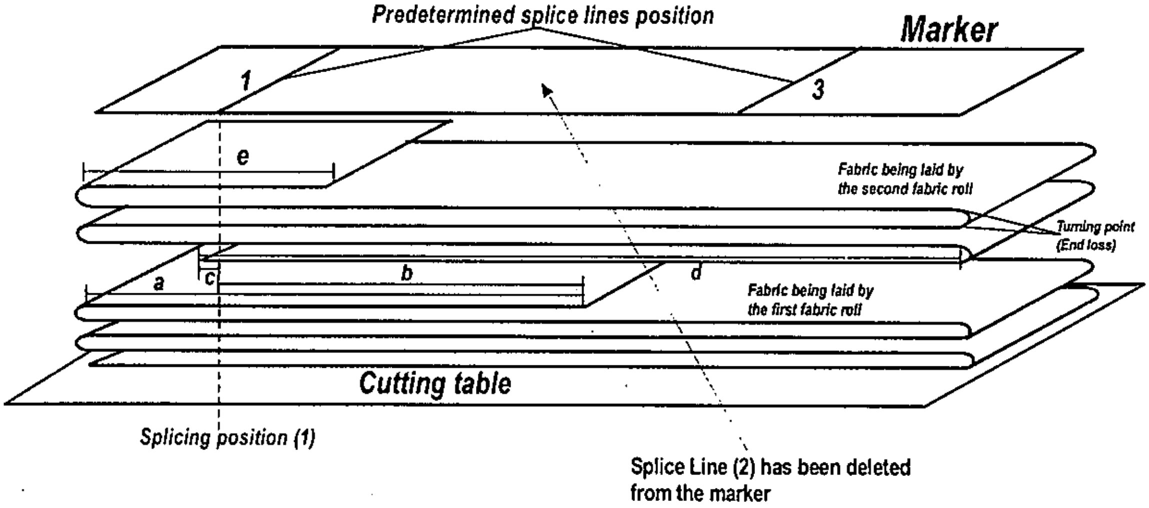


Figure 5.9 A cutting lay with a marker of two splice lines

In the second case, given that all factors in the cutting lay are constant except the splice line (2) in the marker has been deleted, as illustrated figure 5.9. Now, the splice position (1) becomes as the nearest position at which the splicing action will be taken place. Consequently, the distance *d* required for splicing will be longer and thus results in a shorter length of remnant *e* left by the last fabric roll.

Case Three The change of splice allowance

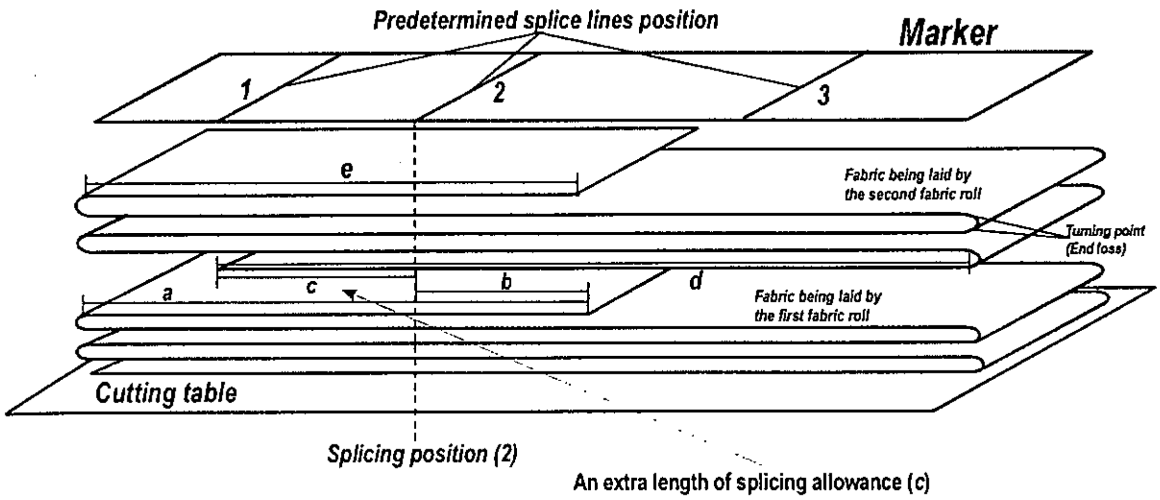


Figure 5.10 A cutting with an enlarged splice allowance

In the third case, referring to figure 5.10, given that all factors in the cutting lay are kept the same, except the tolerance *c* (generally termed splice allowance) provided for splicing, which has been increased. In this case, obviously, a longer splicing allowance *c* provided for splicing will result to a shorter remnant length *e* for the second fabric roll.

Case Three The change of end allowance

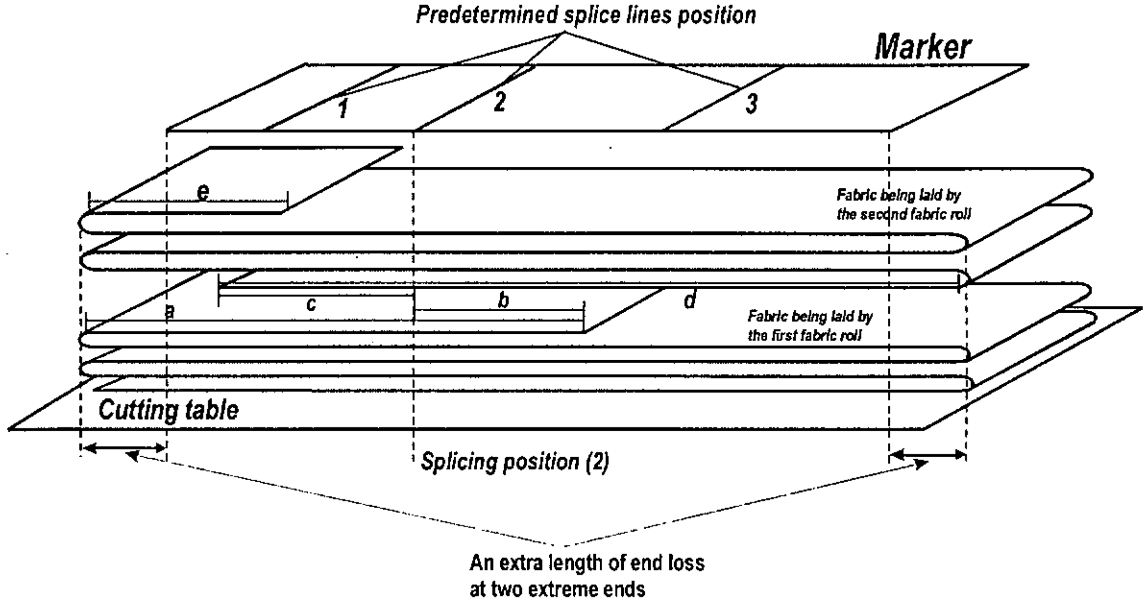


Figure 5.11 A cutting lay with an "oversized" end allowance

In the last case, the change of end loss is another factor which affects the length of the remnant. As referring to figure 5.11, at the extreme ends of each fabric ply, an extra length of fabric is provided for each turning point (known as end loss) so as to ensure that the cutting lay has sufficient length to cover the whole maker length. In fact, for some kinds of fabric (e.g. Denim), an extra amount of allowance is needed for each turning point due to the high bulkiness of the fabric. In this situation, even when all factors in the cutting lay are kept constant, the length of remnant *e* left by the last fabric roll will be shorter as a certain amount of fabric is absorbed by the "over sized" end allowance.

As illustrated by the four cases, we can understand that the length of remnant V_p of the last fabric roll in cutting lay can be significantly affected by many factors such as the fabric roll length, splice line position, splice allowance and end loss. Apart from these, there are some other items (e.g. the type of fabric, human spreading skill and number of fabric rolls in cutting lay, etc.), which could influence the length of remnant to a certain extent.

The above mentioned factors (fabric roll length, splice line position, splice allowance and end loss) are the common cases that will cause variation of total fabric loss during the spreading process. For accurate prediction of total fabric loss, all these factors should be included in the theoretical model. However, the inclusion of all factors in theoretical computation is impractical. This will cause difficulties and inconveniences for determining the input variables. On the contrary, the neglect of these factors in a theoretical equation may lead to an underestimation of total fabric loss.

Since the above mentioned factors can directly or indirectly affect the value of remnant length V_p, it is believed that this input variable V_p can be used to represent all of them in the cutting lay, for the prediction of total fabric loss, therefore, V_p becomes the most significant variable in the prediction model. However, the value of these mentioned factors may be associated with or affected by some "external factors" such as human spreading skill, type of material, etc. in the real production environment. Such "external factors" may cause a potential error in the value of V_p. For this reason, the coming sections are focused on the study of the input variable V_p for improving the accuracy of the prediction of total fabric loss.

5.3 THE NEW EQUATION

In order to improve the accuracy of prediction of total fabric loss during spreading, the error ε itself in the Ng's theoretical model must be analyzed so that a new equation could be formed. From the result of regression analysis, it was found that remnant length has a positive linear relationship with the error ε. Thus, length of remnant V_p in the equation can be expressed in terms of error ε by means of linear regression.

Since ε has a linear relationship with V_p, then:

$$\varepsilon = a + b\,V_p \tag{13}$$

Referring to the equation (12) as described in Chapter 4:

$$a_t = \frac{A_w}{A} + \varepsilon = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) + V_p - \sum_{i=1}^{P} B_i\} + \varepsilon \tag{12}$$

Combining (12) and (13), the new equation becomes:-

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P} B_i\} + a + V_p(b - \frac{w}{WL_t}) \tag{14}$$

where a and b are the two adjusting factors.

Using the real data collected from the factory, for the case of men's shirt manufacturing, the coefficient of variables a and b were worked out as 0.000105 and 0.0000636 respectively. Thus, for equation (13), it should be written as:

$$\varepsilon = 0.000105 + 0.0000636\, V_p \qquad (15)$$

Now, substitute (13) into (14), an equation for the prediction of total fabric loss during spreading in men's shirt manufacturing becomes:-

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P}B_i\} + 0.000105 + V_p(0.0000636 - \frac{w}{WL_t}) \qquad (16)$$

In order to examine the degree of accuracy in the prediction of fabric loss by the new equation, a study was carried out to compare the fabric loss between the actual measurement from a men's shirt factory and that worked out by the new equation. The actual measurement of fabric loss is based on the same set of industrial data that was collected from the men's shirt factory as presented in the previous chapter – section 4.3. If the outcome of this comparison shows that the error ε is smaller than the previous comparison between the actual measurement and Ng's theoretical model, it implies that the degree of accuracy in the prediction of fabric loss derived by the new equation is improved.

Having derived the new equation (14), and after the values of two variables (a = 0.000105 & b = 0.0000636) had been found from the regression analysis, a comparison between the new equation and the actual measurements collected from the men's shirt factory was carried out. The comparison results are shown in table 5.2.

Table 5.2 Comparison of total fabric loss computed by the new theoretical equation and the actual measurements

Sample	Percentage of total fabric loss from actual measurements (A)	Percentage of total fabric loss computed by the equation (6) (B)	Error (A) - (B)
1	14.38%	14.30%	0.08%
2	16.17%	16.18%	-0.01%
3	9.87%	9.89%	-0.02%
4	11.74%	11.76%	-0.02%
5	13.83%	13.85%	-0.02%
6	16.74%	16.72%	0.02%
7	12.96%	12.97%	-0.01%
8	11.89%	11.90%	-0.01%
9	14.51%	14.59%	-0.08%
10	11.74%	11.78%	-0.04%
11	13.62%	13.58%	0.04%
12	14.37%	14.34%	0.03%
13	16.39%	16.35%	0.04%
14	14.87%	14.88%	-0.01%
15	13.37%	13.38%	-0.01%
16	14.84%	14.82%	0.02%
17	14.59%	14.60%	-0.01%
18	12.46%	12.49%	-0.03%
19	12.76%	12.77%	-0.01%
20	12.81%	12.85%	-0.04%
21	11.99%	12.02%	-0.03%
22	11.42%	11.43%	-0.01%
23	13.19%	13.18%	0.01%
24	11.84%	11.80%	0.04%
25	13.99%	13.91%	0.08%
26	14.32%	14.33%	-0.01%
27	12.99%	12.99%	0.00%
28	11.66%	11.66%	0.00%
29	14.18%	14.17%	0.01%
30	11.67%	11.68%	-0.01%

Referring to table 5.2, using the new equation (16) for computing the amount of total fabric loss, the range of error was narrowed from (0 to 0.81%) to (-0.08% to +0.08%). The results revealed that the new equation can help to improve the accuracy of prediction on the total fabric loss during spreading. Since the range of error predicted by the new equation lies between the negative and positive real number (-0.08% to +0.08%), this result of estimation is more reliable than the Ng's theoretical model because the prediction results generated by it tend to be underestimation.

Although there is still an error in the new equation, the range of such error is much smaller than Ng's theoretical model. The range of error ε predicted by the Ng's model was 0.81%, while the range of error ε predicted by the new equation was 0.1%. This showed that the new equation provides a significant improvement on the accuracy of prediction, therefore, it can truly reflect the total fabric loss during spreading. As there is still a small amount of error present in new equation (14),

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P}B_i\} + a + V_p(b - \frac{w}{WL_t}) \qquad (14)$$

therefore, incorporated such error ε'' into the equation (14), the final expression of the new equation for total fabric loss prediction would become:

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P}B_i\} + a + V_p(b - \frac{w}{WL_t}) + \varepsilon'' \qquad (17)$$

As discussed in section 5.2, the number of splice lines, fabric roll length, end allowance, splice allowance and some "external" factors can influence the accuracy for prediction of total fabric loss. Therefore, two new variables *a* and *b* had been introduced in the new equation (17). In actual operation of fabric spreading, those mentioned factors such as number of splice lines, end allowance, etc., are mainly governed by two external factors in the lay planning process. They are "type of garment" and "type of material".

The first external factor "type of garment" determines the number and position of splice lines in marker. According to a previous study[19], the effect of garment type was found to be a dominant factor which influences the placing of garment panels in the marker. Therefore, the layout of garment panels will change accordingly with different types of garment drafted, eventually, the distributions of number and position of splice line will be altered.

The second external factor “type of material” mainly governs the splice allowance and end allowance required during spreading. In actual operation, different material may need different amount of allowance in the spreading process.

Although the real dominants in affecting the two adjusting variables *a* and *b* in the new equation have not been identified. It is believed that they are highly associated with the two mentioned external factors (type of material and the type of garment).

In order to verify the generic nature of the new equation by the change of these external factors, the equation was also tested on another kind of apparel product that made of another type of material. The validation work is discussed in the next chapter.

CHAPTER 6 : VALIDATION OF THE NEW EQUATION

6.1 INTRODUCTION

By means of the real industrial data and statistical analysis, a new equation (17) was formulated. However, this equation was derived from the set of industrial data collected from the men's shirt manufacturing, it may only be applicable in a particular production environment for shirt production. The coefficient of the two variables *a* and *b* were not fully investigated of their adaptability on other types of apparel production. Since the new equation may not be able to provide a high accuracy for predicting total fabric loss during spreading under different types of production environment except in the men's shirt manufacturing. Therefore, it is necessary to examine whether this equation is applicable to different production environment, it means that the generality of this equation should be studied.

In order to validate the new equation, it was decided to apply another set of production data based on another type of apparel product other than the men's shirt. The aims of this validation work are stated as follow:

1. To examine the generality and accuracy of the new equation for predicting total fabric loss

2. To test the practicality of the proposed method (as described in Chapter 4 – section 4.2) for measuring various kinds of fabric loss during spreading.

6.2 COLLECTION OF INDUSTRIAL DATA

In order to obtain another set of production data for the validation analysis, a factory which producing the apparel product other than men's shirt should be selected for the study. The major criteria for factory selection was same to the previous one as described in Chapter 4 (section 4.2.1). The selected apparel production should be a basic staple garment that has little demand of style change and little seasonal influence among various production orders. Moreover, the yardage for each cutting should be up to a considerable quantity and there the variance of the sample cutting lays should be kept in minimum.

With the considerations on the above selection requirements, a pants manufacturing company in mainland China was chosen for data collection. The selected factory produces basic staple pants for both genders.

It is preferable to select two completely different apparel products for this study. The men's shirt is staple clothing item for the tops while pants are basic item for the bottom. The data of these two types of apparel product would have great variations because the pattern blocks in the marker certainly would be of outmost difference. Such great variations between the two sets of data could help to reveal distinctly on the practicality of the new equation.

Moreover, the production of men's shirts basically use the fine and subtle fabric such as pinpoint oxford or cotton Dobby, but the production of pants uses more bulky and thicker materials such as denim or twill. The great differences between the materials to be used in spreading can help to study whether the change of fabric type would affect the accuracy of the equation.

The data measuring method for the pants factory was same to that used for the previous case of men's shirt manufacturing. Totally 35 sets of production data were collected from the pants factory.

The actual measurements of the six input variables (marker width, total fabric area used in spreading, marker length, number of complete fabric plies in the cutting lay, length of remnant, and total area of marker loss in the cutting lay) for the new equation are summarized in table 6.1. The detail breakdowns of total fabric loss in each sample cutting lay are shown in Appendix C.

Table 6.1 The actual measurements of six input variables obtained from the pants factory

Sample	Marker width (w) in meter	Total area of fabric used in spreading (WLt) in Sqm.	Marker length (m) in meter	No. of complete fabric plies in cutting lay	Length of remnant (V_p) in meter	Total area of marker loss in cutting lay (wBi) in Sqm.
1	1.092	1411.858	9.597	120	87	133.8
2	1.473	2737.318	13.984	126	34.6	260.568
3	1.08	1635.045	11.699	120	44.2	153
4	1.092	2070.819	12.59	140	59	224.28
5	1.118	2534.661	19.01	115	0	257.14
6	1.08	1732	11.699	125	82	159.375
7	1.473	2604.06	13.6	118	97.92	229.51
8	1.473	2442.148	10.21	150	72.5	243
9	1.092	1892.893	10.97	145	69	220.11
10	1.524	2891.161	12.796	140	52	275.24
11	1.092	2213.71	14.8	125	93	256
12	1.105	2096.407	14.7	120	60	219.12
13	1.524	2702.655	12.796	130	65.3	255.58
14	1.08	1750.426	11.699	125	98.4	159.375
15	1.461	2650.443	12.67	135	39	249.885
16	1.168	2071.526	14.63	110	86	213.51
17	1.473	2617.569	13.984	120	46.6	248.16
18	1.092	1732.733	10.97	135	44.2	204.93
19	1.092	1942.726	12.59	135	17.5	216.27
20	1.524	2561.54	11.49	140	20	254.94
21	1.118	1908.595	19.01	85	34.3	190.06
22	1.524	2447.268	12.796	120	20.5	235.92
23	1.499	2514.783	14.75	105	78.2	247.695
24	1.092	2196.38	16.8	110	98.9	230.45
25	1.473	2422.56	13.6	110	98.9	213.95
26	1.473	2414.091	10.21	150	56.5	243
27	1.092	2040.406	14.8	120	20.5	245.76
28	1.105	1862.088	14.7	110	10.6	200.86
29	1.092	1323.056	9.597	120	10.3	133.8
30	1.079	1772.512	11.699	130	60.5	165.75
31	1.118	1988.617	19.01	90	8.7	201.24
32	1.524	2659.892	12.796	130	30.4	255.58
33	1.473	2295.111	10.21	145	26.9	234.9
34	1.168	1928.531	14.63	105	50.3	203.805
35	1.079	1811.912	11.699	135	36.5	172.125

In the new equation, the input value of the two variables a and b for pant manufacturing required computation of the total fabric loss in spreading. Instead by direct measurement, the value of these variables was derived through the production data collected from the field study.

As explained in the previous case of men's shirt manufacturing, the error ε was found to have a positive linear relationship with the remnant length V_p, and since the coefficient of a and b variables are dependent on the linear equation (13) as stated in Chapter 5, the two variables could then be derived by linear regression. For the case of pants manufacturing, it was assumed that the above assumption is still valid for the determination of a and b, and thus these two variables can be derived by regression analysis. The procedures for determining their value are stated briefly as below:

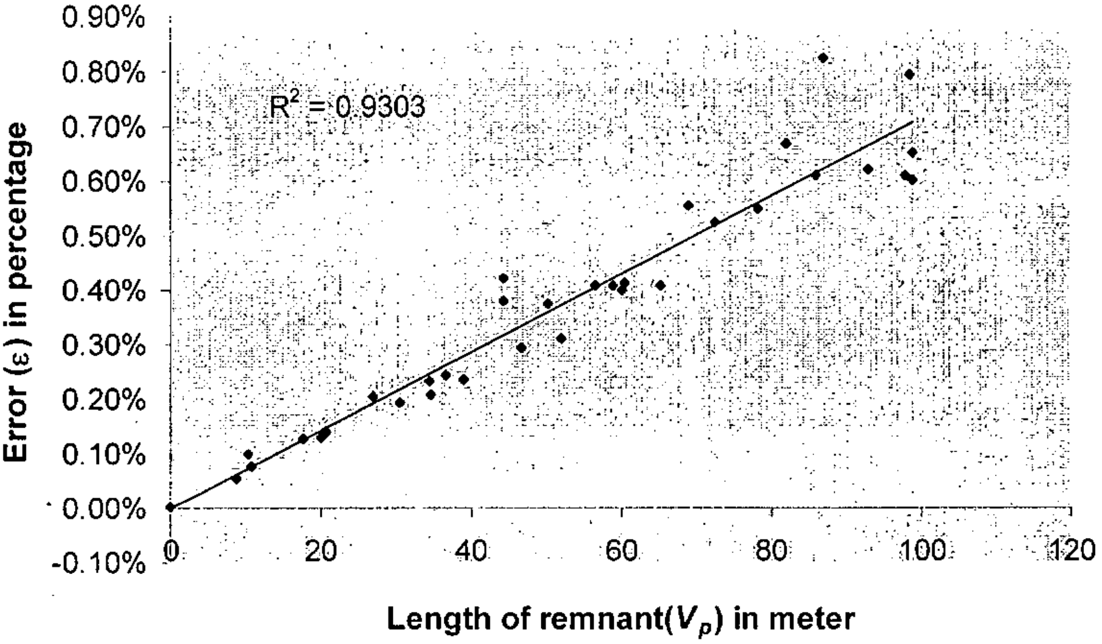
Firstly, the total fabric loss derived by Ng's theoretical model (see Chapter 3, equation (11)) was used and compared with the actual fabric loss collected from the pants factory, hence, the prediction error ε in each sample cutting lay can be obtained. The comparison results are summarized in table 6.2.

Table 6.2 Comparison of total fabric loss (%) between the actual measurement in pants factory and the theoretical calculation based on Ng's model

Sample	Percentage of total fabric loss from actual measurement in factory (A)	Percentage of total fabric loss obtained by Ng's theoretical calculation (B)	Error (A) - (B)
1	14.50%	13.67%	0.83%
2	13.05%	12.84%	0.21%
3	14.13%	13.71%	0.42%
4	15.18%	14.77%	0.41%
5	13.72%	13.72%	0.00%
6	13.57%	12.90%	0.67%
7	13.11%	12.50%	0.61%
8	13.73%	13.20%	0.53%
9	16.44%	15.88%	0.56%
10	12.66%	12.35%	0.31%
11	16.34%	15.72%	0.62%
12	14.71%	14.31%	0.40%
13	12.38%	11.97%	0.41%
14	13.60%	12.81%	0.79%
15	13.23%	12.99%	0.24%
16	15.33%	14.72%	0.61%
17	12.72%	12.43%	0.29%
18	16.09%	15.71%	0.38%
19	14.74%	14.61%	0.13%
20	13.19%	13.06%	0.13%
21	13.53%	13.30%	0.23%
22	12.88%	12.74%	0.14%
23	13.42%	12.87%	0.55%
24	14.30%	13.70%	0.60%
25	12.51%	11.86%	0.65%
26	13.58%	13.17%	0.41%
27	16.04%	15.90%	0.14%
28	14.28%	14.20%	0.08%
29	14.31%	14.21%	0.10%
30	13.50%	13.09%	0.41%
31	13.50%	13.44%	0.06%
32	12.75%	12.56%	0.19%
33	13.70%	13.49%	0.21%
34	14.86%	14.49%	0.37%
35	13.52%	13.27%	0.25%

Secondly, based on the previous finding that the remnant length is the factor that has a high positive linear relationship with the error ε in prediction of the total fabric loss. Referring to the computational results of the error ε as shown in table 6.2, using the regression analysis, a trend line with the intercept (a) and the slope (b) was determined (see figure 6.1). The value of the intercept and slope of the trend line will become the coefficients of the two input variables a and b respectively.

Figure 6.1 X-Y Plot of Error (ε) Percentage Against Length of Remnant(V_p) in Cutting Lay by Ng's model (For the case of pants)



As explained in Chapter 5, the linear relationship of the error ε and the remnant length V_p is:

$$\varepsilon = a + b\,(V_p) \qquad (13)$$

After regression analysis (the details of regression output are listed in Appendix D), the values of a and b variables for the case of pants manufacturing were determined as –0.00000841 and 0.0000717 respectively. Thus, equation (13) would become:

$$\varepsilon = -0.00000841 + 0.0000717(V_p) \qquad (18)$$

After the value of a and b were determined, the verification work of the new model can be proceeded and discussed in detail in the following sections.

6.3 VERIFICATION OF THE NEW EQUATION

Referring to the final expression of the new equation:

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P}B_i\} + a + V_p(b - \frac{w}{WL_t}) \tag{14}$$

In the case of pants manufacturing, combining (14) and (18), equation (14) becomes:

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P}B_i\} - 0.00000841 + V_p(0.0000717 - \frac{w}{WL_t}) \tag{19}$$

Hence, equation (19) was used to predict the amount of total fabric loss for each sample cutting lay in the case of pants manufacturing. Similar to the case of men's shirt production, the error ε'' could be determined by comparing the actual fabric loss with the theoretical calculation by using equation (19). The result of this comparison is shown in table 6.3.

As shown in table 6.3, for pants manufacturing, the range of error ε'' lies between –0.1% to +0.08%. This finding is almost the same as in the previous case of men's shirt manufacturing. Based on the findings of these two cases, the range of error ε'' remains at the level of +0.1%. Although the error ε'' still exists, the new equation exhibited a high accuracy in the prediction of total fabric loss for both men's shirt and pants manufacturing.

Based on the result of the validation, equation (19) would become:

$$a_t = 1 - \frac{w}{WL_t}\{m\sum_{i=1}^{P}(1+p_i) - \sum_{i=1}^{P}B_i\} - 0.00000841 + V_p(0.0000717 - \frac{w}{WL_t}) + \varepsilon'' \quad (20)$$

Table 6.3 Comparison results of total fabric loss between actual measurements and theoretical calculations for pants manufacturing

Sample	Percentage of total fabric loss from actual measurement in factory (A)	Percentage of total fabric loss obtained by the new derived theoretical calculation (B)	Error (A) - (B)
1	14.50%	14.46%	0.04%
2	13.05%	13.09%	-0.04%
3	14.13%	14.08%	0.05%
4	15.18%	15.19%	-0.01%
5	13.72%	13.72%	0.00%
6	13.57%	13.49%	0.08%
7	13.11%	13.18%	-0.07%
8	13.73%	13.72%	0.01%
9	16.44%	16.38%	0.06%
10	12.66%	12.72%	-0.06%
11	16.34%	16.38%	-0.04%
12	14.71%	14.74%	-0.03%
13	12.38%	12.44%	-0.06%
14	13.60%	13.53%	0.07%
15	13.23%	13.27%	-0.04%
16	15.33%	15.34%	-0.01%
17	12.72%	12.76%	-0.04%
18	16.09%	16.03%	0.06%
19	14.74%	14.74%	0.00%
20	13.19%	13.20%	-0.01%
21	13.53%	13.54%	-0.01%
22	12.88%	12.89%	-0.01%
23	13.42%	13.43%	-0.01%
24	14.30%	14.40%	-0.10%
25	12.51%	12.56%	-0.05%
26	13.58%	13.58%	0.00%
27	16.04%	16.04%	0.00%
28	14.28%	14.28%	0.00%
29	14.31%	14.28%	0.03%
30	13.50%	13.52%	-0.02%
31	13.50%	13.51%	-0.01%
32	12.75%	12.77%	-0.02%
33	13.70%	13.69%	0.01%
34	14.86%	14.85%	0.01%
35	13.52%	13.53%	-0.01%

6.4 DISCUSSION

The validation result of the new equation showed that there is a small residual error ε'' in the prediction equation for the total fabric loss during spreading. Comparing with the Ng's theoretical model, there is a great improvement on the accuracy of prediction from -0.08% to 0.1%. Such small error ε'' may be caused by some external factors such as the skill of the spreader, the performance of the spreading machinery, and the fabric flaws. As the value of the error ε'' is close to zero, the prediction accuracy of this new equation is within the acceptable tolerance in material estimation. In practice, it is impossible to work out a prediction method that without any error involved as it is impractical to take all minor factors into account. Therefore, it is inevitable that a certain amount of error will exist when using any theoretical prediction.

Among all input variables in the new equation, a and b are the two main variables that are closely associated with the change on type of garment and the material used in the spreading process. These two variables a and b in the equation are essential for the prediction of the total fabric loss in spreading under a particular production environment. Referring to the two cases studied, these two variables could be worked out from industrial data by means of regression analysis. As the value of a and b will change accordingly to the type of garment and material used, thus, it is vital to identify accurately the value of these two variables under different production environments.

Based on the experimental results, the variable a is a very small real number which tends to zero, that is not practical in the real production environment. When the data quality such as the number of sample size is improved, the value of a will become more significant in relative to the deviation ε.

To achieve the objectives of this study, two study cases (men's shirt and pants manufacturing) were chosen for the purposes of development and validation of the new equation. Men's shirts are staple garments that are mainly made from soft and subtle material, while the pants are a basic lower garment made from thicker and stiffer material. These two types of garment are typical examples in the full range of garments, and they are completely different in nature in terms of design, pattern, marker and garment assembly. Such differences are able to reveal the generality and practicality of the new equation. For both cases, the range of the error ε'' in the prediction of fabric loss lies between +0.1% to –0.08%, it is believed that other apparel product will also fall within such range by the use of the new equation. From the validation work, it explicated that the generality and adaptability of the new equation are high, and therefore it can be applied to different types of apparel product that made of different materials.

CHAPTER 7 : CONCLUSION & FUTURE WORKS

7.1 CONCLUSION

The importance of material utilization has long been recognized by the apparel manufacturers. Previous study[1] provides the evidence that material usually shares the largest portion of a garment's manufacturing cost. A considerable value of extra profit can be brought by saving or increasing the efficiency on material utilization. Stimulated by the needs on this concern, many researches and studies[1, 10, 26-35] have been carried out to explore and investigate the possible areas for material saving.

Among different processes in garment manufacturing, losses due to cutting dominate the largest sum of material wastage, as a result, rigorous material control over cutting is substantial and necessary. In the cutting process, marker loss generates the greatest amount of wastage and thus a lot of studies had been conducted to explore the ways to minimize it. Just below it, fabric loss in spreading shares the second largest part of material wastage. For this type of loss, most people mainly focus on the use of practical guidelines, procedures and techniques to control it. In fact, prior to the use of these means, cut-planning (or lay-planning) should be firstly considered. Cut-planning involves the selection of the most efficient cutting lay which produces the lowest fabric wastage. On this aspect, the prediction of fabric loss is an important indicator to help cutting room staff in making their decision on cut planning. However, the existing methods for the prediction of fabric loss in the cutting lay are considered insufficient or inaccurate.

For this reason, this study aimed to design an appropriate method for predicting total fabric loss during spreading in an accurate manner. It was hoped that the proposed method could help cutting room management to determine precisely for the amount of fabric loss of a particular cutting lay before the cutting takes place.

Through intensive reviewing, Ng's theoretical model[37, 38], which provides a systematic and comprehensive analysis of fabric loss during spreading, was selected as the groundwork of this study. By the use of industrial data and statistical analysis, a new equation was formulated. In comparison to the equations in Ng's theoretical model, this is a more extensive equation which incorporates two adjusting factors for fabric loss prediction. With the support of real data collected from two apparel factories, the new equation was validated and verified on its generality and accuracy. From the outcomes, they revealed that this equation furnished a precise prediction of total fabric loss during spreading with an average deviation near to zero. Meanwhile, the major objective was achieved.

While concerning on the new equation's generality for its application on various apparel products, a bipolar study was employed. Two kinds of apparel product with great difference in terms of the material used and garment style were examined. In the first case, a manufacturing company producing men's shirts that were made from soft and subtle materials was selected. On the contrary, another manufacturing company that produces pants from thick and stiff materials was chosen in the second case. For verification, the new equation was applied to predict total fabric loss in both cases. From the results generated, the model exhibited a very high accuracy in the prediction of total fabric loss in all sample cutting lays. Since two cases for verification were selected in a bipolar manner and with large differences in the product's nature, it is believed that the error for predicting total fabric loss for other types of apparel product will also lie within a low level.

For application, the new equation is most suitable for application to staple garments which will be produced in large quantities. Practically, two major variables, which are highly associated with the type of garment and material, have to be determined by a number of sample cutting lays. For fashionable items, the demands for changing their style and material used are high, but, the production volume is low. If the new equation is applied, values of the mentioned variables have to be determined many times along with each change of the garment style or material used in manufacturing. Such changes will raise difficulties and consume a lot of effort.

Besides, for small order quantity of production, the number of sample cutting lay required for determining of these variables may not be enough. This may cause a certain extent of influence on the accuracy of the equation. For this type of production, the concern on material utilization control should be focused on marker loss rather than the spreading loss.

All in all, material utilization control is an important and long lasting task of cutting-room management nowadays. In spreading, lay planning acted as a vital part for the control of fabric loss. In this study, the proposed method can provide an accurate prediction of total fabric loss. Therefore, the use of this method can offer cutting room people an additional reference and alternative while they are considering which would be the most efficient cutting lay for production.

7.2 RECOMMENDATION FOR FUTURE STUDIES

In the new equation developed by this study, the two input variables *a* and *b* have to be determined for different kinds of apparel products. In this work, the values of them were determined merely on two kinds of product (men's shirt and pants) for development and validation of the new equation. In fact, these input variables will change accordingly with the types of garment and material used. It is suggested that extra study work can be conducted to study these two variables among various apparel products. It is believed that provision of this findings can furnish garment manufacturers with a reference to determine their values on different apparel products, thus, the effort for determination of these variables could be saved.

Besides, to deal with total fabric loss during spreading, this study derived an appropriate method for fabric loss prediction on this aspect. Actually, the reason behind the need of an accurate prediction of total fabric loss is mainly for planning. That is, before the actual spreading and cutting process, cutting room people should plan for a cutting lay which will produce the lowest fabric wastage – known as lay planning.

In addition to "lay planning" as considered by this study, monitoring is another vital task in material utilization control which mainly deals with individual kind of fabric loss involved with the human skill. It is suggested that, for monitoring and controlling purposes, a theoretical model could be developed for the prediction of each individual kind of loss (such as end loss, width loss, splice loss, etc.) with the inclusion of human factor.

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APPENDIX A

Fabric Wastage Report of Sample Cutting Lay (Measured From The Men's Shirt Factory)

Report of Fabric Wastage of Sample 1

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1241.28		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		28.5	1212.78	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =19.978 * 60	1198.68		98.84%
2. Splicing loss		7.424		0.61%
3. Splice allowance		3.136		0.26%
4. End loss	Total end loss of each ply time total spread plies	3.54	1212.78	0.29%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1241.28 * 1.502	1864.403		
Minus remnant area of the last roll = Actual usable area of all rolls	=28.5 * 1.502	42.807	1821.596	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(29.308-3.315) * 60	1559.580		85.62%
2. Total area of marker fallout	Fallout area * spread plies =3.315 * 60	198.900		10.92%
3. Splicing loss	Total length of splice loss * marker width = 7.424 * 1.467	10.891		0.60%
4. Splicing allowance	Total length of splice allowance * marker width = 3.136 * 1.467	4.601		0.25%
5. End loss	Total length of end loss * marker width = 3.54 * 1.467	5.193		0.29%
6. Width loss	Actual used length of all rolls * measured width loss = 1212.78 * 0.035	42.447	1821.612	2.33%
Difference			-0.016	100.00%

Report of Fabric Wastage of Sample 2

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1242.264		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		0	1242.264	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =20.205 * 61	1232.505		99.21%
2. Splicing loss		4.753		0.38%
3. Splice allowance		1.407		0.11%
4. End loss	Total end loss of each ply time total spread plies	3.599	1242.264	0.29%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1242.264 * 1.487	1847.247		
Minus remnant area of the last roll = Actual usable area of all rolls		0	1847.247	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(29.398-4.013) * 61	1548.485		83.83%
2. Total area of marker fallout	Fallout area * spread plies =4.013 * 61	244.793		13.25%
3. Splicing loss	Total length of splice loss * marker width = 4.753 * 1.455	6.916		0.37%
4. Splicing allowance	Total length of splice allowance * marker width = 1.407 * 1.455	2.047		0.11%
5. End loss	Total length of end loss * marker width = 3.599 * 1.455	5.237		0.28%
6. Width loss	Actual used length of all rolls * measured width loss = 1242.264 * 0.032	39.752	1847.230	2.15%
Difference			0.017	100.00%

Report of Fabric Wastage of Sample 3

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1831.019		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		14.813	1816.206	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =23.013 * 78	1795.014		98.83%
2. Splicing loss		14.685		0.81%
3. Splice allowance		1.515		0.08%
4. End loss	Total end loss of each ply time total spread plies	4.992	1816.206	0.27%
Difference			0.00	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1831.019 * 1.128	2065.389		
Minus remnant area of the last roll = Actual usable area of all rolls	=14.813 * 1.128	16.709	2048.68	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(25.867-2.193) * 78	1846.572		90.13%
2. Total area of marker fallout	Fallout area * spread plies =2.193 * 78	171.054		8.35%
3. Splicing loss	Total length of splice loss * marker width = 14.685 * 1.124	16.506		0.81%
4. Splicing allowance	Total length of splice allowance * marker width = 1.515 * 1.124	1.703		0.08%
5. End loss	Total length of end loss * marker width = 4.992 * 1.124	5.611		0.27%
6. Width loss	Actual used length of all rolls * measured width loss = 1816.206 * 0.004	7.265	2048.711	0.35%
Difference			-0.030	100.00%

Report of Fabric Wastage of Sample 4

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1560.237		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		15.877	1544.36	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =20.977 * 73	1531.321		99.16%
2. Splicing loss		6.413		0.42%
3. Splice allowance		1.297		0.08%
4. End loss	Total end loss of each ply time total spread plies	5.329	1544.36	0.35%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1560.237 * 1.521	2373.12		
Minus remnant area of the last roll = Actual usable area of all rolls	=15.877 * 1.521	24.149	2348.972	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(31.046-2.645) * 73	2073.273		88.26%
2. Total area of marker fallout	Fallout area * spread plies =2.645 * 73	193.085		8.22%
3. Splicing loss	Total length of splice loss * marker width = 6.413 * 1.48	9.491		0.40%
4. Splicing allowance	Total length of splice allowance * marker width = 1.297 * 1.48	1.920		0.08%
5. End loss	Total length of end loss * marker width = 5.329 * 1.48	7.887		0.34%
6. Width loss	Actual used length of all rolls * measured width loss = 1544.36 * 0.041	63.319	2348.974	2.70%
Difference			-0.003	100.00%

Report of Fabric Wastage of Sample 5

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1841.562		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		11.27	1830.292	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =34.868 * 52	1813.136		99.06%
2. Splicing loss		11.885		0.65%
3. Splice allowance		2.255		0.12%
4. End loss	Total end loss of each ply time total spread plies	3.016	1830.292	0.16%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1841.562 * 1.152	2121.479		
Minus remnant area of the last roll = Actual usable area of all rolls	=11.27 * 1.152	12.98304	2108.496	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(38.982-4.042) * 52	1816.88		86.17%
2. Total area of marker fallout	Fallout area * spread plies =4.042 * 52	210.184		9.97%
3. Splicing loss	Total length of splice loss * marker width = 11.885 * 1.118	13.287		0.63%
4. Splicing allowance	Total length of splice allowance * marker width = 2.255 * 1.118	2.521		0.12%
5. End loss	Total length of end loss * marker width = 3.016 * 1.118	3.372		0.16%
6. Width loss	Actual used length of all rolls * measured width loss = 1830.292 * 0.034	62.230	2108.474	2.95%
Difference			0.022	100.00%

Report of Fabric Wastage of Sample 6

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1238.895		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		7.132	1231.763	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =23.853 * 51	1216.503		98.76%
2. Splicing loss		11.66		0.95%
3. Splice allowance		1.05		0.09%
4. End loss	Total end loss of each ply time total spread plies	2.55	1231.763	0.21%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1238.895 * 1.145	1418.535		
Minus remnant area of the last roll = Actual usable area of all rolls	=7.132 * 1.145	8.166	1410.369	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(26.668-3.644) * 51	1174.224		83.26%
2. Total area of marker fallout	Fallout area * spread plies =3.644 * 51	185.844		13.18%
3. Splicing loss	Total length of splice loss * marker width = 11.66 * 1.118	13.036		0.92%
4. Splicing allowance	Total length of splice allowance * marker width = 1.05 * 1.118	1.174		0.08%
5. End loss	Total length of end loss * marker width = 2.55 * 1.118	2.851		0.20%
6. Width loss	Actual used length of all rolls * measured width loss = 1231.804 * 0.027	33.259	1410.387	2.36%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 7

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1616.262		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		18.4	1597.862	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =23.269 * 68	1582.292		99.03%
2. Splicing loss		11.239		0.70%
3. Splice allowance		0.931		0.06%
4. End loss	Total end loss of each ply time total spread plies	3.4	1597.862	0.21%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1616.262 * 1.15	1858.701		
Minus remnant area of the last roll = Actual usable area of all rolls	=18.4 * 1.15	21.16	1837.541	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(26.015-2.495) * 68	1599.360		87.04%
2. Total area of marker fallout	Fallout area * spread plies =2.495 * 68	169.660		9.23%
3. Splicing loss	Total length of splice loss * marker width = 11.239 * 1.118	12.565		0.68%
4. Splicing allowance	Total length of splice allowance * marker width = 0.931 * 1.118	1.041		0.06%
5. End loss	Total length of end loss * marker width = 3.4 * 1.118	3.801		0.21%
6. Width loss	Actual used length of all rolls * measured width loss = 1597.862 * 0.032	51.132	1837.559	2.78%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 8

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1251.828		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		0	1251.828	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.872 * 48	1241.856		99.20%
2. Splicing loss		6.08		0.49%
3. Splice allowance		1.06		0.08%
4. End loss	Total end loss of each ply time total spread plies	2.832	1251.828	0.23%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1251.828 * 1.509	1889.008		
Minus remnant area of the last roll = Actual usable area of all rolls		0.000	1889.008	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(38.109-3.434) * 48	1664.400		88.11%
2. Total area of marker fallout	Fallout area * spread plies =3.434 * 48	164.832		8.73%
3. Splicing loss	Total length of splice loss * marker width = 6.08 * 1.473	8.956		0.47%
4. Splicing allowance	Total length of splice allowance * marker width = 1.06 * 1.473	1.561		0.08%
5. End loss	Total length of end loss * marker width = 2.832 * 1.473	4.172		0.22%
6. Width loss	Actual used length of all rolls * measured width loss = 1251.828 * 0.036	45.066	1888.987	2.39%
Difference			0.022	100.00%

Report of Fabric Wastage of Sample 9

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1876.683		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		92	1784.683	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =29.573 * 60	1774.38		99.42%
2. Splicing loss		6.345		0.36%
3. Splice allowance		0.87		0.05%
4. End loss	Total end loss of each ply time total spread plies	3.088	1784.683	0.17%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1876.683 * 1.164	2184.459		
Minus remnant area of the last roll = Actual usable area of all rolls	=92 * 1.164	107.088	2077.371	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(33.063-3.463) * 60	1776.000		85.49%
2. Total area of marker fallout	Fallout area * spread plies =3.463 * 60	207.780		10.00%
3. Splicing loss	Total length of splice loss * marker width = 6.345 * 1.118	7.094		0.34%
4. Splicing allowance	Total length of splice allowance * marker width = 0.87 * 1.118	0.973		0.05%
5. End loss	Total length of end loss * marker width = 3.088 * 1.118	3.452		0.17%
6. Width loss	Actual used length of all rolls * measured width loss = 1784.683 * 0.046	82.095	2077.394	3.95%
Difference			-0.023	100.00%

Report of Fabric Wastage of Sample 10

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1623.21		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		86	1537.21	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =30.25 * 50	1512.5		98.39%
2. Splicing loss		20.581		1.34%
3. Splice allowance		0.979		0.06%
4. End loss	Total end loss of each ply time total spread plies	3.15	1537.21	0.20%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1623.21 * 1.147	1861.822		
Minus remnant area of the last roll = Actual usable area of all rolls	=86 * 1.147	98.642	1763.18	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(34.001-2.877) * 50	1556.200		88.26%
2. Total area of marker fallout	Fallout area * spread plies =2.877 * 50	143.850		8.16%
3. Splicing loss	Total length of splice loss * marker width = 20.581 * 1.124	23.133		1.31%
4. Splicing allowance	Total length of splice allowance * marker width = 0.979 * 1.124	1.100		0.06%
5. End loss	Total length of end loss * marker width = 3.15 * 1.124	3.541		0.20%
6. Width loss	Actual used length of all rolls * measured width loss = 1537.21 * 0.023	35.356	1763.180	2.01%
Difference			0.000	100.00%

Report of Fabric Wastage of Sample 11

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1464.767		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		56.1	1408.667	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =28.417 * 49	1392.433		98.85%
2. Splicing loss		12.49		0.89%
3. Splice allowance		1		0.07%
4. End loss	Total end loss of each ply time total spread plies	2.744	1408.667	0.19%
Difference			0.00	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1464.767 * 1.152	1687.412		
Minus remnant area of the last roll = Actual usable area of all rolls	=56.1 * 1.152	64.627	1622.784	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(31.77-3.164) * 49	1401.694		86.38%
2. Total area of marker fallout	Fallout area * spread plies =3.164 * 49	155.036		9.55%
3. Splicing loss	Total length of splice loss * marker width = 12.49 * 1.118	13.964		0.86%
4. Splicing allowance	Total length of splice allowance * marker width = 1 * 1.118	1.118		0.07%
5. End loss	Total length of end loss * marker width = 2.744 * 1.118	3.068		0.19%
6. Width loss	Actual used length of all rolls * measured width loss = 1408.667 * 0.034	47.895	1622.774	2.95%
Difference			0.010	100.00%

Report of Fabric Wastage of Sample 12

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1325.258		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		18.474	1306.784	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =33.174 * 39	1293.786		99.01%
2. Splicing loss		10.355		0.79%
3. Splice allowance		1.005		0.08%
4. End loss	Total end loss of each ply time total spread plies	1.638	1306.784	0.13%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1325.258 * 1.155	1530.673		
Minus remnant area of the last roll = Actual usable area of all rolls	=18.474 * 1.155	21.337	1509.336	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(37.089-3.949) * 39	1292.460		85.63%
2. Total area of marker fallout	Fallout area * spread plies =3.949 * 39	154.011		10.20%
3. Splicing loss	Total length of splice loss * marker width = 10.355 * 1.118	11.577		0.77%
4. Splicing allowance	Total length of splice allowance * marker width = 1.005 * 1.118	1.124		0.07%
5. End loss	Total length of end loss * marker width = 1.638 * 1.118	1.831		0.12%
6. Width loss	Actual used length of all rolls * measured width loss = 1306.784 * 0.037	48.351	1509.354	3.20%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 13

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1780.134		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		67.448	1712.686	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =26.516 * 64	1697.024		99.09%
2. Splicing loss		7.061		0.41%
3. Splice allowance		1.689		0.10%
4. End loss	Total end loss of each ply time total spread plies	6.912	1712.686	0.40%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1780.134 * 1.479	2632.818		
Minus remnant area of the last roll = Actual usable area of all rolls	= 67.448 * 1.479	99.756	2533.063	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(37.706 - 4.612) * 64	2118.016		83.61%
2. Total area of marker fallout	Fallout area * spread plies =4.612 * 64	295.168		11.65%
3. Splicing loss	Total length of splice loss * marker width = 7.061 * 1.422	10.041		0.40%
4. Splicing allowance	Total length of splice allowance * marker width = 1.689 * 1.422	2.402		0.09%
5. End loss	Total length of end loss * marker width = 6.912 * 1.422	9.829		0.39%
6. Width loss	Actual used length of all rolls * measured width loss = 1712.686 * 0.057	97.623	2533.078	3.85%
Difference			-0.016	100.00%

Report of Fabric Wastage of Sample 14

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1496.95		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		0	1496.95	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =23.186 * 64	1483.904		99.13%
2. Splicing loss		5.683		0.38%
3. Splice allowance		1.027		0.07%
4. End loss	Total end loss of each ply time total spread plies	6.336	1496.95	0.42%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1496.95 * 1.459	2184.05		
Minus remnant area of the last roll = Actual usable area of all rolls		0.000	2184.05	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(32.97-3.919) * 64	1859.264		85.13%
2. Total area of marker fallout	Fallout area * spread plies =3.919 * 64	250.816		11.48%
3. Splicing loss	Total length of splice loss * marker width = 5.683 * 1.422	8.081		0.37%
4. Splicing allowance	Total length of splice allowance * marker width = 1.027 * 1.422	1.460		0.07%
5. End loss	Total length of end loss * marker width = 6.336 * 1.422	9.010		0.41%
6. Width loss	Actual used length of all rolls * measured width loss = 1496.95 * 0.037	55.387	2184.019	2.54%
Difference			0.031	100.00%

Report of Fabric Wastage of Sample 15

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1671.818		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		4.066	1667.752	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =22.616 * 73	1650.968		98.99%
2. Splicing loss		10.65		0.64%
3. Splice allowance		1.17		0.07%
4. End loss	Total end loss of each ply time total spread plies	4.964	1667.752	0.30%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1671.818 * 1.452	2427.48		
Minus remnant area of the last roll = Actual usable area of all rolls		5.904	2421.576	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(32.16-3.422) * 73	2097.874		86.63%
2. Total area of marker fallout	Fallout area * spread plies =3.422 * 73	249.806		10.32%
3. Splicing loss	Total length of splice loss * marker width = 10.65 * 1.422	15.144		0.63%
4. Splicing allowance	Total length of splice allowance * marker width = 1.17 * 1.422	1.664		0.07%
5. End loss	Total length of end loss * marker width = 4.964 * 1.422	7.059		0.29%
6. Width loss	Actual used length of all rolls * measured width loss = 1667.752 * 0.03	50.033	2421.579	2.07%
Difference			-0.004	100.00%

Report of Fabric Wastage of Sample 16

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1083.106		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		6.563	1076.543	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =16.863 * 63	1062.369		98.68%
2. Splicing loss		7.025		0.65%
3. Splice allowance		2.235		0.21%
4. End loss	Total end loss of each ply time total spread plies	4.914	1076.543	0.46%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1083.106 * 1.459	1580.252		
Minus remnant area of the last roll = Actual usable area of all rolls	=6.563 * 1.459	9.575	1570.676	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(23.979-2.748) * 63	1337.553		85.16%
2. Total area of marker fallout	Fallout area * spread plies =2.748 * 63	173.124		11.02%
3. Splicing loss	Total length of splice loss * marker width = 7.025 * 1.422	9.990		0.64%
4. Splicing allowance	Total length of splice allowance * marker width = 2.235 * 1.422	3.178		0.20%
5. End loss	Total length of end loss * marker width = 4.914 * 1.422	6.988		0.44%
6. Width loss	Actual used length of all rolls * measured width loss = 1076.543 * 0.037	39.832	1570.665	2.54%
Difference			0.012	100.00%

Report of Fabric Wastage of Sample 17

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1684.903		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		0.828	1684.075	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =16.628 * 100	1662.8		98.74%
2. Splicing loss		12.38		0.74%
3. Splice allowance		0.69		0.04%
4. End loss	Total end loss of each ply time total spread plies	8.205	1684.075	0.49%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1684.903 * 1.475	2485.232		
Minus remnant area of the last roll = Actual usable area of all rolls	=0.828 * 1.475	1.221	2484.011	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(23.961-2.744) * 100	2121.700		85.41%
2. Total area of marker fallout	Fallout area * spread plies =2.744 * 100	274.400		11.05%
3. Splicing loss	Total length of splice loss * marker width = 12.38 * 1.441	17.840		0.72%
4. Splicing allowance	Total length of splice allowance * marker width = 0.69 * 1.441	0.994		0.04%
5. End loss	Total length of end loss * marker width = 8.205 * 1.441	11.823		0.48%
6. Width loss	Actual used length of all rolls * measured width loss = 1684.075 * 0.034	57.259	2484.016	2.31%
Difference			-0.005	100.00%

Report of Fabric Wastage of Sample 18

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1941.904		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		12.8	1929.104	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =28.505 * 67	1909.835		99.00%
2. Splicing loss		13.06		0.68%
3. Splice allowance		1.815		0.09%
4. End loss	Total end loss of each ply time total spread plies	4.394	1929.104	0.23%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1941.904 * 1.144	2221.538		
Minus remnant area of the last roll = Actual usable area of all rolls	=12.8 * 1.144	14.643	2206.895	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(31.869-3.036) * 67	1931.811		87.54%
2. Total area of marker fallout	Fallout area * spread plies =3.036 * 67	203.412		9.22%
3. Splicing loss	Total length of splice loss * marker width = 13.06 * 1.118	14.601		0.66%
4. Splicing allowance	Total length of splice allowance * marker width = 1.815 * 1.118	2.029		0.09%
5. End loss	Total length of end loss * marker width = 4.394 * 1.118	4.912		0.22%
6. Width loss	Actual used length of all rolls * measured width loss = 1929.104 * 0.026	50.157	2206.922	2.27%
Difference			-0.027	100.00%

Report of Fabric Wastage of Sample 19

A. Loss Calculation In Terms Of Length

Item	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		2253.728		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		3.994	2249.734	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.094 * 89	2233.366		99.27%
2. Splicing loss		8.125		0.36%
3. Splice allowance		1.835		0.08%
4. End loss	Total end loss of each ply time total spread plies	6.408	2249.734	0.28%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

Item	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =2253.728 * 1.516	3416.652		
Minus remnant area of the last roll = Actual usable area of all rolls	=3.994 * 1.516	6.055	3410.597	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(37.139 - 3.706) * 89	2975.537		87.24%
2. Total area of marker fallout	Fallout area * spread plies =3.706 * 89	329.834		9.67%
3. Splicing loss	Total length of splice loss * marker width = 8.125 * 1.48	12.025		0.35%
4. Splicing allowance	Total length of splice allowance * marker width = 1.835 * 1.48	2.716		0.08%
5. End loss	Total length of end loss * marker width = 6.408 * 1.48	9.484		0.28%
6. Width loss	Actual used length of all rolls * measured width loss = 2249.734 * 0.036	80.990	3410.586	2.37%
Difference			0.011	100.00%

Report of Fabric Wastage of Sample 20

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		2269.113		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		16.494	2252.619	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.094 * 89	2233.366		99.15%
2. Splicing loss		10.017		0.44%
3. Splice allowance		2.383		0.11%
4. End loss	Total end loss of each ply time total spread plies	6.853	2252.619	0.30%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =2269.113 * 1.515	3437.706		
Minus remnant area of the last roll = Actual usable area of all rolls	=16.494 * 1.515	24.988	3412.718	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(37.139 - 3.706) * 89	2975.537		87.19%
2. Total area of marker fallout	Fallout area * spread plies =3.706 * 89	329.834		9.66%
3. Splicing loss	Total length of splice loss * marker width = 10.017 * 1.48	14.825		0.43%
4. Splicing allowance	Total length of splice allowance * marker width = 2.383 * 1.48	3.527		0.10%
5. End loss	Total length of end loss * marker width = 6.853 * 1.48	10.142		0.30%
6. Width loss	Actual used length of all rolls * measured width loss = 2252.619 * 0.035	78.842	3412.707	2.31%
Difference			0.011	100.00%

Report of Fabric Wastage of Sample 21

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1744.442		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		73	1671.442	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.094 * 66	1656.204		99.09%
2. Splicing loss		8.776		0.53%
3. Splice allowance		1.314		0.08%
4. End loss	Total end loss of each ply time total spread plies	5.148	1671.442	0.31%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1744.442 * 1.5	2616.663		
Minus remnant area of the last roll = Actual usable area of all rolls	=73 * 1.5	109.500	2507.163	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(37.139 - 3.706) * 66	2206.578		88.01%
2. Total area of marker fallout	Fallout area * spread plies =3.706 * 66	244.596		9.76%
3. Splicing loss	Total length of splice loss * marker width = 8.776 * 1.48	12.988		0.52%
4. Splicing allowance	Total length of splice allowance * marker width = 1.314 * 1.48	1.945		0.08%
5. End loss	Total length of end loss * marker width = 5.148 * 1.48	7.619		0.30%
6. Width loss	Actual used length of all rolls * measured width loss = 1671.442 * 0.02	33.429	2507.155	1.33%
Difference			0.008	100.00%

Report of Fabric Wastage of Sample 22

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1424.844		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		2.919	1421.925	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.669 * 55	1411.795		99.29%
2. Splicing loss		7.15		0.50%
3. Splice allowance		0.7		0.05%
4. End loss	Total end loss of each ply time total spread plies	2.31	1421.955	0.16%
Difference			-0.03	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1424.844 * 1.511	2152.939		
Minus remnant area of the last roll = Actual usable area of all rolls	=2.919 * 1.511	4.411	2148.529	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(38.144-3.54) * 55	1903.220		88.58%
2. Total area of marker fallout	Fallout area * spread plies =3.54 * 55	194.700		9.06%
3. Splicing loss	Total length of splice loss * marker width = 7.12 * 1.486	10.580		0.49%
4. Splicing allowance	Total length of splice allowance * marker width = 0.7 * 1.486	1.040		0.05%
5. End loss	Total length of end loss * marker width = 2.31 * 1.486	3.433		0.16%
6. Width loss	Actual used length of all rolls * measured width loss = 1421.925 * 0.025	35.548	2148.521	1.65%
Difference			0.007	100.00%

Report of Fabric Wastage of Sample 23

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1347.65		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		19.5	1328.15	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =16.91 * 78	1318.98		99.31%
2. Splicing loss		3.87		0.29%
3. Splice allowance		0.62		0.05%
4. End loss	Total end loss of each ply time total spread plies	4.68	1328.15	0.35%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1347.65 * 1.135	1529.583		
Minus remnant area of the last roll = Actual usable area of all rolls	=19.5 * 1.135	22.133	1507.45	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(18.635-1.858) * 78	1308.606		86.81%
2. Total area of marker fallout	Fallout area * spread plies =1.858 * 78	144.924		9.61%
3. Splicing loss	Total length of splice loss * marker width = 3.87 * 1.102	4.265		0.28%
4. Splicing allowance	Total length of splice allowance * marker width = 0.62 * 1.102	0.683		0.05%
5. End loss	Total length of end loss * marker width = 4.68 * 1.102	5.157		0.34%
6. Width loss	Actual used length of all rolls * measured width loss = 1328.15 * 0.033	43.829	1507.464	2.91%
Difference			-0.014	100.00%

Report of Fabric Wastage of Sample 24

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1500.919		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		89	1411.919	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.793 * 119	1403.367		99.39%
2. Splicing loss		3.175		0.22%
3. Splice allowance		0.855		0.06%
4. End loss	Total end loss of each ply time total spread plies	4.522	1411.919	0.32%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1500.919 * 1.151	1727.558		
Minus remnant area of the last roll = Actual usable area of all rolls	=89 * 1.151	102.439	1625.119	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(13.373-1.333) * 119	1432.760		88.16%
2. Total area of marker fallout	Fallout area * spread plies =1.333 * 119	158.627		9.76%
3. Splicing loss	Total length of splice loss * marker width = 3.175 * 1.134	3.600		0.22%
4. Splicing allowance	Total length of splice allowance * marker width = 0.855 * 1.134	0.970		0.06%
5. End loss	Total length of end loss * marker width = 4.522 * 1.134	5.128		0.32%
6. Width loss	Actual used length of all rolls * measured width loss = 1411.919 * 0.017	24.003	1625.088	1.48%
Difference			0.031	100.00%

Report of Fabric Wastage of Sample 25

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1344.93		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		36.3	1308.63	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =19.978 * 65	1298.57		99.23%
2. Splicing loss		4.574		0.35%
3. Splice allowance		1.586		0.12%
4. End loss	Total end loss of each ply time total spread plies	3.9	1308.63	0.30%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1344.93 * 1.501	2018.74		
Minus remnant area of the last roll = Actual usable area of all rolls	=36.3 * 1.501	54.486	1964.254	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(29.308-3.315) * 65	1689.545		86.01%
2. Total area of marker fallout	Fallout area * spread plies =3.315 * 65	215.475		10.97%
3. Splicing loss	Total length of splice loss * marker width = 4.574 * 1.467	6.710		0.34%
4. Splicing allowance	Total length of splice allowance * marker width = 1.586 * 1.467	2.327		0.12%
5. End loss	Total length of end loss * marker width = 3.9 * 1.467	5.721		0.29%
6. Width loss	Actual used length of all rolls * measured width loss = 1308.63 * 0.034	44.493	1964.271	2.27%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 26

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1560.096		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		10.568	1549.528	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =34.868 * 44	1534.192		99.01%
2. Splicing loss		11.01		0.71%
3. Splice allowance		1.73		0.11%
4. End loss	Total end loss of each ply time total spread plies	2.596	1549.528	0.17%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1560.096 * 1.158	1806.591		
Minus remnant area of the last roll = Actual usable area of all rolls	=10.568 * 1.158	12.238	1794.353	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(38.982-4.042) * 44	1537.36		85.68%
2. Total area of marker fallout	Fallout area * spread plies =4.042 * 44	177.848		9.91%
3. Splicing loss	Total length of splice loss * marker width = 11.01 * 1.118	12.309		0.69%
4. Splicing allowance	Total length of splice allowance * marker width = 1.73 * 1.118	1.934		0.11%
5. End loss	Total length of end loss * marker width = 2.596 * 1.118	2.902		0.16%
6. Width loss	Actual used length of all rolls * measured width loss = 1549.528 * 0.04	61.981	1794.335	3.45%
Difference			0.018	100.00%

Report of Fabric Wastage of Sample 27

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1160.663		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		4.769	1155.894	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.469 * 79	1143.051		98.89%
2. Splicing loss		7.69		0.67%
3. Splice allowance		0.65		0.06%
4. End loss	Total end loss of each ply time total spread plies	4.503	1155.894	0.39%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1160.663 * 1.155	1340.566		
Minus remnant area of the last roll = Actual usable area of all rolls	=4.769 * 1.155	5.508	1335.058	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(16.176-1.472) * 79	1161.616		87.01%
2. Total area of marker fallout	Fallout area * spread plies =1.472 * 79	116.288		8.71%
3. Splicing loss	Total length of splice loss * marker width = 7.69 * 1.118	8.597		0.64%
4. Splicing allowance	Total length of splice allowance * marker width = 0.65 * 1.118	0.727		0.05%
5. End loss	Total length of end loss * marker width = 4.503 * 1.118	5.034		0.38%
6. Width loss	Actual used length of all rolls * measured width loss = 1155.894 * 0.037	42.768	1335.031	3.20%
Difference			0.027	100.00%

Report of Fabric Wastage of Sample 28

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1454.412		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		126	1328.412	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.872 * 51	1319.472		99.33%
2. Splicing loss		4.224		0.32%
3. Splice allowance		1.656		0.12%
4. End loss	Total end loss of each ply time total spread plies	3.06	1328.412	0.23%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1454.412 * 1.507	2191.799		
Minus remnant area of the last roll = Actual usable area of all rolls	=126 * 1.507	189.882	2001.917	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(38.109-3.434) * 51	1768.425		88.34%
2. Total area of marker fallout	Fallout area * spread plies =3.434 * 51	175.134		8.75%
3. Splicing loss	Total length of splice loss * marker width = 4.224 * 1.473	6.222		0.31%
4. Splicing allowance	Total length of splice allowance * marker width = 1.656 * 1.473	2.439		0.12%
5. End loss	Total length of end loss * marker width = 3.06 * 1.473	4.507		0.23%
6. Width loss	Actual used length of all rolls * measured width loss = 1328.412 * 0.034	45.166	2001.894	2.26%
Difference			0.023	100.00%

Report of Fabric Wastage of Sample 29

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1285.178		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		8.05	1277.128	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =33.174 * 38	1260.612		98.71%
2. Splicing loss		13.065		1.02%
3. Splice allowance		1.285		0.10%
4. End loss	Total end loss of each ply time total spread plies	2.166	1277.128	0.17%
Difference			0	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1285.178 * 1.149	1476.67		
Minus remnant area of the last roll = Actual usable area of all rolls	=8.05 * 1.149	9.249	1467.42	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(37.089-3.949) * 38	1259.320		85.82%
2. Total area of marker fallout	Fallout area * spread plies =3.949 * 38	150.062		10.23%
3. Splicing loss	Total length of splice loss * marker width = 13.065 * 1.118	14.607		1.00%
4. Splicing allowance	Total length of splice allowance * marker width = 1.285 * 1.118	1.437		0.10%
5. End loss	Total length of end loss * marker width = 2.166 * 1.118	2.422		0.17%
6. Width loss	Actual used length of all rolls * measured width loss = 1277.128 * 0.031	39.591	1467.438	2.70%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 30

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1450.068		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		0	1450.068	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =25.669 * 56	1437.464		99.13%
2. Splicing loss		8.4		0.58%
3. Splice allowance		0.9		0.06%
4. End loss	Total end loss of each ply time total spread plies	3.304	1450.068	0.23%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1450.068 * 1.513	2193.953		
Minus remnant area of the last roll = Actual usable area of all rolls		0.000	2193.953	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(38.144-3.54) * 56	1937.824		88.33%
2. Total area of marker fallout	Fallout area * spread plies =3.54 * 56	198.240		9.04%
3. Splicing loss	Total length of splice loss * marker width = 8.4 * 1.486	12.482		0.57%
4. Splicing allowance	Total length of splice allowance * marker width = 0.9 * 1.486	1.337		0.06%
5. End loss	Total length of end loss * marker width = 3.304 * 1.486	4.910		0.22%
6. Width loss	Actual used length of all rolls * measured width loss = 1450.068 * 0.027	39.152	2193.945	1.78%
Difference			0.008	100.00%

APPENDIX B

Regression Outputs of input variables taken from the men's shirt factory

Regression outputs on marker width w against the prediction error ε

Regression Statistics	
Multiple R	0.087832972
R Square	0.007714631
Adjusted R Square	-0.027724132
Standard Error	0.002241848
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.09408E-06	1.09408E-06	0.217689057	0.64441634
Residual	28	0.000140725	5.02588E-06		
Total	29	0.000141819			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.003319048	0.003139033	1.057347263	0.299390596	-0.003110977	0.009749073	-0.003110977	0.009749073
X Variable 1	-0.001116412	0.002392799	-0.466571599	0.64441634	-0.006017844	0.00378502	-0.006017844	0.00378502

Regression outputs on total area of fabric used WL_t against the prediction error ε

Regression Statistics	
Multiple R	0.016577641
R Square	0.000274818
Adjusted R Square	-0.035429653
Standard Error	0.002250236
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.89744E-08	3.89744E-08	0.007697025	0.930713596
Residual	28	0.00014178	5.06356E-06		
Total	29	0.000141819			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.002016691	0.001755333	1.148893458	0.260320064	-0.00157895	0.005612332	-0.00157895	0.005612332
X Variable 1	-7.22797E-08	8.23863E-07	-0.087732689	0.930713596	-1.75989E-06	1.61533E-06	-1.75989E-06	1.61533E-06

Regression outputs on marker length m against the prediction error ε

Regression Statistics	
Multiple R	0.013906672
R Square	0.000193396
Adjusted R Square	-0.035513983
Standard Error	0.002250328
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.74271E-08	2.74271E-08	0.005416122	0.94185644
Residual	28	0.000141791	5.06398E-06		
Total	29	0.000141819			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.001738507	0.001793225	0.969486647	0.340603023	-0.001934751	0.005411766	-0.001934751	0.005411766
X Variable 1	5.26876E-06	7.1592E-05	0.073594308	0.94185644	-0.000141381	0.000151918	-0.000141381	0.000151918

Regression outputs on total number of fabric plies P against the prediction error ε

Regression Statistics	
Multiple R	0.017424821
R Square	0.000303624
Adjusted R Square	-0.035399818
Standard Error	0.002250204
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.30596E-08	4.30596E-08	0.008504065	0.927181884
Residual	28	0.000141776	5.06342E-06		
Total	29	0.000141819			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.001727913	0.001562863	1.105607478	0.278306076	-0.001473471	0.004929297	-0.001473471	0.004929297
X Variable 1	2.1404E-06	2.32104E-05	0.092217486	0.927181884	-4.54039E-05	4.96847E-05	-4.54039E-05	4.96847E-05

Regression outputs on length of remnant V_p against the prediction error ε

Regression Statistics	
Multiple R	0.988534287
R Square	0.977200037
Adjusted R Square	0.976385752
Standard Error	0.000339825
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000138585	0.000138585	1200.072145	1.54965E-24
Residual	28	3.23346E-06	1.15481E-07		
Total	29	0.000141819			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.000104744	8.02313E-05	1.305531337	0.202337913	-5.96021E-05	0.000269091	-5.96021E-05	0.000269091
X Variable 1	6.36285E-05	1.83674E-06	34.64205746	1.54965E-24	5.98661E-05	6.73909E-05	5.98661E-05	6.73909E-05

Regression outputs on total area of marker loss wB_i against the prediction error ε

Regression Statistics	
Multiple R	0.149018735
R Square	0.022206583
Adjusted R Square	-0.01271461
Standard Error	0.002225417
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	1	3.14931E-06	3.14931E-06	0.635905625	0.431908225
Residual	28	0.000138669	4.95248E-06		
Total	29	0.000141819			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.003106683	0.001606842	1.933409548	0.063354574	-0.000184787	0.006398153	-0.000184787	0.006398153
X Variable 1	-6.11569E-06	7.66918E-06	-0.797436909	0.431908225	-2.18253E-05	9.59394E-06	-2.18253E-05	9.59394E-06

APPENDIX C

Fabric Wastage Report of Sample Cutting Lay
(Measured From The Pant's Factory)

Report of Fabric Wastage of Sample 1

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1259.463		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		87	1172.463	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =9.597 * 120	1151.64		98.22%
2. Splicing loss		11.553		0.99%
3. Splice allowance		2.297		0.20%
4. End loss	Total end loss of each ply times total spread plies	6.973	1172.463	0.59%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1259.463 * 1.121	1411.858		
Minus remnant area of the last roll = Actual usable area of all rolls	=87 * 1.121	97.527	1314.331	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(10.48-1.115) * 120	1123.800		85.50%
2. Total area of marker fallout	Fallout area * spread plies =1.115 * 120	133.800		10.18%
3. Splicing loss	Total length of splice loss * marker width = 11.553 * 1.092	12.616		0.96%
4. Splicing allowance	Total length of splice allowance * marker width = 2.297 * 1.092	2.508		0.19%
5. End loss	Total length of end loss * marker width = 6.973 * 1.092	7.615		0.58%
6. Width loss	Actual used length of all rolls * measured width loss = 1172.463 * 0.029	34.000	1314.339	2.59%
Difference			-0.008	100.00%

Report of Fabric Wastage of Sample 2

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1821.236		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		34.6	1786.636	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =13.984 * 126	1761.984		98.62%
2. Splicing loss		16.06		0.90%
3. Splice allowance		1.41		0.08%
4. End loss	Total end loss of each ply times total spread plies	7.182	1786.636	0.40%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1821.236 * 1.503	2737.318		
Minus remnant area of the last roll = Actual usable area of all rolls	=34.6 * 1.503	52.000	2685.318	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(20.598-2.068) * 126	2334.780		86.95%
2. Total area of marker fallout	Fallout area * spread plies =2.068 * 126	260.568		9.70%
3. Splicing loss	Total length of splice loss * marker width = 16.06 * 1.473	23.656		0.88%
4. Splicing allowance	Total length of splice allowance * marker width = 1.41 * 1.473	2.077		0.08%
5. End loss	Total length of end loss * marker width = 7.182 * 1.473	10.580		0.39%
6. Width loss	Actual used length of all rolls * measured width loss = 1786.636 * 0.03	53.600	2685.261	2.00%
Difference			0.057	100.00%

Report of Fabric Wastage of Sample 3

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1470.364		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		44.2	1426.164	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.699 * 120	1403.88		98.44%
2. Splicing loss		13.234		0.93%
3. Splice allowance		1.97		0.14%
4. End loss	Total end loss of each ply times total spread plies	7.08	1426.164	0.50%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1470.364 * 1.112	1635.045		
Minus remnant area of the last roll = Actual usable area of all rolls	=44.2 * 1.112	49.150	1585.894	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(12.623-1.275) * 120	1361.760		85.87%
2. Total area of marker fallout	Fallout area * spread plies =1.275 * 120	153.000		9.65%
3. Splicing loss	Total length of splice loss * marker width = 13.234 * 1.08	14.293		0.90%
4. Splicing allowance	Total length of splice allowance * marker width = 1.97 * 1.08	2.128		0.13%
5. End loss	Total length of end loss * marker width = 7.08 * 1.08	7.646		0.48%
6. Width loss	Actual used length of all rolls * measured width loss = 1426.164 * 0.033	47.063	1585.890	2.97%
Difference			0.004	100.00%

Report of Fabric Wastage of Sample 4

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1847.296		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		59	1788.296	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.59 * 140	1762.6		98.56%
2. Splicing loss		13.69		0.77%
3. Splice allowance		3.08		0.17%
4. End loss	Total end loss of each ply times total spread plies	8.926	1788.296	0.50%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1847.296 * 1.121	2070.819		
Minus remnant area of the last roll = Actual usable area of all rolls	=59 * 1.121	66.139	2004.68	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(13.748-1.602) * 140	1700.440		84.82%
2. Total area of marker fallout	Fallout area * spread plies =1.602 * 140	224.280		11.19%
3. Splicing loss	Total length of splice loss * marker width = 13.69 * 1.092	14.949		0.75%
4. Splicing allowance	Total length of splice allowance * marker width = 3.08 * 1.092	3.363		0.17%
5. End loss	Total length of end loss * marker width = 8.926 * 1.092	9.747		0.49%
6. Width loss	Actual used length of all rolls * measured width loss = 1788.296 * 0.029	51.861	2004.641	2.59%
Difference			0.039	100.00%

Report of Fabric Wastage of Sample 5

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		2211.746		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		0	2211.746	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =19.01 * 115	2186.15		98.84%
2. Splicing loss		15.146		0.68%
3. Splice allowance		2.86		0.13%
4. End loss	Total end loss of each ply times total spread plies	7.59	2211.746	0.34%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =2211.746 * 1.146	2534.661		
Minus remnant area of the last roll = Actual usable area of all rolls	=0	0.000	2534.661	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(21.253-2.236) * 115	2186.955		86.28%
2. Total area of marker fallout	Fallout area * spread plies =2.236 * 115	257.140		10.14%
3. Splicing loss	Total length of splice loss * marker width = 15.146 * 1.118	16.933		0.67%
4. Splicing allowance	Total length of splice allowance * marker width = 2.86 * 1.118	3.197		0.13%
5. End loss	Total length of end loss * marker width = 7.59 * 1.118	8.486		0.33%
6. Width loss	Actual used length of all rolls * measured width loss = 2211.746 * 0.028	61.929	2534.640	2.44%
Difference			0.021	100.00%

Report of Fabric Wastage of Sample 6

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1564.589		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		82	1482.589	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.699 * 125	1462.375		98.64%
2. Splicing loss		10.791		0.73%
3. Splice allowance		1.923		0.13%
4. End loss	Total end loss of each ply times total spread plies	7.5	1482.589	0.51%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1564.589 * 1.107	1732		
Minus remnant area of the last roll = Actual usable area of all rolls	=82 * 1.107	90.774	1641.226	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(12.623-1.275) * 125	1418.500		86.43%
2. Total area of marker fallout	Fallout area * spread plies =1.275 * 125	159.375		9.71%
3. Splicing loss	Total length of splice loss * marker width = 10.791 * 1.08	11.654		0.71%
4. Splicing allowance	Total length of splice allowance * marker width = 1.923 * 1.08	2.077		0.13%
5. End loss	Total length of end loss * marker width = 7.5 * 1.08	8.100		0.49%
6. Width loss	Actual used length of all rolls * measured width loss = 1482.589 * 0.028	41.512	1641.219	2.53%
Difference			0.007	100.00%

Report of Fabric Wastage of Sample 7

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1725.686		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		97.92	1627.766	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =13.6 * 118	1604.8		98.59%
2. Splicing loss		13.104		0.81%
3. Splice allowance		2.9		0.18%
4. End loss	Total end loss of each ply times total spread plies	6.962	1627.766	0.43%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1725.686 * 1.509	2604.06		
Minus remnant area of the last roll = Actual usable area of all rolls	=97.92 * 1.509	147.761	2456.299	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(20.033-1.945) * 118	2134.384		86.89%
2. Total area of marker fallout	Fallout area * spread plies =1.945 * 118	229.510		9.34%
3. Splicing loss	Total length of splice loss * marker width = 13.104 * 1.473	19.302		0.79%
4. Splicing allowance	Total length of splice allowance * marker width = 2.9 * 1.473	4.272		0.17%
5. End loss	Total length of end loss * marker width = 6.962 * 1.473	10.255		0.42%
6. Width loss	Actual used length of all rolls * measured width loss = 1627.766 * 0.036	58.59958	2456.322	2.39%
Difference			-0.024	100.00%

Report of Fabric Wastage of Sample 8

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1624.849		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		72.5	1552.349	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =10.21 * 150	1531.5		98.66%
2. Splicing loss		10.409		0.67%
3. Splice allowance		1.89		0.12%
4. End loss	Total end loss of each ply times total spread plies	8.55	1552.349	0.55%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1624.849 * 1.503	2442.148		
Minus remnant area of the last roll = Actual usable area of all rolls	=72.5 * 1.503	108.9675	2333.181	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(15.039-1.62) * 150	2012.85		86.27%
2. Total area of marker fallout	Fallout area * spread plies =1.62 * 150	243.000		10.41%
3. Splicing loss	Total length of splice loss * marker width = 10.409 * 1.473	15.332		0.66%
4. Splicing allowance	Total length of splice allowance * marker width = 1.89 * 1.473	2.784		0.12%
5. End loss	Total length of end loss * marker width = 8.55 * 1.473	12.594		0.54%
6. Width loss	Actual used length of all rolls * measured width loss = 1552.349 * 0.03	46.570	2333.131	2.00%
Difference			0.049	100.00%

Report of Fabric Wastage of Sample 9

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1681.077		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		69	1612.077	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =10.97 * 145	1590.65		98.67%
2. Splicing loss		11.482		0.71%
3. Splice allowance		1.26		0.08%
4. End loss	Total end loss of each ply times total spread plies	8.685	1612.077	0.54%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1681.077 * 1.126	1892.893		
Minus remnant area of the last roll = Actual usable area of all rolls	=69 * 1.126	77.694	1815.199	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(11.979-1.518) * 145	1516.845		83.56%
2. Total area of marker fallout	Fallout area * spread plies =1.518 * 145	220.110		12.13%
3. Splicing loss	Total length of splice loss * marker width = 11.482 * 1.092	12.538		0.69%
4. Splicing allowance	Total length of splice allowance * marker width = 1.26 * 1.092	1.376		0.08%
5. End loss	Total length of end loss * marker width = 8.685 * 1.092	9.484		0.52%
6. Width loss	Actual used length of all rolls * measured width loss = 1612.077 * 0.034	54.811	1815.164	3.02%
Difference			0.035	100.00%

Report of Fabric Wastage of Sample 10

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1867.675		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		52	1815.675	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.796 * 140	1791.44		98.67%
2. Splicing loss		13.851		0.76%
3. Splice allowance		1.844		0.10%
4. End loss	Total end loss of each ply times total spread plies	8.54	1815.675	0.47%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1867.675 * 1.548	2891.161		
Minus remnant area of the last roll = Actual usable area of all rolls	=52 * 1.548	80.496	2810.665	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(19.501-1.966) * 140	2454.9		87.34%
2. Total area of marker fallout	Fallout area * spread plies =1.966 * 140	275.240		9.79%
3. Splicing loss	Total length of splice loss * marker width = 13.851 * 1.524	21.109		0.75%
4. Splicing allowance	Total length of splice allowance * marker width = 1.844 * 1.524	2.810		0.10%
5. End loss	Total length of end loss * marker width = 8.54 * 1.524	13.015		0.46%
6. Width loss	Actual used length of all rolls * measured width loss = 1815.675 * 0.024	43.5762	2810.650	1.55%
Difference			0.015	100.00%

Report of Fabric Wastage of Sample 11

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1964.25		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		93	1871.25	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.8 * 125	1850		98.86%
2. Splicing loss		15.89		0.85%
3. Splice allowance		1.61		0.09%
4. End loss	Total end loss of each ply times total spread plies	3.75	1871.25	0.20%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1964.25 * 1.127	2213.71		
Minus remnant area of the last roll = Actual usable area of all rolls	=93 * 1.127	104.811	2108.899	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(16.162-2.048) * 125	1764.25		83.66%
2. Total area of marker fallout	Fallout area * spread plies =2.048 * 125	256.000		12.14%
3. Splicing loss	Total length of splice loss * marker width = 15.89 * 1.092	17.352		0.82%
4. Splicing allowance	Total length of splice allowance * marker width = 1.61 * 1.092	1.758		0.08%
5. End loss	Total length of end loss * marker width = 3.75 * 1.092	4.095		0.19%
6. Width loss	Actual used length of all rolls * measured width loss = 1871.25 * 0.035	65.494	2108.949	3.11%
Difference			-0.050	100.00%

Report of Fabric Wastage of Sample 12

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1851.95		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		60	1791.95	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.7 * 120	1764		98.44%
2. Splicing loss		19.07		1.06%
3. Splice allowance		1.68		0.09%
4. End loss	Total end loss of each ply times total spread plies	7.2	1791.95	0.40%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1851.95 * 1.132	2096.407		
Minus remnant area of the last roll = Actual usable area of all rolls	=60 * 1.132	67.920	2028.487	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(16.244-1.826) * 120	1730.16		85.29%
2. Total area of marker fallout	Fallout area * spread plies =1.826 * 120	219.120		10.80%
3. Splicing loss	Total length of splice loss * marker width = 19.07 * 1.105	21.072		1.04%
4. Splicing allowance	Total length of splice allowance * marker width = 1.68 * 1.105	1.856		0.09%
5. End loss	Total length of end loss * marker width = 7.2 * 1.105	7.956		0.39%
6. Width loss	Actual used length of all rolls * measured width loss = 1791.95 * 0.027	48.383	2028.547	2.39%
Difference			-0.060	100.00%

Report of Fabric Wastage of Sample 13

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1749.291		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		65.3	1683.991	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.796 * 130	1663.48		98.78%
2. Splicing loss		12.847		0.76%
3. Splice allowance		1.554		0.09%
4. End loss	Total end loss of each ply times total spread plies	6.11	1683.991	0.36%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1749.291 * 1.545	2702.655		
Minus remnant area of the last roll = Actual usable area of all rolls	=65.3 * 1.545	100.889	2601.766	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(19.501-1.966) * 130	2279.55		87.62%
2. Total area of marker fallout	Fallout area * spread plies =1.966 * 140	255.580		9.82%
3. Splicing loss	Total length of splice loss * marker width = 12.847 * 1.524	19.579		0.75%
4. Splicing allowance	Total length of splice allowance * marker width = 1.554 * 1.524	2.368		0.09%
5. End loss	Total length of end loss * marker width = 6.11 * 1.524	9.312		0.36%
6. Width loss	Actual used length of all rolls * measured width loss = 1683.991 * 0.021	35.36381	2601.753	1.36%
Difference			0.014	100.00%

Report of Fabric Wastage of Sample 14

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1584.096		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		98.4	1485.696	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.699 * 125	1462.375		98.43%
2. Splicing loss		16.045		1.08%
3. Splice allowance		1.33		0.09%
4. End loss	Total end loss of each ply times total spread plies	5.946	1485.696	0.40%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1584.096 * 1.105	1750.426		
Minus remnant area of the last roll = Actual usable area of all rolls	=98.4 * 1.105	108.732	1641.694	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(12.623-1.275) * 125	1418.500		86.40%
2. Total area of marker fallout	Fallout area * spread plies =1.275 * 125	159.375		9.71%
3. Splicing loss	Total length of splice loss * marker width = 16.045 * 1.08	17.329		1.06%
4. Splicing allowance	Total length of splice allowance * marker width = 1.33 * 1.08	1.436		0.09%
5. End loss	Total length of end loss * marker width = 5.946 * 1.08	6.422		0.39%
6. Width loss	Actual used length of all rolls * measured width loss = 1485.696 * 0.026	38.628	1641.690	2.35%
Difference			0.004	100.00%

Report of Fabric Wastage of Sample 15

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1768.141		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		39	1729.141	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.67 * 135	1710.45		98.92%
2. Splicing loss		10.631		0.61%
3. Splice allowance		2.39		0.14%
4. End loss	Total end loss of each ply times total spread plies	5.67	1729.141	0.33%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1768.141 * 1.499	2650.443		
Minus remnant area of the last roll = Actual usable area of all rolls	=39 * 1.499	58.461	2591.982	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(18.511-1.851) * 135	2249.100		86.77%
2. Total area of marker fallout	Fallout area * spread plies =1.851 * 135	249.885		9.64%
3. Splicing loss	Total length of splice loss * marker width = 10.631 * 1.461	15.532		0.60%
4. Splicing allowance	Total length of splice allowance * marker width = 2.39 * 1.461	3.492		0.13%
5. End loss	Total length of end loss * marker width = 5.67 * 1.461	8.284		0.32%
6. Width loss	Actual used length of all rolls * measured width loss = 1729.141 * 0.038	65.707	2592.000	2.54%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 16

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1717.683		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		86	1631.683	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.63 * 110	1609.3		98.63%
2. Splicing loss		14.313		0.88%
3. Splice allowance		1.47		0.09%
4. End loss	Total end loss of each ply times total spread plies	6.6	1631.683	0.40%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1717.683 * 1.206	2071.526		
Minus remnant area of the last roll = Actual usable area of all rolls	=86 * 1.206	103.716	1967.81	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(17.088-1.941) * 110	1666.170		84.67%
2. Total area of marker fallout	Fallout area * spread plies =1.941 * 110	213.510		10.85%
3. Splicing loss	Total length of splice loss * marker width = 14.313 * 1.168	16.718		0.85%
4. Splicing allowance	Total length of splice allowance * marker width = 1.47 * 1.168	1.717		0.09%
5. End loss	Total length of end loss * marker width = 6.6 * 1.168	7.709		0.39%
6. Width loss	Actual used length of all rolls * measured width loss = 1631.683 * 0.038	62.00395	1967.827	3.15%
Difference			-0.018	100.00%

Report of Fabric Wastage of Sample 17

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1747.376		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		46.6	1700.776	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =13.984 * 120	1678.08		98.67%
2. Splicing loss		16.41		0.96%
3. Splice allowance		1.126		0.07%
4. End loss	Total end loss of each ply times total spread plies	5.16	1700.776	0.30%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1747.376 * 1.498	2617.569		
Minus remnant area of the last roll = Actual usable area of all rolls	=46.6 * 1.498	69.807	2547.762	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(20.598-2.068) * 120	2223.6		87.28%
2. Total area of marker fallout	Fallout area * spread plies =2.068 * 120	248.16		9.74%
3. Splicing loss	Total length of splice loss * marker width = 16.41 * 1.473	24.172		0.95%
4. Splicing allowance	Total length of splice allowance * marker width = 1.126 * 1.473	1.659		0.07%
5. End loss	Total length of end loss * marker width = 5.16 * 1.473	7.601		0.30%
6. Width loss	Actual used length of all rolls * measured width loss = 1700.776 * 0.025	42.519	2547.711	1.67%
Difference			0.052	100.00%

Report of Fabric Wastage of Sample 18

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1542.95		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		44.2	1498.75	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =10.97 * 135	1480.95		98.81%
2. Splicing loss		10.055		0.67%
3. Splice allowance		1.13		0.08%
4. End loss	Total end loss of each ply times total spread plies	6.615	1498.75	0.44%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1542.95 * 1.123	1732.733		
Minus remnant area of the last roll = Actual usable area of all rolls	=44.2 * 1.123	49.637	1683.096	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(11.979-1.518) * 135	1412.235		83.91%
2. Total area of marker fallout	Fallout area * spread plies =1.518 * 135	204.93		12.18%
3. Splicing loss	Total length of splice loss * marker width = 10.055 * 1.092	10.980		0.65%
4. Splicing allowance	Total length of splice allowance * marker width = 1.13 * 1.092	1.234		0.07%
5. End loss	Total length of end loss * marker width = 6.615 * 1.092	7.224		0.43%
6. Width loss	Actual used length of all rolls * measured width loss = 1498.75 * 0.031	46.461	1683.064	2.76%
Difference			0.032	100.00%

Report of Fabric Wastage of Sample 19

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1737.68		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		17.5	1720.18	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.59 * 135	1699.65		98.81%
2. Splicing loss		13.18		0.77%
3. Splice allowance		1.41		0.08%
4. End loss	Total end loss of each ply times total spread plies	5.94	1720.18	0.35%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1737.68 * 1.118	1942.726		
Minus remnant area of the last roll = Actual usable area of all rolls	=17.5 * 1.118	19.565	1923.161	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(13.748-1.602) * 135	1639.710		85.26%
2. Total area of marker fallout	Fallout area * spread plies =1.602 * 135	216.270		11.25%
3. Splicing loss	Total length of splice loss * marker width = 13.18 * 1.092	14.393		0.75%
4. Splicing allowance	Total length of splice allowance * marker width = 1.41 * 1.092	1.540		0.08%
5. End loss	Total length of end loss * marker width = 5.94 * 1.092	6.486		0.34%
6. Width loss	Actual used length of all rolls * measured width loss = 1720.18 * 0.026	44.72468	1923.123	2.33%
Difference			0.038	100.00%

Report of Fabric Wastage of Sample 20

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1649.414		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		20	1629.414	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.49 * 140	1608.6		98.72%
2. Splicing loss		12.079		0.74%
3. Splice allowance		1.1		0.07%
4. End loss	Total end loss of each ply times total spread plies	7.635	1629.414	0.47%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1649.414 * 1.553	2561.54		
Minus remnant area of the last roll = Actual usable area of all rolls	=20 * 1.553	31.06	2530.48	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(17.511-1.821) * 140	2196.6		86.81%
2. Total area of marker fallout	Fallout area * spread plies =1.821 * 140	254.940		10.07%
3. Splicing loss	Total length of splice loss * marker width = 12.079 * 1.524	18.408		0.73%
4. Splicing allowance	Total length of splice allowance * marker width = 1.1 * 1.524	1.676		0.07%
5. End loss	Total length of end loss * marker width = 7.635 * 1.524	11.636		0.46%
6. Width loss	Actual used length of all rolls * measured width loss = 1629.414 * 0.029	47.253	2530.514	1.87%
Difference			-0.034	100.00%

Report of Fabric Wastage of Sample 21

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1669.812		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		34.3	1635.512	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =19.01 * 85	1615.85		98.80%
2. Splicing loss		13.747		0.84%
3. Splice allowance		1.41		0.09%
4. End loss	Total end loss of each ply times total spread plies	4.505	1635.512	0.28%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1669.812 * 1.143	1908.595		
Minus remnant area of the last roll = Actual usable area of all rolls	=34.3 * 1.143	39.205	1869.39	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(21.253-2.236) * 85	1616.445		86.47%
2. Total area of marker fallout	Fallout area * spread plies =2.236 * 85	190.06		10.17%
3. Splicing loss	Total length of splice loss * marker width = 13.747 * 1.118	15.369		0.82%
4. Splicing allowance	Total length of splice allowance * marker width = 1.41 * 1.118	1.576		0.08%
5. End loss	Total length of end loss * marker width = 4.505 * 1.118	5.037		0.27%
6. Width loss	Actual used length of all rolls * measured width loss = 1635.512 * 0.025	40.888	1869.375	2.19%
Difference			0.015	100.00%

Report of Fabric Wastage of Sample 22

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1573.806		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		20.5	1553.306	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.796 * 120	1535.52		98.85%
2. Splicing loss		10.758		0.69%
3. Splice allowance		1.148		0.07%
4. End loss	Total end loss of each ply times total spread plies	5.88	1553.306	0.38%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1573.806 * 1.555	2447.268		
Minus remnant area of the last roll = Actual usable area of all rolls	=20.5 * 1.555	31.878	2415.391	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(19.501-1.966) * 120	2104.2		87.12%
2. Total area of marker fallout	Fallout area * spread plies =1.966 * 120	235.920		9.77%
3. Splicing loss	Total length of splice loss * marker width = 10.758 * 1.524	16.395		0.68%
4. Splicing allowance	Total length of splice allowance * marker width = 1.148 * 1.524	1.750		0.07%
5. End loss	Total length of end loss * marker width = 5.88 * 1.524	8.961		0.37%
6. Width loss	Actual used length of all rolls * measured width loss = 1553.306 * 0.031	48.152	2415.378	1.99%
Difference			0.012	100.00%

Report of Fabric Wastage of Sample 23

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1644.724		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		78.2	1566.524	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.75 * 105	1548.75		98.87%
2. Splicing loss		11.039		0.70%
3. Splice allowance		1.26		0.08%
4. End loss	Total end loss of each ply times total spread plies	5.475	1566.524	0.35%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1644.724 * 1.529	2514.783		
Minus remnant area of the last roll = Actual usable area of all rolls	=78.2 * 1.529	119.568	2395.215	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(22.11-2.359) * 105	2073.855		86.58%
2. Total area of marker fallout	Fallout area * spread plies =2.359 * 105	247.695		10.34%
3. Splicing loss	Total length of splice loss * marker width = 11.039 * 1.499	16.547		0.69%
4. Splicing allowance	Total length of splice allowance * marker width = 1.26 * 1.499	1.889		0.08%
5. End loss	Total length of end loss * marker width = 5.475 * 1.499	8.207		0.34%
6. Width loss	Actual used length of all rolls * measured width loss = 1566.524 * 0.03	46.996	2395.189	1.96%
Difference			0.026	100.00%

Report of Fabric Wastage of Sample 24

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1968.082		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		98.9	1869.182	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =16.8 * 110	1848		98.87%
2. Splicing loss		13.472		0.72%
3. Splice allowance		1.44		0.08%
4. End loss	Total end loss of each ply times total spread plies	6.27	1869.182	0.34%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1968.082 * 1.116	2196.38		
Minus remnant area of the last roll = Actual usable area of all rolls	=98.9 * 1.116	110.372	2086.007	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(18.346-2.095) * 110	1787.61		85.70%
2. Total area of marker fallout	Fallout area * spread plies =2.095 * 110	230.45		11.05%
3. Splicing loss	Total length of splice loss * marker width = 13.472 * 1.092	14.711		0.71%
4. Splicing allowance	Total length of splice allowance * marker width = 1.44 * 1.092	1.572		0.08%
5. End loss	Total length of end loss * marker width = 6.27 * 1.092	6.847		0.33%
6. Width loss	Actual used length of all rolls * measured width loss = 1869.182 * 0.024	44.860	2086.051	2.15%
Difference			-0.044	100.00%

Report of Fabric Wastage of Sample 25

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1613.964		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		98.9	1515.064	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =13.6 * 110	1496		98.74%
2. Splicing loss		12.454		0.82%
3. Splice allowance		1.33		0.09%
4. End loss	Total end loss of each ply times total spread plies	5.28	1515.064	0.35%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1613.964 * 1.501	2422.56		
Minus remnant area of the last roll = Actual usable area of all rolls	=98.9 * 1.501	148.449	2274.111	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(20.033-1.945) * 110	1989.68		87.49%
2. Total area of marker fallout	Fallout area * spread plies =1.945 * 118	213.950		9.41%
3. Splicing loss	Total length of splice loss * marker width = 12.454 * 1.473	18.345		0.81%
4. Splicing allowance	Total length of splice allowance * marker width = 1.33 * 1.473	1.959		0.09%
5. End loss	Total length of end loss * marker width = 5.28 * 1.473	7.777		0.34%
6. Width loss	Actual used length of all rolls * measured width loss = 1515.064 * 0.028	42.422	2274.133	1.87%
Difference			-0.022	100.00%

Report of Fabric Wastage of Sample 26

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1607.251		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		56.5	1550.751	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =10.21 * 150	1531.5		98.76%
2. Splicing loss		10.261		0.66%
3. Splice allowance		1.34		0.09%
4. End loss	Total end loss of each ply times total spread plies	7.65	1550.751	0.49%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1607.251 * 1.502	2414.091		
Minus remnant area of the last roll = Actual usable area of all rolls	=56.5 * 1.502	84.863	2329.228	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(15.039-1.62) * 150	2012.85		86.42%
2. Total area of marker fallout	Fallout area * spread plies =1.62 * 150	243.000		10.43%
3. Splicing loss	Total length of splice loss * marker width = 10.261 * 1.473	15.114		0.65%
4. Splicing allowance	Total length of splice allowance * marker width = 1.34 * 1.473	1.974		0.08%
5. End loss	Total length of end loss * marker width = 7.65 * 1.473	11.268		0.48%
6. Width loss	Actual used length of all rolls * measured width loss = 1550.751 * 0.029	44.97178	2329.179	1.93%
Difference			0.049	100.00%

Report of Fabric Wastage of Sample 27

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1815.308		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		20.5	1794.808	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.8 * 120	1776		98.95%
2. Splicing loss		13.878		0.77%
3. Splice allowance		1.33		0.07%
4. End loss	Total end loss of each ply times total spread plies	3.6	1794.808	0.20%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1815.308 * 1.124	2040.406		
Minus remnant area of the last roll = Actual usable area of all rolls	=20.5 * 1.124	23.042	2017.364	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(16.162-2.048) * 120	1693.68		83.96%
2. Total area of marker fallout	Fallout area * spread plies =2.048 * 120	245.760		12.18%
3. Splicing loss	Total length of splice loss * marker width = 13.878 * 1.092	15.155		0.75%
4. Splicing allowance	Total length of splice allowance * marker width = 1.33 * 1.092	1.452		0.07%
5. End loss	Total length of end loss * marker width = 3.6 * 1.092	3.931		0.19%
6. Width loss	Actual used length of all rolls * measured width loss = 1794.808 * 0.032	57.434	2017.412	2.85%
Difference			-0.048	100.00%

Report of Fabric Wastage of Sample 28

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1644.954		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		10.6	1634.354	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.7 * 110	1617		98.94%
2. Splicing loss		10.964		0.67%
3. Splice allowance		1.22		0.07%
4. End loss	Total end loss of each ply times total spread plies	5.17	1634.354	0.32%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1644.954 * 1.132	1862.088		
Minus remnant area of the last roll = Actual usable area of all rolls	=10.6 * 1.132	11.999	1850.089	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(16.244-1.826) * 110	1585.98		85.72%
2. Total area of marker fallout	Fallout area * spread plies =1.826 * 110	200.860		10.86%
3. Splicing loss	Total length of splice loss * marker width = 10.964 * 1.105	12.115		0.65%
4. Splicing allowance	Total length of splice allowance * marker width = 1.22 * 1.105	1.348		0.07%
5. End loss	Total length of end loss * marker width = 5.17 * 1.105	5.713		0.31%
6. Width loss	Actual used length of all rolls * measured width loss = 1634.354 * 0.027	44.128	1850.144	2.39%
Difference			-0.055 *	100.00%

Report of Fabric Wastage of Sample 29

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1182.356		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		10.3	1172.056	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =9.597 * 120	1151.64		98.26%
2. Splicing loss		13.506		1.15%
3. Splice allowance		0.91		0.08%
4. End loss	Total end loss of each ply times total spread plies	6	1172.056	0.51%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1182.356 * 1.119	1323.056		
Minus remnant area of the last roll = Actual usable area of all rolls	=10.3 * 1.119	11.526	1311.531	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(10.48-1.115) * 120	1123.800		85.69%
2. Total area of marker fallout	Fallout area * spread plies =1.115 * 120	133.800		10.20%
3. Splicing loss	Total length of splice loss * marker width = 13.506 * 1.092	14.749		1.12%
4. Splicing allowance	Total length of splice allowance * marker width = 0.91 * 1.092	0.994		0.08%
5. End loss	Total length of end loss * marker width = 6 * 1.092	6.552		0.50%
6. Width loss	Actual used length of all rolls * measured width loss = 1172.056 * 0.027	31.646	1311.540	2.41%
Difference			-0.009	100.00%

Report of Fabric Wastage of Sample 30

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1601.185		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		60.5	1540.685	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.699 * 130	1520.87		98.71%
2. Splicing loss		12.874		0.84%
3. Splice allowance		1.091		0.07%
4. End loss	Total end loss of each ply times total spread plies	5.85	1540.685	0.38%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1601.185 * 1.107	1772.512		
Minus remnant area of the last roll = Actual usable area of all rolls	=60.5 * 1.107	66.974	1705.538	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(12.623-1.275) * 130	1475.240		86.50%
2. Total area of marker fallout	Fallout area * spread plies =1.275 * 130	165.750		9.72%
3. Splicing loss	Total length of splice loss * marker width = 12.874 * 1.08	13.904		0.82%
4. Splicing allowance	Total length of splice allowance * marker width = 1.091 * 1.08	1.178		0.07%
5. End loss	Total length of end loss * marker width = 5.85 * 1.08	6.318		0.37%
6. Width loss	Actual used length of all rolls * measured width loss = 1540.685 * 0.028	43.139	1705.529	2.53%
Difference			0.009	100.00%

Report of Fabric Wastage of Sample 31

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1738.302		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		8.7	1729.602	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =19.01 * 90	1710.9		98.92%
2. Splicing loss		12.722		0.74%
3. Splice allowance		1.3		0.08%
4. End loss	Total end loss of each ply times total spread plies	4.68	1729.602	0.27%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1738.302 * 1.144	1988.617		
Minus remnant area of the last roll = Actual usable area of all rolls	=8.7 * 1.144	9.953	1978.665	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(21.253-2.236) * 90	1711.53		86.50%
2. Total area of marker fallout	Fallout area * spread plies =2.236 * 90	201.240		10.17%
3. Splicing loss	Total length of splice loss * marker width = 12.722 * 1.118	14.223		0.72%
4. Splicing allowance	Total length of splice allowance * marker width = 1.3 * 1.118	1.453		0.07%
5. End loss	Total length of end loss * marker width = 4.68 * 1.118	5.232		0.26%
6. Width loss	Actual used length of all rolls * measured width loss = 1729.602 * 0.026	44.970	1978.648	2.27%
Difference			0.016	100.00%

Report of Fabric Wastage of Sample 32

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1713.848		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		30.4	1683.448	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =12.796 * 130	1663.48		98.81%
2. Splicing loss		11.398		0.68%
3. Splice allowance		1.16		0.07%
4. End loss	Total end loss of each ply times total spread plies	7.41	1683.448	0.44%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1713.848 * 1.552	2659.892		
Minus remnant area of the last roll = Actual usable area of all rolls	=30.4 * 1.552	47.181	2612.711	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(19.501-1.966) * 130	2279.55		87.25%
2. Total area of marker fallout	Fallout area * spread plies =1.966 * 130	255.580		9.78%
3. Splicing loss	Total length of splice loss * marker width = 11.398 * 1.524	17.371		0.66%
4. Splicing allowance	Total length of splice allowance * marker width = 1.16 * 1.524	1.768		0.07%
5. End loss	Total length of end loss * marker width = 7.41 * 1.524	11.293		0.43%
6. Width loss	Actual used length of all rolls * measured width loss = 1683.448 * 0.028	47.137	2612.698	1.80%
Difference			0.014	100.00%

Report of Fabric Wastage of Sample 33

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1527.02		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		26.9	1500.12	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =10.21 * 145	1480.45		98.69%
2. Splicing loss		11.26		0.75%
3. Splice allowance		1.16		0.08%
4. End loss	Total end loss of each ply times total spread plies	7.25	1500.12	0.48%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1527.02 * 1.503	2295.111		
Minus remnant area of the last roll = Actual usable area of all rolls	=26.9 * 1.503	40.431	2254.68	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(15.039-1.62) * 145	1945.755		86.30%
2. Total area of marker fallout	Fallout area * spread plies =1.62 * 145	234.900		10.42%
3. Splicing loss	Total length of splice loss * marker width = 11.26 * 1.473	16.586		0.74%
4. Splicing allowance	Total length of splice allowance * marker width = 1.16 * 1.473	1.709		0.08%
5. End loss	Total length of end loss * marker width = 7.25 * 1.473	10.679		0.47%
6. Width loss	Actual used length of all rolls * measured width loss = 1500.12 * 0.03	45.004	2254.633	2.00%
Difference			0.048	100.00%

Report of Fabric Wastage of Sample 34

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1605.771		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		50.3	1555.471	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =14.63 * 105	1536.15		98.76%
2. Splicing loss		12.046		0.77%
3. Splice allowance		1.29		0.08%
4. End loss	Total end loss of each ply times total spread plies	5.985	1555.471	0.38%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1605.771 * 1.201	1928.531		
Minus remnant area of the last roll = Actual usable area of all rolls	=50.3 * 1.201	60.410	1868.121	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(17.088-1.941) * 105	1590.435		85.14%
2. Total area of marker fallout	Fallout area * spread plies =1.941 * 110	203.805		10.91%
3. Splicing loss	Total length of splice loss * marker width = 12.046 * 1.168	14.070		0.75%
4. Splicing allowance	Total length of splice allowance * marker width = 1.29 * 1.168	1.507		0.08%
5. End loss	Total length of end loss * marker width = 5.985 * 1.168	6.990		0.37%
6. Width loss	Actual used length of all rolls * measured width loss = 1555.471 * 0.033	51.331	1868.137	2.75%
Difference			-0.017	100.00%

Report of Fabric Wastage of Sample 35

A. Loss Calculation In Terms Of Length

	Formula	Meter	Meter	Percentage
Actual length of all fabric rolls		1635.3		
Minus remnant length of the last fabric roll = Actual length used in cutting lay		36.5	1598.8	
Actual roll length used in cutting lay				
Minus the length of marker usage and other spreading losses:				
1. Marker usage	Marker length times total plies of cutting lay =11.699 * 135	1579.365		98.78%
2. Splicing loss		10.844		0.68%
3. Splice allowance		1.091		0.07%
4. End loss	Total end loss of each ply times total spread plies	7.5	1598.8	0.47%
Difference			0.000	100.00%

B. Loss Calculation In Terms Of Area

	Formula	Sqm.	Sqm.	Percentage
Actual usable area of all fabric rolls	Total Length of all rolls times actual width measurement =1635.3 * 1.108	1811.912		
Minus remnant area of the last roll = Actual usable area of all rolls	=36.5 * 1.108	40.442	1771.47	
Minus the area on marker usage and other spreading losses:				
1. Total area of all garment usage	Total marker area - fallout area * spread plies =(12.623-1.275) * 135	1531.980		86.48%
2. Total area of marker fallout	Fallout area * spread plies =1.275 * 135	172.125		9.72%
3. Splicing loss	Total length of splice loss * marker width = 10.844 * 1.08	11.712		0.66%
4. Splicing allowance	Total length of splice allowance * marker width = 1.091 * 1.08	1.178		0.07%
5. End loss	Total length of end loss * marker width = 7.5 * 1.08	8.100		0.46%
6. Width loss	Actual used length of all rolls * measured width loss = 1598.8 * 0.029	46.365	1771.460	2.62%
Difference			0.010	100.00%

APPENDIX D

Regression Outputs of input variable V_p taken from the pants factory

Regression outputs on length of remnant V_p against the prediction error ε

Regression Statistics	
Multiple R	0.964530763
R Square	0.930319593
Adjusted R Square	0.928208065
Standard Error	0.000590295
Observations	35

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.000153523	0.000153523	440.590803	1.16273E-20
Residual	33	1.14988E-05	3.48448E-07		
Total	34	0.000165022			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-8.41252E-06	0.000202794	-0.041483141	0.967160709	-0.000421	0.000404175	-0.000421	0.000404175
X Variable 1	7.16506E-05	3.41352E-06	20.99025495	1.16273E-20	6.47058E-05	7.85955E-05	6.47058E-05	7.85955E-05