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Design of an intelligent support system for fabric quality inspection

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ABSTRACT

Efficient quality management in production process is the key factor for firm's permanence and prosperity. The rapped globalization development and shortage of resources leading to enhance the efforts toward good raw material exploitation. The present work aims to develop a Decision Support System (DSS) that may provide and facilitate one of the most difficult multi-decision problems that quality managers, in textile manufacturing firm face. In addition, the DSS is developed for a textile manufacturer and it will automate a variety of tasks to improve rolls quality; control the defect distribution on rolls by inventing anew cutting scenarios with respect to inspection results, rolls length, and number of assemblies. The DSS tool, applied for more than 100 fabric lots, will be demonstrated through a short selection of practical case studies.

Keywords: Quality management; fabric inspection; optimization; Demerit Point.

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1. Introduction

In the textile and clothing industry, globalization directs manufacturer to think about quality assurance of products as one vital focus. Optimizing the quality related cost becomes strong impact on the company's performance aspect that may enhance its status in the global market [1,2]. For textile and apparel firms, the challenges are complex due to vast unpredictability of the global cloths style market, that resulting the rapid changes of consumers needs in quality and quantity. Therefore, sophisticated tools should be prepared to answer these demands and manage efficiently daily activities [3,4,5]. The application of IT and Decision Support Systems (DSS) introduces efficiency into management systems, exclusively in both fast and precise responses to solve multi-criteria problems. Logical and mathematical models are used in these intelligent systems to manage hard situation [6,7,8,9]. Control quality management systems are representing an important module of these intelligent systems tools. They are looking constantly for ways to increase customer satisfaction while reducing operation's costs. Even though these systems use scientific methods to assess quality and associated costs and with the respect of constraints and implement a continuous improvement, they should take a total systems approach in which all functions, processes, and departments across the organization are integral to ensure success in the manufacture of products or delivery of services. To reach for success, total quality management approaches aims to adopt a philosophy that stresses on learning and adaptation to continual change [10,11,12]. Under a quality management approach, early defect detection is very important to save money and assure consumer satisfaction. In most manufacturing firms, defect finding becomes an important stage in both quality control and management [13,14,15]. In the textile industry a lot of effort has been spent during the weaving process on discovering defects in woven fabric and many ways have been used in this context [16,17]. Quite A Few methods of image analysis have been recommended for this reason. G. M.Nasira [16] found that by using a digital image processing and a system based on BPN (Back Propagation Neutral Network) identifier, they achieve a success rate of 93%. Kumar [18] have used two approaches to detect defects, the first based on the segmentation of defects using FFN (Feed Forward Neutral Network) and the second have introduced webbased assessment system built on linear Neutral Network. Many researchers developed Automated Visual Inspection (AVI) system for weaving defection based on image processing and recognition algorithms. The purpose of the developed system is for the quality control of fabrics and weaving products from a textile factory [19]. Although defect detection has taken the most important part of the research, the management of the inspection results does not be the subject of any research. Several technical reports state that quality managers consider this step as a management dilemma, since it requires a multi-criteria decision. At this level, many constrains appear to the manager hailing from: fabric supplier, customer and manufacturing responsible.

1.1. Fabric inspection

For garments manufacturing process, fabric is considered as the main raw material. For this reason, fabric inspection is a crucial task in the garment industry. Fabric inspection is a visual check which focuses on fault/defect rate such as: shade, broken yarn, hole, stain slub… etc. The purpose of this step is to minimize the refused pieces and clothes resulting from fabric defects, enhances productivity and well-timed textile distributions [20]. Figure.1 shows a fabric inspection machine is generally used for this task.

Figure 1. Fabric inspection machine

Fabric defects are facilely detected using instruments with human in good experience with fabric detection. Furthermore, the fabric is not required to be reversed to detect defects. The process of defects finding starts with found, marked, and recording using special form. The machines also can determine the length of fabric roll and observe the fabric width as well. Defect statistics are recorded for each roll and each sort delivered to the garment manufacturer. The Four-Point System inspection method is Examining and Rating visually the fabric ASTM D5430 - 07(2011). Four basic scaling rules can be evaluated for any defect. In addition. After inspection, recorded defects will be assigned points under the criteria presented in table 1.

Table1. Defect Classification Using Four-Point System

Points Evaluation	Defect length (Inches)	Defect length (mm)
1 Point	Up to 3 inches	Up to 75mm
2 Points	D_l > 3 inches ≤ 6 inches	D_l > 75mm< 150mm
3 Points	D_l > 6 inches < 9 inches	D_l > 150mm< 230mm
4 Points	D_l > 9 inches	D_l > 230mm

After rolls inspection, the calculation result for each yard with the number of points will determine the acceptance or rejection of the roll shipment. The summation of points per 100 square yards of defects is called "Demerit Point". The acceptance criteria are stated before between the customer and the supplier. The formula for the Demerit Point (DP) calculation is shown below:

$$D_P = \frac{P_V}{(Fabric\ length \times Fabric\ width)} \times 100$$

The general procedure for fabric rolls inspection requires special environment with enough air circulation and good light. The textile fabric should be between 45 - 60-degree angles when it passes through inspection. The speed of roll should not exceed 15 yards per minutes. The inspector gives marks for the defects during inspection process. The length of every roll examined need to be contrasted to length and any difference should be recorded [20-23].

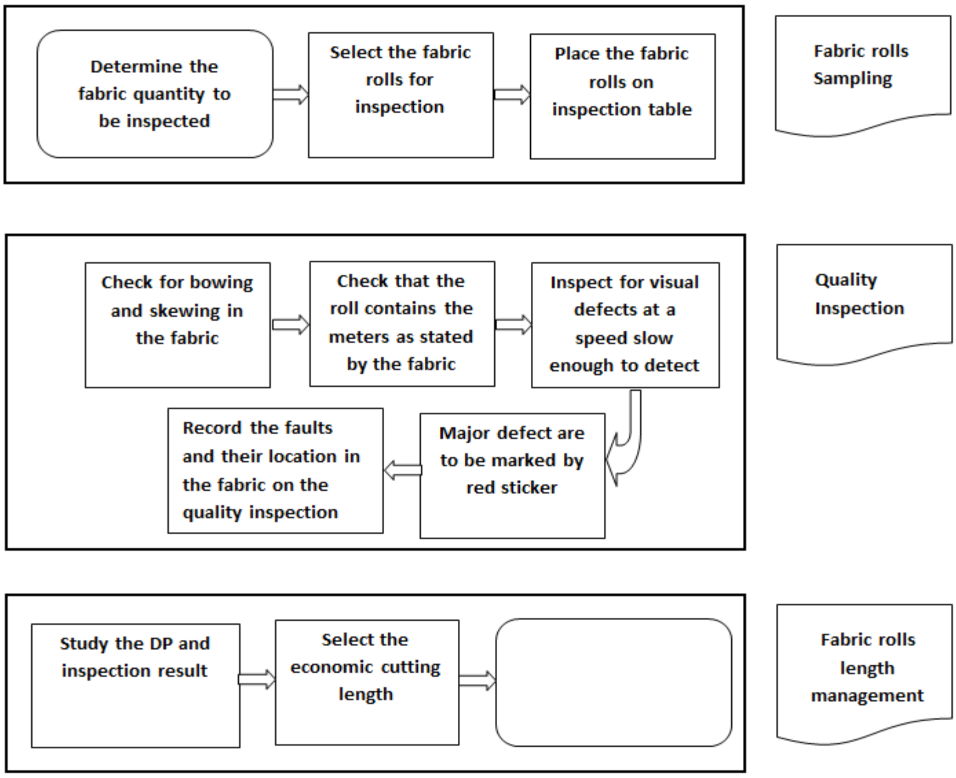

Figure 2. Fabric rolls inspection procedure

Figure 2. present the different steps of fabric inspection and cutting length management which precede orders preparation and delivery.

2. Research methodology

After the fabric inspection, the quality manager receives an inspection report which contains the list of defects in this fabric roll, the defect location longwise along the roll, and the points allocated to everyone. In addition, two types of cuttings exist with different causes. The first cut is mandatory resulted by some major defect, especially the continuous defects. Therefore, the inspection report mentions the location of these cuttings. Different smaller rolls will be obtained as results. The second cut will be the result of a deep research achieved by the manager who tries to respect different constraint to find the optimum cutting and selling length. This step can be considered as very crucial for different reasons related to quality, selling price, cutting length.

The different constraints for this cutting plan can be summarized as follows:

1. Demerit Point: Obtained rolls will have different DP coefficient according to the number and severity of defects. In the contract between fabric supplier and garment manufacturer, a provision states the maximum DP value that delivered rolls cannot exceed.

$$P_V = \sum_{i=1} N_i \times Cf_i \quad (1)$$

$$D_P = \frac{P_V}{F_W l_k} \times 100 \quad (2)$$

$$D_P \le DP_{max} \quad (3)$$

2. Roll length: Another agreement between fabric supplier and customer, states that the roll length should be between lower and upper limit.

$$l_{Min} \le l_k \le l_{Max} \quad (4)$$

3. Number of assemblies: garment manufacturer limit usually the number of assemblies per commercial roll, given that they are considered as a major defect.

$$N_{Ass} \le N_{A\,Max} \quad (5)$$

4. Woven exploitation: Manager who will prepare the cutting plan should accord a high importance to use the maximum length of the initial roll and avoid the short lengths less than the lower limit.

$$W_E = \frac{\sum_{k=1} l_k}{L} \times 100 \qquad (6)$$

In this paper, we introduced the DSS-COPT algorithm to solve the problem of cutting the fabric rolls. Control the defect distribution on rolls by creating reasonable cutting order depend on inspection results, rolls length, and number of assemblies. The algorithm can recognize the fabric roll length (L), Demerit Point (DP), the position of the Demerit Point, and the type of defects. In the first iteration, the DP will be computed incrementally and be compared with the DPmax based on the customer request. If the computed DP is equal or greater than the DPmax, then the second iteration determines the cut length end and moves to the next cut and so on. With maximizing the roll length and minimizing the Demerit Point in each assembly and recommending solutions to decompose the roll into number of assemblies with minimum defects, we introduced a new technique to meet the customers' demands in quantity and quality.

Table 2. Notation description

type	Notation	Description
Indices	i j k	index of defect class. index of defect localization. index of resulting rolls.
Parameters	L	length of the main roll.
	W	width of the main roll.
	l_k	length of resulting roll k.
	X_j	defect position in roll.
	N_i	Number of defects in class i.
	P_V	Point value
	DP_{max}	Maximum acceptable Demerit Point
	Cf_i	defect class coefficient.
	W_{pts}	weaving defect point value.
	M_{aj}	Major defect of resulting roll.
	SON_B	Number of stickers benchmarked.
	l_{max}	Maximum length of resulting roll
	l_{min}	Minimum length of resulting roll
	N_a	Number of assemblies in resulting roll
	$N_{a\,max}$	Maximum of assemblies in resulting roll
	l_{exp}	Expected length of resulting roll
Decision variables	W_E D_P O_l	Woven exploitation of initial roll. Demerit Point. Optimized length

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Set RL to L, Set DPm to DPmax , Set DP to zero, Set PT to zero, Set j to 1 , Set Width to W, Set Length to lex ,
Set Cut to 0
While i less than or equal RL   Lstart[j] = lower (i)
            while DP less than DPm and i less than or equal to (Cut + Length)
             { Input PV(i) , Compute PT= PT + PV(i), Compute DP= PT /(i*W)*100, Increase i by 0.1}
         endwhile
             Compute Lend [j] = lower (i)
             Compute Cut = Cut + i
             Increase j by 1
endwhile
```

3. Computational results

To test the DP algorithm performance, we conducted computational experiment on six realistic problems instances. Each case is a fabric lot (roll) which represent a weaving machine output with an important length.

This lot should be catted in shorter length according to a set of constrains previously described. On the other hand, to make the comparison with the current practice, we also computed the improvement percentage for principal and secondary selection criteria. Table 3 summarizes the Comparison of Computational results with current practices in a fabric manufacturing firm. Results indicate that a good choice of the cutting length may reverse the cutting order decision and provides improvement in principal criteria: Dp average and woven exploitation.

Table 3. Comparison of computational results with current practices

		Principal criteria			Secondary criteria	
Lot reference		Cutting Length (m)	Average DP	W_E(%)	Max W_{pts}/ roll	Max N_{SON}/ roll
Lot DF823	Result	180	8.97	98.4	32	8
	Current Practices	100	9.08	95.6	28	7
	Improvement (%)	-	1.21	2.8	-	-
Lot DF269	Result	120	9.16	98.5	17	5
	Current Practices	160	10.15	96.8	21	6
	Improvement (%)	-	9.75	1.75	4	1

4. Decision support systems

We aim to implement a Decision support system (DSS) intended to help quality and marketing authority to make use of data to recognize and solve problems. DSS can assist in choosing effective methods to enhance rolls quality; control the defect distribution on rolls by creating realistic cutting order strategies according to inspection results, rolls length, and number of assemblies. To perform the cutting DSS tasks, the tool requires the implementation of several modules whose complexity had to be in accordance with the type of issues to be faced and the predominant criterion. Therefore, we conduct as following:

- Step1: The inspector records the inspection data which gives: the defect localization, defect type and code.
- Step2: The inspection data will be used as an input for the dynamic algorithm. The results allow the inspection manager to compare several solutions with different DP and cutting length.
- Step3: To address this multi-criteria problem, a dashboard which contains different statistics may help manager to take a good decision. These statistics concern: the average DP for each cutting length, the woven exploitation, the cutting solutions compared to objectives.
- Step4: After issuing many lots for different suppliers, data will be assessed to determine potential improvement areas and develop and implement a comprehensive improvement plan. Therefore, supplier evaluation seems to be affordable at this level.

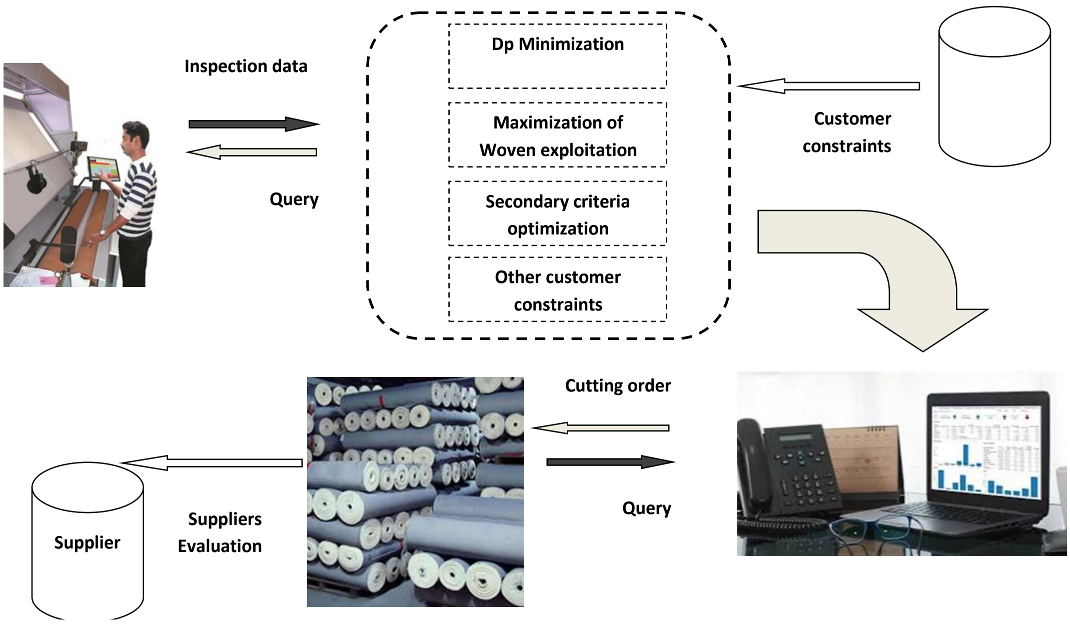

Figure 3. Steps to perform the cutting DSS tasks

we use our application on lot DF927 evaluation. As we mentioned before, the Decision support systems will assist decision-makers of a fabric manufacturer in selecting efficient ways to improve rolls quality; control the defect distribution on rolls by developing feasible cutting order plans with respect to inspection results and rolls length. We will discuss after, the performance dimensions offered by this DSS through the indicators that can be considered as a guideline for optimum result as shown in Figure 4.

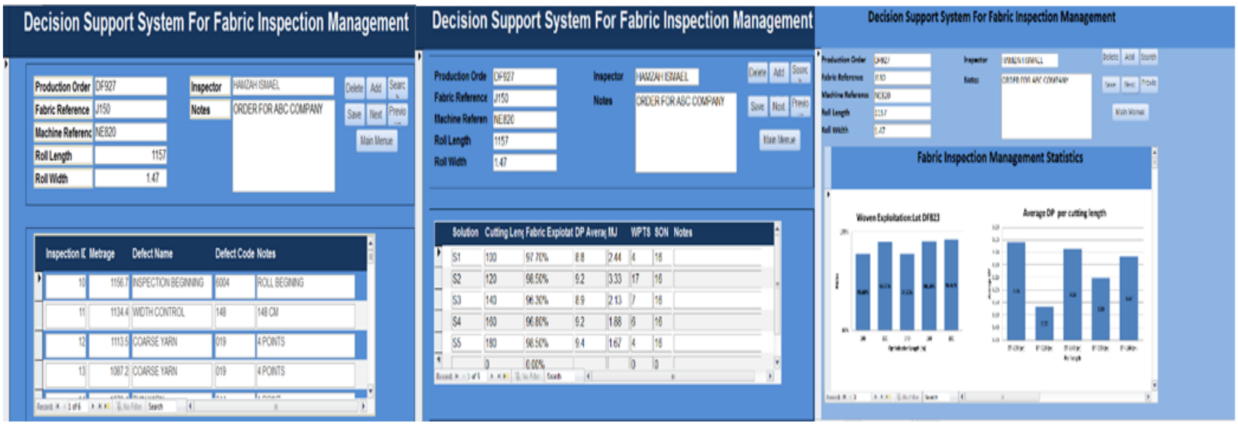

Figure 4. Fabric inspection interfaces.

Before the initial roll cutting, manager should analyse and select the optimum length for woven exploitation maximization. Figure 5 presents the woven exploitation variation with resulting roll length. Results indicate that the cutting length affects irregularly the woven exploitation, without any clear variation trend. For each lot or initial roll, such as lot DF927, 180 meters is the optimum one which maximize the exploitation to 98.40%. This length as it is mentioned before should be between lower and upper limits according to customer/ supplier agreement. The Decision support systems will assist decision-makers using this distribution for a multi decision problem.

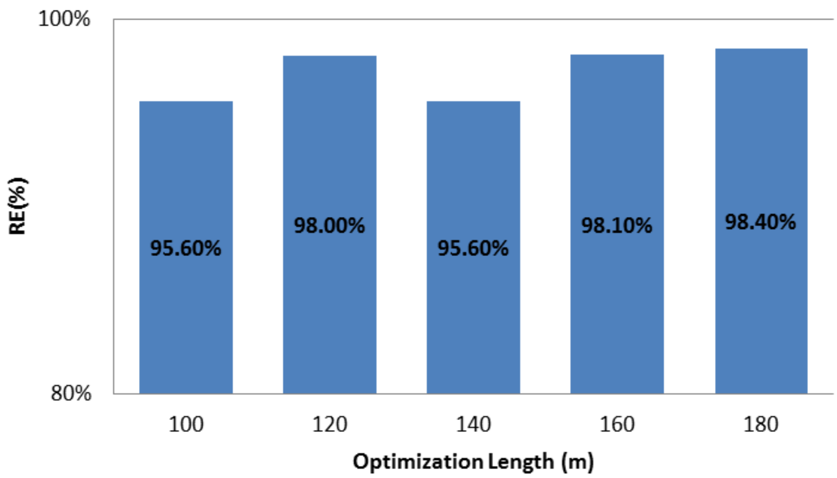

Figure 5. Woven exploitation: Lot DF823

For each chosen cutting length, a series of rolls with different DP, will be generated. Figure 6 presents the distribution of Demerit Point coefficient DP with the cutting length. Certainly, the number of resulting rolls decreases inversely proportional with the cutting length. For example, with lot DF927, we can note 8 rolls for a meterage of 180 meters and 13 rolls for a meterage of 100 meters. On the other hand, since the cutting length is a multi-decision function; the distribution of DP is to be considered as crucial. Results indicate that with a 180-meterage solution, we obtain a set of rolls with a Demerit Point Coefficients less than 14. Contrariwise, the other cutting lengths may exceed this DP if it will be considered as an upper limit. These outcomes may foster the choice of this meterage (180 m), even it presents the best woven exploitation.

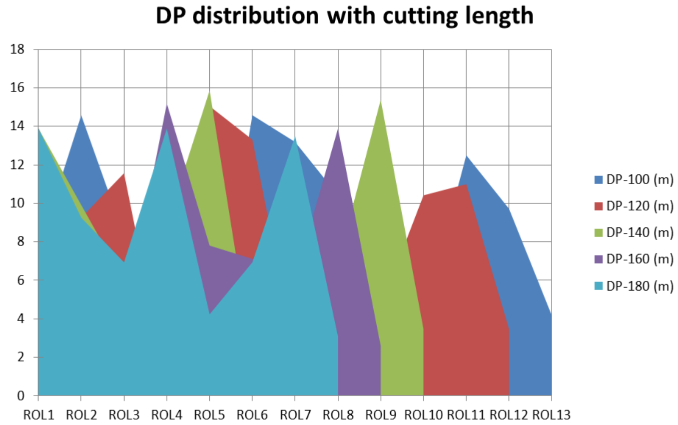

Figure 6. DP distribution with cutting length

As we know that every cutting length adduce a set of rolls with different demerit Point coefficient, the average of theses DP for each solution takes a great importance in the multi-criteria decision. Figure 7 presents the variation of the average DP per cutting length. Results for the same lot, indicate that even though 180 meterage has the highest woven exploitation in addition to a good DP distribution, its DP average becomes after 100 and 140 meterage. The average DP, in addition to woven exploitation and DP distribution are the guidelines which orientate the manager's decision. Such decision is facilitated by our Decision support systems.

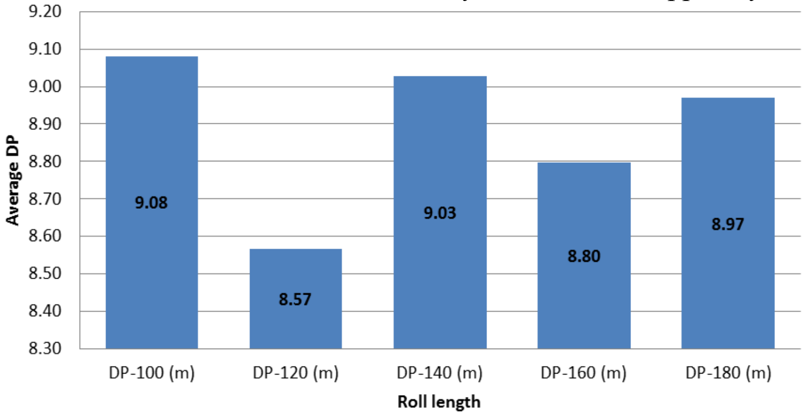

Figure 7. Average DP per cutting length

After issuing many lots, results may be compared to the objective, and determine the different areas of improvements. Figure 10 shows a radar chart for cutting management. Results of three lots are compared to the firm objectives. According to these results (Figure 8), manager could fix his priorities and work to improve Demerit point, weaving defect points value and number of stickers benchmark. In addition, lots have exceeded the objectives and an improvement action plan should be established.

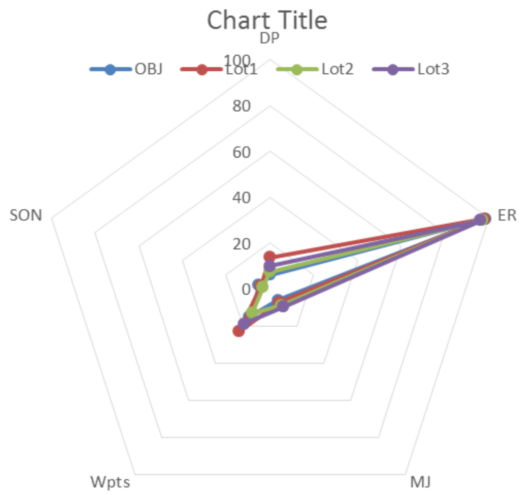

Figure 8. Radar diagram for cutting management

5. Conclusion

This paper resolves the issue of fabric inspection problem which has technical and financial effect on the delivered orders. A systematic approach was followed to find out an optimum cutting length which considers customer and technical constraints. On the first hand, a DSS-COPT algorithm was introduced to solve the problem of cutting the fabric rolls. Then, realistic cutting order strategies was developed based on inspection results, rolls length, and number of assemblies. On the second hand, to help quality and marketing authority to make use of data to recognize and solve problems, a Decision support system (DSS) was established. Consequently, we computerized tasks and helped decision makers within a given set of constraints. In addition, this DSS can improve rolls quality; control the defect distribution on rolls by developing feasible cutting order plans with respect to inspection results, rolls length, and number of assemblies. An economic study which includes the effect of the resulting demerit point and the other factor on the lot price seems to be very important as a future related works. An effective management of the fabric remains with shorter lengths seems to be lucrative for the company and needs specific and deep studies.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

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