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A Dynamic Optimization Model for Multi-Objective Maintenance of Sewing Machine

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Abstract. In textile and garment industry sewing machine has a foremost role in production. Due to despicable maintenance, there will be a frequent breakdown and loss of production. Dynamic programming models are the optimization techniques which gives an ideal solution. In a sewing machine, with a specific end goal to decrease the breakdown, this research focuses on multi-objective optimization by using probabilistic dynamic programming model. Parameters considered in this optimization are the maintenance costs of a sewing machine including routine maintenance. The created model is utilized to find the optimal maintenance policy to be carried out and to decrease their costs in the textile industry. To solve this problem, four multi-objective functions have been framed these objectives and constraints were solved by linear programming. Periodic maintenance policy for a sewing machine was discussed. The current research work would optimize the maintenance cost and the results are validated with the actual data.

Keywords: Dynamic simplex method, probabilistic dynamic programming, multi-objective optimization, sewing machine

1. Introduction

In Indian economy, garment and textile sector are one among the industries which are increasing rapidly [1]. Maintenance plays a vital role in increasing the productivity of organizational sector goals and objectives [2]. The role of maintenance is to reduce the equipment downtime, breakdowns and to increase the productivity and quality. Around 15 to 70 percent of maintenance cost varies in total production cost [3]. On investigating south Indian textile research association, the major cause for poor quality yarn is unplanned and poor maintenance [4].

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1.1. Maintenance in textile industry

In a recent inspection by the south Indian textile research association, it was incurred that inadequate maintenance is the major reason for low yield of yarn. For the improvement in productivity, planned maintenance is carried throughout the process [5]. Hence, each part of machinery has the different origin of energy such as electrical, mechanical, pneumatic, and hydraulic and those were carried out by repair (or) maintenance work on the machine [6] [7]. Machine break- down in sewing industries has more impact on the operation and extends to maintenance cost, for better results maintenance strategy is obtained [8].

Preventive maintenance used to inspect, adjustments, repairs, and replacements in maintaining of an individual machine [9]. The main objective of

preventive maintenance is to detect the machine failure before breakdown occurs [10]. The main role of preventive maintenance is Routine attention, Routine examination, Preventive replacement, and Inspection measurements [11].

1.2. Sewing Machine

In this, the object using stitches made with a needle and thread. The sewing machine is used in various industries such as shoemaking, bookbinding, textile, and garment industries [12]. Industrial sewing machines are greater, faster, and changed in their size, cost, appearance, and task. Industrial machines perform a single committed job and are adequate for long hours of utilization and as such have heavier acting parts and comparatively much larger motors [13]. The straight-stitch machine motors are the same [14] [15] [16].

1.3. Types of Sewing Machine Used in Clothing Industry

As per the working framework, there are two sorts of sewing machines are accessible in the instant article of clothing pieces of clothing part [17]. Those are-

- Manually operated sewing machine
- Electrically operated sewing machine

1.3.1. Manually operated sewing machine

The machine where sewing is done by using physical power is named as a physically worked sewing machine [18]. These sorts of sewing machines are colossally used as a piece of fitting and nearby purpose behind sewing surfaces. This machine composes are not used as a piece of garments creating organizations because of the less bits of attire age [19].

1.3.2. Electrically operated sewing machine

The machine where sewing is done by using electrical power is known as an electrically worked sewing machine [12] [7, 20]. This sort of machines is extensively used as a piece of vestment creating wanders because of the higher clothing age. These sewing machines in like manner named as a mechanical sewing machine.

2. Research Biography of Sewing machines

The optimization of the cost is the enormous research which helped to increase the performance and controlling the breakdown of production line [21]. The research biography is as shown below.

G. Levitin et al. [2000] had proposed the optimization of the cost of preventive maintenance for a multi-state system which had a scope of performance levels is approached by the technique of genetic algorithm and it is evaluated by the basic procedures and he implemented universal generating function technique for demonstration. Maintenance activities are to be considered that are suggested by their power to reduce their age. So that they achieved the redundancy and maintenance optimization.

Usher et.al [2001] present an enhancement support and swap model for a solitary part framework. They decide an ideal preventive upkeep plan for another framework subject to disintegration, by considering the time estimation of cash in all future costs, expanding rate of an event of disappointment after some time and the utilization of the change element to accommodate the instance of blemished support activities. Furthermore, they give an examination of computational results among arbitrary hunt, hereditary calculation, and branch and bound calculations.

Chan et al. [2001] present a reproduction structure to look at the results of preventive support approaches on cradle size, stock characterizing principles, and procedure intrusions in a streamline of a push creation framework. He introduces the execution of the creation framework beneath various operational conditionsand preventive upkeep arrangements.

Jongprasithporn.S et al. [2003] had focused on preventive maintenance technique which is used for improving the efficiency of a machine in that Mean Time Between Failure (MTBF) index is used to eliminate the breakdown times and they suggested daily routine plans for inspection. 3They're concerned on weaving machine to produce high quality of products. They collected the data’s of weaving machine output and they analyzed the causes of the inefficiency of production and they suggested several solutions for problems and some of the future works to be carried out.

Jayakumar et al. [2004] proposed a Linear programming (LP) structure to streamline the upkeep arrangement for disappointment rate and found the minor and significant preventive support activities by expanding the accessibility of the segment achieved by Markov choice procedure.

Samrout et al. [2005] applied a genetic algorithm to minimize preventive maintenance cost problem for the series-parallel systems. Their work is based on some other proficiency, the ant colony optimization (ACO).

Fig. 1. Sewing machine (www.fibre2fashion.com)

Sortrakulet et al. [2005] also formulated the genetic algorithms to Figures out an integrated optimization model for production scheduling and preventive maintenance planning.

M.C Eti et al. [2006] had studied on the reduction of cost and energy expenditures in an organization. So, they interchanged the reactive repair concentrated on position by a proactive reliability-focused culture to reduce the downtime failure and to increase the product quality and to improve the instrument effective-ness. Hence they concluded that the lean manufacturing and optimal maintenance involves the recognition and evacuation of waste through repeated improvement.

S.D. Probert et al.[2006] developed failure modes and effect analysis, root cause and fault tree analysis to reduce the cost of preventive maintenance and better maintenance process such as RCM, TPM, RCFA, FMEA have been implemented to attain maintenance targets. They implemented four strategic dimensions of maintenance. Their concept is to consider the maintenance targets such as RCM, TPM, RCFA, and FMEA to achieve maintenance.

Canto [2006] acquaint an enhancement model with calendar a preventive upkeep of a forced plant. He expected the aggregate expense of a few methodology as the target capacity and utilization the Bender's disintegration strategy to explain a blended whole number direct programming model.

Konak et al [2006] introduced a study on multi-objective genetic algorithms and their applications in reliability optimization problems. They review 55 research papers and demonstrate the recent techniques and methodologies.

Quan et al [2007] figured a novel multi-objective hereditary calculation to enhance preventive support plan issues. They decided the issue as a multi-target streamlining issue by taking the minimization of workforce unmoving time and the minimization of support time and specify that there is a trade-off between the goal capacities. As the outcome, they utilize utility hypothesis option of strength based Pareto inquiry to impact the non-mediocre arrangements and demonstrate the benefit of this strategy by numerical case.

Kuo and Chang [2007] figured a coordinated support booking and creation arranging advancement technique for a solitary machine in view of preventive upkeep methodologies on generation plans to minimize all out lateness. They find that the ideal support approach is an imperative on the generation plan when machine closes down because of total harm disappointment process. The computational results accomplished by element programming demonstrate that by expanding- in the quantity of employment the impact of occupations due dates on the ideal upkeep arrangement is diminished.

Verma et al. [2007] applied multi-objective preventive maintenance scheduling for engineering plants. By using genetic algorithm they solved the model and with the help of the non-linear mathematical program, they formed the constraint.

Tan et al. [2008] suggested an elementary virtual model for predictive maintenance (PdM) based on scheduling of multistate systems (MSS). Through the framework development, various elements influencing PdM based scheduling are defined and their involvement in the system reliability and performance are quantitatively studied.

Tomasz Nowakowski et al. [2009] formulated a mathematical framework of maintenance determination for multi-unit systems. In this paper, they have in-expected the literature on the most usually applied optimal multicomponent maintenance framework.

Ruey Huei Yeh et al. [2009] developed an efficient algorithm to deduce the optimal preventive maintenance policy and he compared the various maintenance schemes with numerical examples of Weibull and they detected the operation of the periodical policy.

3. Mode of Research

Sewing machine plays an import role in garment and textile sector and it is also one of the major rapid growing industry in India [22]. Many textile industries are facing difficulties in maintaining machines, in current research we used multi-objective programming model by considering various constraints. We have also listed the research divergences on sewing machines and formulated the linear programming model to optimize breakdown and maintenance of sewing machine, were explained as follows [23].

3.1. Research Divergences on sewing machines

Dynamic programming (DP) is an optimization technique, which gives the feasibility of solving using the software and also shows the mathematical relations between textile and garment industry [24] [25]

. After extracting the ideas from literature review, the following problems need to be formulated

- To estimate the minimum cost associated with various production lines in a textile industry by using dynamic programming model and to propose a Lindo software to solve these issues.
- Application of the dynamic programming model is not much proposed in textile and garment industry.
- Concerning to the sewing machine, dynamic programming optimization has not addressed in order to reduce the maintenance cost [26].
- As the sewing machines have unexpected breakdowns due to improper maintenance, which has effects on production in the garment industry.
- To estimate the minimum cost associated with different production lines in a textile industry by using dynamic programming model for solving these issues [27].

3.2. The manifestation of Defects from research divergences

These are manifested as

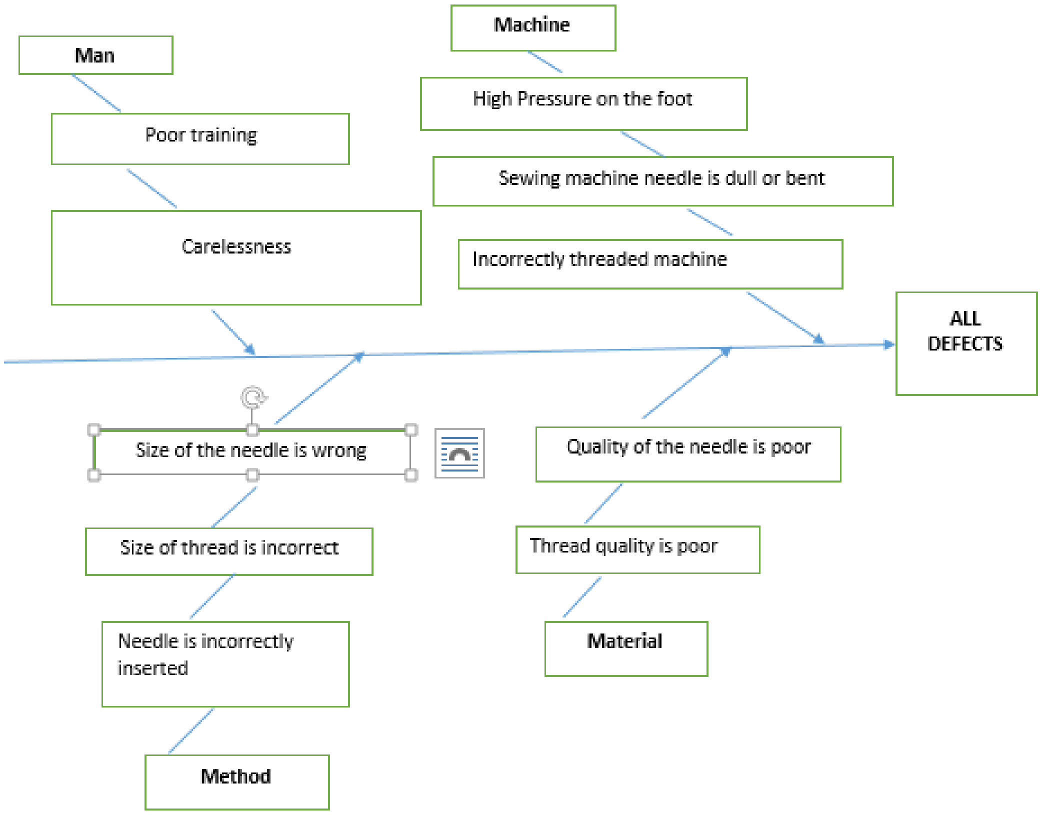

Fig. 2. Fig. 1. Manifestation of Defects

3.3. Formulation of Probabilistic dynamic model

Formulation of the dynamic model includes varies steps where parameters are the essential part. The formulation is as follows.

The parameters are

- C_{pm} = Average cost of preventive maintenance for one unit of the equipment
- C_{bd} = Average cost of breakdown maintenance for unit of the equipment
- M = number of units of equipment requiring maintenance
- N = number of periods in the planning horizon
- P_i = probability of breakdown in the ith period after preventive maintenance
- B_i = Number of breakdowns during a preventive maintenance cycle of a duration.

Let us considered the piece of equipment that could be subjected to either preventive maintenance or breakdown maintenance [28]. When preventive maintenance is done after some inspection certain components are replaced. This results in preventive maintenance cost. The frequency with which the preventive maintenance is carried out is known as PM cycle [29]

. For example, if it is decided that preventive maintenance is done in every three months, then the PM cycle is three months.

$B_1 = m * p_1$

Similarly, for i=2, 3,4,5,6 we have,

$B_2 = m * (p_1 + p_2)\ b_1 * p_1$

$B_3 = m(p_1 + p_2 + p_3) + b_1 p_2 + b_2 p_1$

$B_4 = m(p_1 + p_2 + p_3 + p_4) + b_1 p_3 + b_2 p_2 + b_3 p_1$

$B_5 = m(p_1 + p_2 + p_3 + p_4 + p_5) + b_1 p_4 + b_2 p_3 + b_3 p_2 + b_4 p_1$

$B_6 = m(p_1 + p_2 + p_3 + p_4 + p_5 + p_6) + b_1 p_5 + b_2 p_4 + b_3 p_3 + b_4 p_2 + b_5 p_1$

It corresponds that the number of first-time failures from the population of M machines.

- Cost of preventive maintenance for a preventive maintenance cycle of $i = m * C_{pm}$
- Cost of breakdown maintenance for a preventive maintenance cycle $i = b_i * C_{bd}$

The following data of sewing machine are collected from the garment industry. The obtained data represent the months following the preventive maintenance cycle, i.e., 6 months. From the data, we have analyzed that the probability of breakdown will vary for every month.

Based on cost estimates made by costing department it is to be noted that

- The cost of preventive maintenance per sewing machine is about the average of Rs.300
- The cost of breakdown maintenance per sewing machine is about the average of Rs.950

Since the sewing machines are a critical production resource, the breakdowns are unpredictable and there is a loss of production. The main reason for failure rate is as there is no preventive maintenance carried out properly. So, from the probability of the breakdown data and with our proposed model we would implement the maintenance policy for a sewing machine to reduce the maintenance cost and breakdown.

Therefore, the mean time between the failures of one sewing machine is 3.45 months.

- In other words, the number of breakdowns for one machine per month = 1/3.45
- Therefore, for 200 machines the number of breakdowns every month are 200/3.45 = 57.97
- Hence the cost of breakdown for above data = 57.97 x 950 = Rs. 55,072.00.

4. Results and Discussion

4.1. Breakdowns

By using the above equations, we got the number of breakdowns for each preventive maintenance cycle. And the results are listed below.

$B_1 = m * p_1 = 20$

Similarly,

$B_2 = 52$, $B_3 = 118.2$, $B_4 = 175.62$, $B_5 = 234.89$, $B_6 = 298$

4.2. Maintenance

The total maintenance cost is calculated using the no of breakdowns as shown below.

The total cost is converted into per month values. From the below tabular column, the total cost is graphically portrayed.

The behavior of two kinds of costs and that of the total cost is portrayed graphically in the above fig 8. From the graph, the optimum maintenance policy for a sewing machine is two months, as the cost of maintenance increases after that. The cost of break-down maintenance is also higher than the preventive maintenance cycle [30]. By following the preventive maintenance for two months once it can reduce the breakdown of the sewing machine. As sewing machine breakdowns are unpredictable till date we can suggest a maintenance policy to be carried out so that we can avoid major breakdowns. From our proposed probabilistic dynamic programming model we identified the requirement of maintenance of individual sewing machines [31]. Preventive maintenance cost is less than the breakdown cost, according to the collected data. So in the garment industry, preventive maintenance should be carried out in the interval of two months from our model so that there will be a decrease in the breakdown. However needle breakage causes a number of breakdowns in a sewing machine, it is to be analyzed and we suggested the possible ways to overcome the needle breakages.

5. Conclusion

In this research, we present a dynamic programming model for optimizing preventive maintenance in the sewing machine. The developed model is used to find the optimal preventive maintenance policy to be carried out and to reduce their costs in the textile industry. In order to solve this problem, four multi-objective functions have been framed and those objectives and constraints were solved by linear programming. The present research work would optimize the maintenance cost and the results are validated with the actual data. The future work in this area is needed to investigate the effects of other constraints such as limited maintenance resources and system availability requirements by considering other strategies for maintenance activities.

Table 1
Breakdown and Probabilities of failure data for sewing machine

Months following Preventive Maintenance cycle (a)	Probability of breakdown (b)	(a) * (b)
1	0.1	0.1
2	0.15	0.3
3	0.3	0.9
4	0.2	0.8
5	0.15	0.75
6	0.1	0.6
	Sum	3.45

Table 2
Total cost of maintenance

Preventive Maintenance Cycle (PM)	No of Breakdowns	Breakdown Maintenance Cost	Preventive Maintenance Cost	Total Cost
1	20.00	19000.00	60000	790000
2	52	49400	60000	109400.00
3	118.20	112290.00	60000	172,290.00
4	175.62	166,839.00	60000	226,839.00
5	234.89	223,147,40	60000	283,147,40
6	298	283,757.59	60000	343,757.59

Table 3
Maintenance cost per month

Preventive Maintenance Cost	Breakdown Maintenance Cost	Total of two Maintenance Cost
60,000.00	19000	79,000.00
30,000.00	24,700.00	54,700.00
20,000.00	37,430.00	57,430.00
15,000.00	41,709.75	56,709.75
12,000.00	44,629.48	56,629.48
10,000.00	47,292.93	57,292.93

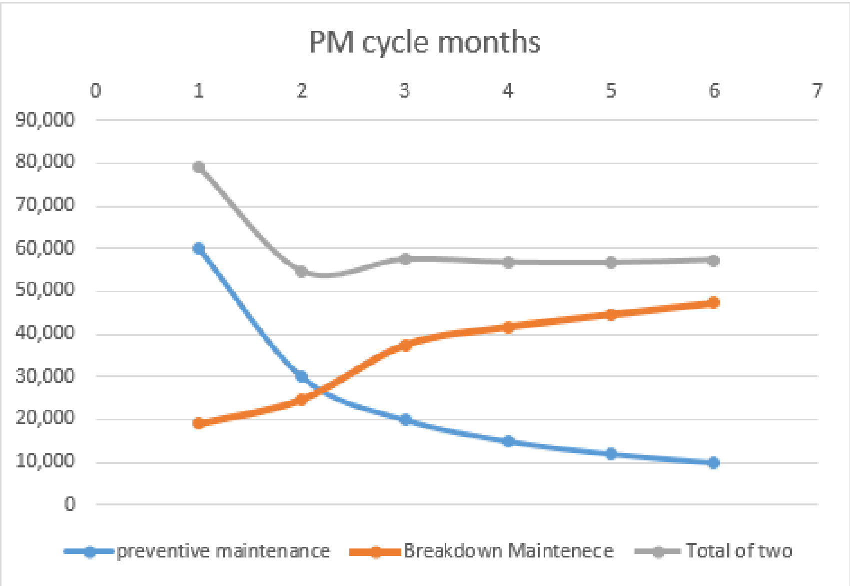

Fig. 3. Total costs of Maintenance

6. Future Scope

- For a large number of problems with more number of periods or components metaheuristic and heuristic solution procedures needed.
- The developed dynamic programming model can be used to reduce the maintenance cost in concern of textile industries.
- This model can be used to generate new preventive maintenance and replacement plans even after an unexpected failure occurs.
- To validate a result, a computational software LINDO 16.0*64 can be used for different methods to obtain optimal results.
- Future work in this area is needed to investigate the use of heuristics, and metaheuristics, as well as techniques for estimating key model parameters, like the improvement factor, real large-scale systems.

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