

Estimation of efficiency in the loomshed

S P Deshpande

Ahmedabad Textile Industry's Research Association, Ahmedabad 380 015, India

Received 31 August 1992; accepted 1 June 1993

The study of loss in loomshed productivity has been largely based on the work of Benson and Cox on machine interference. As the Benson and Cox model did not take into account the implications of textile industry considerations, it has certain drawbacks which should be overcome to benefit the composite textile mills in practice. With this in view, a new model has been proposed which includes some new terms like basic efficiency, non-weaver loss and special attention. The concept of basic efficiency is the hallmark of the proposed model. The invariance of basic efficiency has been used to the hilt to estimate the actual efficiency of a given sort under various conditions. The model also provides an estimate of weaver's workload in any given situation. It can also be used to decide the optimum allocation of looms to a weaver. However, the calculations involved are fairly complex and time consuming and hence require a computer to use the model meaningfully. A software for using the proposed model has, therefore, also been developed at ATIRA.

Keywords: Benson and Cox model, Machine interference, Non-weaver loss, Weaver's workload

1 Introduction

The estimation of loss in production due to interference in loomshed and other related parameters has been largely based on the work of Benson and Cox. However, this work did not take into account the implications of textile industry considerations. In the absence of an appropriate model, the Benson and Cox model is used to estimate the various parameters of loomshed working. In order to eliminate the limitations and drawbacks of Benson and Cox model, a new model is required. In this paper, such a model is proposed by considering numerical examples. The paper exposes the limitations of the Benson and Cox model and shows how better estimates can be obtained by the proposed model.

1.1 Limitations of the Benson and Cox Model

The limitations of the Benson and Cox model are as follows:

- The model assumes that all looms under the charge of a weaver have the same efficiency which, in practice, cannot be accepted.
- The model assumes that the servicing time for mending breaks, changing shuttles, etc. follows exponential distribution¹. Since the weaver's job is of a routine nature the servicing time is more or less deterministic in nature, the assumption

of the exponential distribution may even be inappropriate.

- There is no provision for non-weaver loss and special attention in the model.

If a loom is stopped for attention to be paid by any operator other than a weaver, it is called as non-weaver loss. The implication of non-weaver loss is that the weaver's effective loom allocation is reduced as long as he does not have to attend such a loom. If a weaver has to work on a running loom, for example to avoid a potential break, or he is away from the looms for his personal or other needs, it is called special attention of the weaver. The implication of special attention is that it increases the loss due to interference because he is busy on a running loom and is not available to service a stopped loom.

1.2 Probability View of Efficiency

Strictly speaking the efficiency of a sort cannot be considered as equivalent to probability of running a loom. Suppose a sort running on a given loom has 80% efficiency, the probability assumption expects that no matter how small is observation time of an observer, he will find that the loom is running 80% of that time. However, our estimation of loomshed efficiency by snap study technique is based on the assumption that efficiency

can be considered as probability of running a loom. Experience has shown that the results of the snap study technique closely match with the actual efficiency in the loomshed and, therefore, we can extend the assumption further to cover the estimation of attending loss, interference, etc.

2 The Proposed Model

Let us consider a case of a weaver-in-charge of N looms. The model assumes that each loom under the weaver's charge will have 4 states which are mutually exclusive and exhaustive. These 4 states are as follows:

- (i) A loom is in a state of running at a given rpm and productive with probability E —Efficiency.
- (ii) A loom is in a state of stopped condition and awaiting non-weaver attention with probability D —Non-weaver loss.
- (iii) A loom is in a state of stopped condition and is being attended by the weaver for restarting it with probability A —Attending loss.
- (iv) A loom is in a state of stopped condition awaiting weaver's attention but the weaver is not available with probability I —Interference.

Since the 4 states are mutually exclusive and exhaustive, we obtain

$$E + D + A + I = 1 \quad \dots (1)$$

If a weaver has been allocated N looms and the sorts running on the N looms do not have the same efficiency, Eq. (1) can be written as:

$$E_j + D_j + A_j + I_j = 1 \quad \dots (2)$$

where $j = 1, 2, 3, \dots, N$.

So far as the weaver is concerned the model assumes that he will always be in one of the following two states:

- (i) The weaver is not available for attending the looms with probability S —Special attention.
- (ii) The weaver is available for attending the looms with probability $1 - S$.

2.1 Basic Efficiency

For a sort on j th loom, the efficiency is E_j and the attending loss A_j . It is obvious that $E_j \propto A_j$, no matter what the loom allocation may be. Hence,

an invariant property called basic efficiency (B_j) is proposed such that

$$B_j = \frac{E_j}{E_j + A_j} \quad \dots (3)$$

The basic efficiency for each sort is the maximum efficiency one can get under one loom allocation. From the available standard data on different attention times, etc. the basic efficiency can be computed and then the actual efficiency under an allocation of N looms can be obtained by using the proposed model without collecting data by running the looms.

2.2 Estimation of Attending Loss

The mathematical considerations show that the attending loss A_N on N th loom is given by:

$$A_N = \frac{(1-S)(1-P_N)}{N} \left\{ 1 + \sum_{k=1}^M \frac{\Pi_k}{\binom{M}{K}} \right\} \quad \dots (4)$$

where $M = N - 1$, and $P_j = E_j + D_j$. Further, Π_k is

the sum of $\binom{M}{K}$ terms such that each term is a product

of KP_i 's such that no two terms contain the same P_i 's.

2.3 Estimation of Weaver's Workload

The special attention S described earlier is composed of two parts, S_w and S_o , such that

$$S = S_w + S_o$$

where S_w relates to that workload of weaver which is not concerned with the restarting of a stopped loom, and S_o relates to weaver's neglect of the looms or his absence from the looms for his personal and other needs. We, therefore, obtain weaver's workload W as:

$$W = S_w + \sum_{j=1}^N A_j \quad \dots (5)$$

The interference I_N on the N th loom is given by

$$I_N = (1 - P_N) \left\{ 1 - \frac{(1-S)}{N} \left[1 + \sum_{k=1}^M \frac{\Pi_k}{\binom{M}{K}} \right] \right\} \quad \dots (6)$$

If the loom allocation is 4, then Eq. (4) becomes

$$A_4 = \frac{(1-S)(1-P_4)}{4} \left\{ 1 + \sum_{K=1}^3 \frac{\Pi_K}{\binom{3}{K}} \right\} \quad \dots (7)$$

where

$$P_4 = E_4 + D_4, \text{ and}$$

$$\Pi_1 = P_1 + P_2 + P_3,$$

$$\Pi_2 = P_1P_2 + P_1P_3 + P_2P_3,$$

and

$$\Pi_3 = P_1P_2P_3$$

so that

$$A_4 = \frac{(1-S)(1-P_4)}{4} \left\{ 1 + \frac{(P_1 + P_2 + P_3)}{3} + \frac{(P_1P_2 + P_1P_3 + P_2P_3)}{3} + P_1P_2P_3 \right\} \quad \dots (8)$$

and the expression for I_4 is given by:

$$I_4 = (1-P_4) \left\{ 1 - \frac{(1-S)}{4} \left[1 + \frac{(P_1 + P_2 + P_3)}{3} + \frac{(P_1P_2 + P_1P_3 + P_2P_3)}{3} + P_1P_2P_3 \right] \right\} \quad \dots (9)$$

2.4 Allocation of Identical Sorts

If a weaver is attending on all N looms the same sorts and all N looms perform similarly, then the attending loss A , the interference loss I and the weaver's workload W become special case of Eqs (4), (5) and (6) and are given by:

$$A = \frac{(1-S)[1-(E+D)^N]}{N} \quad \dots (10)$$

$$I = [1-(E+D)] \left\{ 1 - \frac{(1-S)[1-(E+D)^N]}{N[1-(E+D)]} \right\} \quad \dots (11)$$

$$\text{and } W = S_w + (1-S)[1-(E+D)^N] \quad \dots (12)$$

3 Advantages of the Proposed Model

Before seeking the advantages of the model, it is worthwhile to know the interdependent entities of the model. These are as follows:

Weaver's loom allocation (N)

Special attention (S)

Invariant basic efficiencies $(\bar{B})$

Non-weaver losses $(\bar{D})$

Operating efficiencies $(\bar{E})$

Attending losses $(\bar{A})$

Interference losses $(\bar{I})$

where: entities with an overhead bar are column vectors with N elements each. For example, $\bar{B}$ represents a column vector as shown below:

$$\bar{B} = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_N \end{bmatrix}$$

where $B_1, B_2, \dots, B_N$ are the basic efficiencies of the N sorts on the N looms.

The first advantage of the proposed model is that for a given loom allocation, knowing the actual efficiencies, non-weaver losses and the special attention, we can obtain the attending losses and the interference losses. It also helps us in estimating the weaver's workload.

The second advantage is even more important in that from the estimates of stoppage frequencies and weaver's attending times we can 'construct' the basic efficiencies and then obtain the actual estimates of efficiency for any given allocation.

3.1 An Illustrative Example

Let us consider 4 sorts S1, S2, S3 and S4 having the specifications as given in Table 1.

It has been decided to weave these four sorts on 4 looms allocation basis and the relevant details regarding the expected stoppages and mending times of stoppages are given in Table 2.

Table 1—Specifications of sorts

Sort	Type of fabric	Count		Density		Width in
		Warp	Weft	Reeds/in	Picks/in	
S1	Coating	20s	20s	104	64	64
S2	Poplin	30s	36s	96	56	44
S3	Dobby poplin	40s	40s	120	68	44
S4	Shirting	50s	80den	88	88	48

Further, it is expected that the weaver will have an estimated special attention of 25% comprising 15% his workload and 10% his being away from the looms for his personal needs.

Our objective is to estimate the actual efficiencies of the 4 sorts and to estimate the weaver's workload. In order to use the model we need to calculate the basic efficiencies B_1 , B_2 , B_3 and B_4 from the data given in Table 2 for sorts S1, S2, S3 and S4 respectively.

The formula for obtaining the basic efficiency is:

$$\text{Basic efficiency} = \frac{\text{Theoretical time required to insert 10,000 picks}}{\text{Actual time required to insert 10,000 picks}}$$

Thus, by using the above formula we get the basic efficiencies as:

$$B_1 = 83.64\%; B_2 = 86.25\%; B_3 = 90.45\%;$$

$$\text{and } B_4 = 93.33\%$$

To obtain the actual efficiencies we use the formulae of the model. It is of interest to note that the problem stated mathematically amounts to solving N non-linear simultaneous equations. The calculations involved even for 4 looms allocation are quite formidable and hence a computer is needed to obtain the results. The estimated efficiencies, attending losses and interference losses are given in Table 3.

Using the Eq. (5), we find the weaver's workload as 46.06%.

3.2 Sensitivity Analysis

The data given in the illustrative example enables us to carry out the analysis by considering any combination of the given sorts along with any desired loom allocation. Let us, therefore, see some of the possible combinations and their associated analysis.

Case I

Loom allocation : 4 looms

Sorts to be woven : S1 and S2 on 2 looms each

Using the model, we obtain the results as given in Table 4.

Case II

Loom allocation : 4 looms

Sorts to be woven : S3 and S4 on two looms each

Using the model, we obtain the results as given in Table 4.

In case we desire to change the loom allocation, it will be necessary to revise the estimate of special attention since it depends upon the allocation itself. In this illustrative example, the special attention S for 6 looms is such that

$$S_w = 22.5\% \text{ and } S_o = 10\% \text{ and hence, } S = 32.5\%.$$

Table 2—Determinants of loom efficiency for sorts S1-S4

Sort	S1	S2	S3	S4
Type of fabric	Coating	Poplin	Dobby poplin	Shirting
Loom speed, rpm	204	204	198	200
Non-weaver loss, %	3	3	4	3
Warp breaks and warp faults				
Frequency ^a	4.8	4.8	1.6	1.5
Time ^b	65	60	70	63
Shuttle changes				
Frequency ^a	10.0	7.0	7.5	4.5
Time ^b	18	18	20	18
Weft breaks				
Frequency ^a	1.3	0.6	0.5	0.6
Time ^b	18	18	20	18
Misc. stops				
Frequency ^a	1.2	1.1	0.8	0.7
Time ^b	50	40	60	40

^aFrequency per 10,000 picks insertion.

^bTime to mend the stoppage in seconds.

Table 3—Estimated efficiencies, attending losses and interference losses

Sort	Type of fabric	Efficiency %	Attending loss, %	Interference loss, %
S1	Coating	72.86	14.25	9.89
S2	Poplin	76.10	12.13	8.77
S3	Dobby poplin	80.85	8.54	6.61
S4	Shirting	85.89	6.14	4.97

Table 4—Break-up analysis for sorts

Parameter	Case I		Case II	
	S1	S2	S3	S4
Efficiency, %	70.42	73.88	82.27	86.98
Attending loss, %	13.78	11.78	8.69	6.22
Interference loss, %	12.80	11.35	5.05	3.80
Workload, %	66.12		44.82	

Table 5—Estimated efficiencies of sorts on allocation of 4 and 6 looms

Sort	Basic efficiency %	Expected efficiency, %		Loss in efficiency for 6 looms %
		4 looms	6 looms	
S1	83.64	69.45	55.27	20.42
S2	86.25	74.71	64.12	14.17
S3	90.45	81.72	76.83	5.98
S4	93.33	87.37	84.88	2.85

Table 6—Estimated weaver's workload

Sort	Workload, %		Increase in workload for 6 looms %
	4 looms	6 looms	
S1	69.32	87.36	26.02
S2	62.64	83.82	33.81
S3	49.52	71.16	43.70
S4	39.96	58.92	47.45

Case III

Here we will consider the case of allocation of identical sorts to a weaver. In what follows we will see the sensitivity analysis for the 4 sorts. It is interesting to see how the efficiencies and the workload change for all the 4 sorts on change in allocation from 4 to 6 looms. Table 5 gives the estimated efficiencies of the 4 sorts under the alloca-

tion of 4 and 6 looms. The corresponding workload and the relative increase in the workload of the weaver are given in Table 6.

3.3 ATIRA Software Package

ATIRA has developed a software for using the proposed model. It may be noted that the calculations involved are quite formidable which compel the user to use the computer package.

4 Conclusions

The proposed model for the estimation of various aspects of loomshed weaving is superior to the Benson-Cox model in many respects. It permits a sensitivity analysis which can help in deciding the allocation of looms based on the technoeconomics of weaving. It also helps in estimating the weaver's workload which can be used in deciding the loom allocation of weavers while negotiating with the labour unions.

Acknowledgement

The author wishes to thank Shri M C Paliwal of ATIRA for useful discussion and constructions of the examples given in the paper.

Reference

- 1 Benson F & Cox D R, The productivity of machines requiring attention at random intervals, *J R Stat Soc*, 13-B (1951) 67.