The Case of the 'Bad Manufacturer'

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Techniques of Operations Research that can find meaningful application in the textile industry are Linear Programming and Queueing Theory. Work using the Queueing Theory was done by ATIRA in the mid 1950 to find out the impact of relevant factors on the utilization of machine time when an operator minds a number of machines. The automatic looms were just being introduced in the textile industry which was accustomed to giving either two or four looms to a weaver to attend. Tables were developed to show the impact of attention time, number of looms allocated to a weaver, and the stoppage rate of the looms on the efficiency losses. It was clearly seen that as the number of looms allotted to a weaver increases, the 'machine interference' increases slowly at first and much faster after a critical number is reached. The machine interference is the amount of time a stopped loom waits for the weaver to come and restart it. The greater the time needed for 'repairing' the fault at the loom, which mainly depends on the skill of the weaver, and the greater the stoppage rate of the looms, the greater is the time lost on machine interference. In 1980s, when the use of automatic looms had increased substantially, ATIRA developed a diagnostic system for analyzing and improving loom shed efficiency by using these tables. Many mills were helped to detect whether the worker skill, the loom stoppages or the organizational factors were responsible for the low efficiency.

Looms put together the warp and weft yarns to form cloth which is sold as the final product, with or without further chemical processing such as bleaching, dyeing or printing. The average efficiency of the looms in a weaving shed –the shed efficiency –plays a major role in deciding the profit performance of the mill. When a weaver attends to 16 automatic looms, good mills achieve shed efficiencies of the order of 90% and above. A loss of just 1% in efficiency means a loss of about 1% in the profits of the mill, which range usually between 4% and 9% of sales. In other words, achieving high loom shed efficiency is key factor in managing profitability.

A Desperate Overseas Call

The management of a reputed Indian group of mills had taken over the management of a mill in Sri Lanka, which was faring badly in terms of profitability. The CEO whom they had sent to turn around the mill had been in place for over a month, and the situation looked almost incurably hopeless. The efficiency of the loom shed with 384 automatic looms was of the order of 46%, which is about half of what good mills should get. The looms were purchased from an East European manufacturer because these were much less expensive than the Swiss counterpart. The weavers were young girls, freshly trained, with a large turnover of over 30%. The loom stoppages were high, also because of mechanical failures beside breakages of warp and weft yarns. The mill had realised that given these conditions of poor quality of looms and of weavers, the chances of improving loom efficiency were almost nil.

As a last resort, the CEO decided to call in ATIRA, because this group was a member of ATIRA and he was aware of the kind of work we were doing as applied research. After all, it is better for a third party to give the verdict of 'no improvement possible' rather than the mill staff saying so! But there was some reservation on the part of the top management at the headquarters of the group. "These research fellows with their theoretical knowledge may spend too much time to even diagnose the situation. Secondly, we want a practical solution, not some theoretical advice! So, you may call only one person (not a team) as consultant and give that consultant only one week of assignment, no more." ATIRA decided to accept this challenge and sent an experienced consultant familiar with weaving as well as with spinning, since the quality of yarn influences the breakage rates at looms which in turn decide the loom shed efficiency.

The Mill Situation

On reaching the mill, it was seen that the mill had quite a few strengths:

1. The Weaving Manager, in charge of the looms, had extensive experience in erection and repairs of automatic looms of the kind that the mill possessed.
2. The management information system had all the right kind of records on all aspects of working of the mill.
3. The quality and process control system was well developed and was systematically followed.
4. The spinning machinery was reasonably modern and was well maintained by an experienced Spinning Manager, who was a textile degree holder.

5. The supervisory staff was enthusiastic; was ready to cooperate in tackling the situation.

However, all seem to have been convinced that poor quality of looms, and low skills of the girl weavers were the only reasons for the low loom shed efficiency. And also, both these factors are beyond their control.

The Diagnosis

The mill had allotted 16 looms to a weaver and had provided 1 reliever per 4 weavers as was the standard practice in developing countries at that time in 1990s. This meant that the effective loom allocation was [(4x16) / (4+1)=12.8, say] 13. Examination of data on warp (lengthwise yarns) breakages and on weft (widthwise yarn) breakages showed that these were much higher than the standard values for 16 loom allocation.

So, it was necessary to determine with sufficient reliability and with adequate proof the true causes for the observed low level of efficiency. This was done by using the diagnostic system developed by ATIRA (Analysis of Loom Shed Efficiency, P.D. Kimothi and A.R. Garde, 1982, ATIRA Research Note) based on the tables on Machine Efficiency Loss as expected by applying the queueing theory. An extract from these tables is shown in Table 1.

Table 1

Machine Efficiency Loss due to Attending Faults and Machine Interference: Automatic Looms

t	N	a	1.0		4.0		9.0		10.0	
			Att.	Int.	Att.	Int.	Att.	Int.	Att.	Int.
55	6		6.1	1.0	9.4	3.6	14.0	12.4		
	8		5.4	1.4	8.9	5.3	11.9	20.5		
	10		5.1	1.7	8.2	7.4	9.9	31.9		
	12		4.8	2.1	7.5	10.0	8.3	43.2		
	14		4.5	2.4	6.8	13.1	7.1	51.3		
	16		4.3	2.7	6.1	16.7	6.2	57.4		
	20		3.8	3.3	5.0	29.5	5.0	65.9		
	24		3.5	3.8	4.1	41.4	4.1	71.7		

Att. = Percentage loss in running efficiency due to weaver attending faults
Int. = Percentage loss in efficiency due to the looms waiting for attention of the weaver: Machine interference loss.

Table 1 shows an extract from these extensive tables showing the losses in running efficiency of the looms as governed by the loom allocation N, average time in seconds to repair a fault, and the loom stoppages per running hour, a. Losses due to loom stoppages for causes other than these two items of fault clearance and waiting for weaver would be over and above these numbers; for example, if the repair of mechanical fault requires a skilled fitter to be able to attend the loom, it may take an hour of wait. Such losses are to be subtracted from the 'running efficiency' to obtain the loom shed efficiency that corresponds to the production per loom shift.

For any given average time taken to clear a fault, t, and a given rate of machine stoppages, a, the machine efficiency loss due to interference, i, increases with the number of looms allotted, N, to the weaver. The loss increase exponentially as the allotment goes higher. This effect is much greater at high levels of stoppages. As illustration, given t=55 and a =1, for n=6, the loss i is only 1%; but at 24 looms, it is 3.8%. These numbers become much higher when s=9: the loss with just 8 looms is 25% and with 24 looms it is as high as 71.7%.

The first question to be answered in this mill was," Is the skill level of the weavers adequate?" The mill had no data on the time taken by weavers (t in table 1, column 1) to attend to different types of stoppages on the loom. To conduct time and motion studies to determine a truly representative average time for clearing a fault would have taken unduly long time and efforts. Therefore, a simpler way out was to use the 'norm' based on work done in other mills with similar looms. This time was taken as 50 seconds, a little more than the standard time of 45 seconds for this types of looms with skilled workers, to be on the conservative side in estimating the expected efficiency. We looked up Table 1 for an effective allocation of 13 looms, given the high loom stoppage rate.

The expected running efficiency loss for attending is 7.7% and for interference is 43.0 %. The total loss in running efficiency is thus 50.7% which should give the expected running efficiency as 49.3%. Knowing from the mill records that the efficiency loss due to other factors was about 7%, the expected shed efficiency was about 43%. With t as 45 seconds, the expected shed efficiency worked out to be 55 -7 = 48%. But, the mill was getting actual efficiency of about 46%. This would mean that the average time for fault clearance by the weaver girls was around 48 seconds: quite good. So, the average loom efficiency was as expected from well-trained skilled weavers.

Conclusion on day 2: Weaver skill is adequate; low skill is not the reason for low loom efficiency.

The consultant's trust on the results of queueing theory was fine: but the conclusion that the worker skill is not inadequate was not acceptable to the loom shed supervisors as well as to the Weaving Manager and also to the CEO. Obviously, this conclusion went totally against their experience of several years! How can a person from a research institute conclude about the worker skill on the second day of visit to the mill and that, too, without even going to the loom shed and observing the girl weavers doing their work? Frankly, even the consultant was surprised at this conclusion. He decided to test it by a simple but practical way and to demonstrate to the mill that the table of interference losses does indeed work in practice.

Looking up the tables for the right number of looms to be allotted for the existing high rate of loom stoppages, he found that the number is just 9 (in place of 16 with the same allocation of 1 reliever for 4 weavers). So, he showed the machine interference tables to the Weaving Manager and the CEO, and suggested that the mill tries out this allotment in one group of 64 looms (16x4 being replaced by 9x7) and giving 2 relievers to this set of 9 weavers (one of them had to mind 10 looms).The table showed that such a change would increase the running efficiency at t=50 and N=8 (effectively) from 55% to 71%, since the machine interference loss was extremely high for 16 loom allocation. This allocation was implemented the very next day and the efficiencies of each of these 64 looms was tracked. The result was as expected –overnight, this set of looms gave running efficiency of 74% (since the time t for this mill was like 48 seconds) and actual efficiency due to stoppages for maintenance etc. was about 67%. From 46% to 67% overnight was a 'miracle' for the mill. The mill agreed to observe this set off 64 looms for a week and then change over the entire loom shed to 9 looms per weaver. This result was a strong confirmation that weavers' skill level was OK. The same set of weavers gave much higher loom efficiency!

And the same 'poor quality' looms from the East European manufacturer gave this higher efficiency. It could be seen from the interference tables, that if the existing high loom stoppage rate of about 9 per running hour could be brought down to the level of about 1 that good mills achieve, the running efficiency of the loom shed can be as high as 92-93%. Therefore, the next step was to analyse the loom stoppages into three main categories: warp breaks, weft breaks and mechanical failures. (Fortunately, the mill had extensive detailed records on all these.) These numbers per running hour of the loom were about 4, 1 and 4 respectively. The yarn related stoppages were most likely to be due to poor yarn quality, since the maintenance of loom was quite good. The parts with which these warp and weft yarns come in contact were smooth.

The consultant sat down with the loom maintenance supervisor and did a quick exercise: how much time would it take to repair each kind of mechanical fault that occurred in an hour? A somewhat over estimate of time required showed a surprising result: the efficiency loss should be about 1% but was as high as 7%! This category wise fault analysis also showed that one particular small fault was the most recurring fault. This fault consisted of a fork (just like the fork one uses on dining table) which sensed the presence of weft on the loom was getting twisted and the weft yarn was slipping out of it. This would immediately cause the loom to stop, as if the weft is broken. Straightening the fork and inserting the weft yarn in it again was a 'repair' that would take only 3-4 seconds. But the efficiency loss due to this mechanical fault was very high; the loom where the weft yarn had slipped out owing to twisted fork would need to wait till the person from the maintenance team arrived at the loom to repair the fault. The system this mill followed was to send the repair mechanic on a '*first reported, first served*' basis. This observation led the consultant as well as the maintenance supervisor to quickly change the system. Priority was to be given to repair faults that take less time over those which take more time. The machine faults were classified into three categories by the maintenance supervisor who was much more knowledgeable than the consultant in these matters.

Moreover, all agreed that the straightening of the twisted fork may as well be done by the weaver/reliever weaver herself, rather than reporting about it and waiting for the mechanic to appear for this simple repair. Given these system improvements based on common sense 'Queueing Theory', the mill was confident that the efficiency loss due to mechanical failures would come down to about 1% as expected in a good mill.

Conclusion on Day 4: The mechanical condition of the looms is OK;

it is not responsible for the high loss in efficiency ---the quality of manufacture of these looms is good, except for the quality of the weft sensing fork. Replacing the fork on all looms with a stronger version was planned to eliminate this defect. The cost of such replacement was negligibly small.
It was clear by now that even with all these improvements, the efficiency of the loom shed would not reach the 90% level, even with 9 looms allotted to a weaver. It was necessary to reduce the breakage rate of the warp yarns to about 0.5 per loom hour and that of weft yarn to 0.1 per loom hour so that high efficiency of around 90% can be achieved even with 16 looms allotted to a weaver. (The mechanical fault related stoppages reduced almost to 0.1 per loom hour, which is the norm for good mills, when the 'twisted fork' fault was taken away.) The need was to improve yarn 'quality': over to the Spinning Manager.

Assessment of Yarn Quality

The Spinning Manager and his colleagues were surprised to know that the quality of yarn that they supply to the weaving department was not up to the mark. The Quality Control Manager, too, was uncomfortable since the yarn test reports had consistently shown the quality to be good in comparison to the internationally accepted norms. The yarn strength and the yarn unevenness (which is a measure of how irregular the yarn is in terms of variation in thickness of the yarn) were quite good. But the fact of high breakage rates in weaving had to have reasons and these needed to be eliminated.

Applied research at ATIRA had led to two significant observations with respect to yarn quality as it influences the yarn breakages in post spinning operations of winding, warping, sizing and weaving on the loom. Firstly, not only the average quality –yarn strength or yarn evenness–but the frequency of those rare 'outliers' that lie beyond the 'normal' variability also decide the breakage rate. When the averages are poor, the outliers become even more weak. Secondly, during winding, the elimination of unduly thick and unduly weak places in the yarn is critical to warp and weft yarn breakages on the loom. This diagnostic approach helped in tackling quickly the mill situation.(In the absence of such diagnosis, the mill personnel usually take actions at several unimportant places, spend considerable time and efforts, also incur undue expenditure, but still do not get the desired result. Such a situation had prevailed in this mill also.)

We first examined the setting of the electronic yarn clearers employed on the winding machines. These were improved to ensure a good removal of thick places above 3 times the average yarn thickness etc. The yarn tension level was high enough to eliminate weak places in yarn, because the yarn would break at such weak places and a knot or a splice would replace it.

Available data on single thread strength was examined for outliers i.e. values lying outside of the normal range of three times the coefficient of variation on either side of the average value for several different yarn counts. These were pooled and were found to be about 14% ---a very high number compared to the theoretically expected number of maximum 3%. Inspection of the ring frames (last stage of spinning where yarn is formed as a twisted thin strand of fibres) showed defects like eccentric front rollers, damaged drafting aprons, worn out rings and vibrating spindles.

This demonstration of 'poor quality' of yarn in the context of its performance in weaving was revealing to the spinning and quality control staff. They immediately decided to take appropriate maintenance and repair measures to bring down such defectives to the minimum. Such corrective actions would need about a month to cover all ring frames (spinning machines) and the resultant improvement in weaving would need at least a fortnight to be detectable.

Conclusion on Day 6:

Although the average yarn quality was good, **the defectives were too many**. Eliminating the defectives by specific actions would give the desired reduction in breakage rates at looms.

By the **seventh day,** the stipulated last day of the visit of the consultant from ATIRA, two more sections of 64 looms in the weaving shed were changed to 9 looms per weaver. Each of these also showed similar big jump in the loom efficiency. Weavers had started 'repairing' the weft fork fault enthusiastically: after all, their wages were dependent on the efficiency of the looms they attend (i.e. on production in metres per shift in the group of looms they attend). All the 9-loom weavers were happy to receive higher wages owing to the increased productivity of their looms. The CEO, who had half –wondered whether the increase in efficiency due to change in allocation from 16 looms to 9 looms was by 'chance', was fully convinced that the interference tables developed on the basis of queueing theory using simplifying assumptions truly hold in mill practice.

This result was a good demonstration of the fact that the simplifying assumptions such as 'the weavers attend to looms in cyclic manner, the loom stoppages occur at random, averaging the time of fault repair over timings ranging from 3 seconds to as high as 10 minutes (rarely needed) does not hurt the prediction accuracy much etc.

The Case Rests Here

A chance encounter with the CEO, who had returned from Sri Lanka after his contract appointment with the mill was over, gave the ATIRA consultant an opportunity to get a feedback. The overall efficiency of the loom shed had increased to 88% with 16 looms per weaver in about 4 months after the consultation visit. The loss making mill had turned around and was making good profits.

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