

Reduction in Delay in Procurement of Materials using Six Sigma Philosophy

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ABSTRACT *The management of a company was facing the problem of procuring materials in a scheduled time owing to its many pending activities. A study was conducted to reduce the delay in procurement of incoming materials using the six-sigma methodology. The objectives of the study were to understand and internalize the methodology and also to reduce the time taken by critical activities through a disciplined approach. The defect levels for each activity and for the overall system were estimated. The baseline sigma level was found to be 1.8. After taking actions on the critical activities, the average times taken for completing the activities along, with their variabilities, have been reduced satisfactorily. The yield of the overall process has improved to 76% from the level of 62%, leading to an improved sigma level of 2.4.*

KEY WORDS: Six sigma methodology, case study, PERT analysis, PFMEA

Introduction

The Spinning Mill under consideration here was unable to control the delay in procurement of materials (dyes and chemicals). Realizing the severity of the problem, the management of the company took up this study on quality improvement. This study was undertaken to explore the feasibility of reducing the delay in procurement of incoming materials using the six sigma methodology. A number of papers have been published (Hahn *et al.*, 1999; Lucas, 2002; Sanders & Hild, 2000) showing the fundamentals and the successful implementation of six sigma. The objectives of the study were to understand and internalize the methodology and also to reduce the time taken by critical activities through a disciplined approach. It may be mentioned here that the study was carried out in five phases of six sigma. The phases and the activities carried out are described in the following sections.

Define Phase

The primary objectives of the define phase were:

- (a) specifying the scope of the project,
- (b) developing a process map,

- (c) developing a problem statement,
- (d) identifying the defect opportunities,
- (e) formation of a team.

Project Scope

It was decided to carry out the study on the procurement activities of dyes and chemicals, starting from the generation of need of materials, to the clearing of payment of suppliers.

Process Flow Diagram

The core processes to be carried out in procuring materials by the concerned departments are as shown in Figure 1.

Problem Statement

Identify the reasons for discrepancies between the expectation (specification) and the reality related to time taken for the relevant activities, and eliminate the same to the greatest extent possible.

Identification of Defect Opportunities

- *Unit*: An indent/enquiry/quotation/P.O./invoice/GRN/bill/payment advice.
- *Defect*: Any indent/enquiry/quotation/P.O./invoice/GRN/bill/payment advice in the entire process of procurement generates a defect if it is not processed within the stipulated time frame and hence prevents fulfilment of the physical and functional requirements of the internal customer.
- *Defect Opportunity*: A type of potential defect on a unit of throughput (output) which is important to the customer. In this case, any delay in completing an activity for processing a unit could cause a defect in the system.

Therefore, in this study, the number of opportunities for any of the above units is one (1).

- *DPU*: Defects per unit \equiv Defect rate (D).
- *DPO*: amount of defects per opportunity = number of defects/(the number of units \times the number of opportunities) = DPU, here (since number of opportunity = 1).
- *DPMO*: amount of defects in a process per one million opportunities = $DPO \times 10^6$.
- *KPIV*: Key Process Input Variable. In this study, it was considered as a significant (critical) activity for procurement of materials.

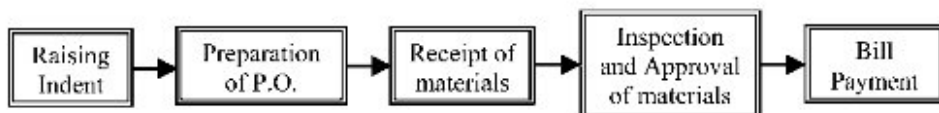


Figure 1. Flow diagram for core processes for procurement

- *KPOV*: Key Process Output Variable. In this study, it was considered as the Overall Delay in procurement of materials. The delay is measured from the target (expected) time of procurement, considered as the defect of the system.
- *CTQ*: Critical to quality characteristics. In this study, time taken in completing an activity was identified as a CTQ related to every unit under consideration.
- *Baseline measures*: Data signifying the level of process performance as it was operating at the initiation of an improvement project (prior to solutions). In this study, the baseline sigma level was measured as an indicator of the existing process performance.

Team Formation

A team was formed to carry out the project with the Purchase Manager as the team leader. The General Manager, Operations was the champion responsible for providing guidance, support as well as the necessary impetus. The Stores Manager was the process owner as well as the executive responsible for providing routine support and resources.

Measure Phase

The objectives of the measure phase were

- (a) To identify the activities in the entire process of procurement, including the supplier–customer (internal) relationships and the expected time of completion (specification) of those activities (both controllable and uncontrollable) through PERT techniques.
- (b) To develop a data collection plan to capture the performance related to time of completion, thereby estimating the defect level.
- (c) To estimate the baseline process performance through the sigma level, and fix the target completion time for procurement.

Identification of all Activities

Table 1 shows the flow of activities.

Identification of Problem Areas of the Current Process

Since external lead time (related activity numbers 4 and 6) was not within the control of management, the management felt interested in studying only the performance of internal lead time for the different activities. Further, activity numbers 5 and 7 were felt less important with respect to sending copies of the documents. Eventually, the critical path shown in Figure 2, showing the interrelationship of the process of procurement, was considered for the study along with the activity numbers.

Identification of KPIV, CTQ and KPOV

For a description of KPIVs and CTQs, see Table 2.

$$\Rightarrow \text{KPOV: } \underline{Y} = f(\underline{X}) = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7)$$

Table 1. Flow of activities (including Supplier–Customer relationship)

Sl. No	Supplier	Activity description	Customer	Expected required time
1	User	Raising of indent and sending to stores	Stores	<2 days
2	Stores	Checking the completeness of indent, materials availability in stores and sending indent to purchase	Purchase	<3 days
3	Purchase	Floating enquiry after receiving the indents	Vendor	<5 days
4	Vendor	Receiving quotations, making comparative charts, then finalization of purchase orders (P.O.)	Purchase	<20 days (local) <30 days (out stationed)
5	Purchase	Sending copies of P.O. to Stores from the date of ordering	Stores	<3 days
6	Vendor	Receiving materials from supplier (vendor)	Stores	As per external lead time
7	Vendor	Sending supplier invoice/challan copy to Stores & Purchase from the date of receipt	Purchase/ Stores	<3 days
8	Stores	Preparation of GRN after the receipt of goods & sending it to User depts.	User	<2 days
9	User	Inspection & approval of mats. from the dt. of GRN	Stores	<5 days
10	Stores	Physical issue of mats. to User depts. from the date of approval	User	<3 days
11	Stores	General payment advice to A/Cs. dept	A/c.	<15 days
12	A/c.	Issuing cheques for general payment	Vendor	<5 days
13	Stores	Advance payment advice to A/Cs.	A/c.	<3 days
14	A/c.	Issuing cheques for advance payment	Vendor	<5 days
15	Purchase	Sending cash purchase bills from the date of incurring the expenditure	A/c.	<7 days
16	A/c.	Passing of cash purchase bills	Vendor	<3 days
17	A/c.	Payment of freight and Octroi bills	Vendor	<5 days

where the KPOV, i.e. \underline{Y} is defined as the Overall Delay in procurement of dyes and chemicals for the Spinning Mill. The delay is measured from the target (expected) time of procurement, considered as a defect of the system. Every KPIV (X) has its own defect rate. This defect rate may represent the degree of non-performance, $D(X)$ of that KPIV. The degree of performance to that KPIV, $P(X)$, is defined by: $P(X) = 1 - D(X)$. Similarly, the degree of performance of KPOV, i.e. $P(Y)$, is determined.

Data Availability

It was planned to put the date of receipt on every unit (indent/enquiry/quotation/P.O. etc) by the concerned department prior to start of their activity. An *activity completion time* (in days) was measured from the difference in receipt dates of two successive departments through which the unit travelled. This exercise was carried out for a duration of about six months for each of the activities related to KPIVs and the respective departments/owners of the processes. Altogether 395 samples (units) were considered.

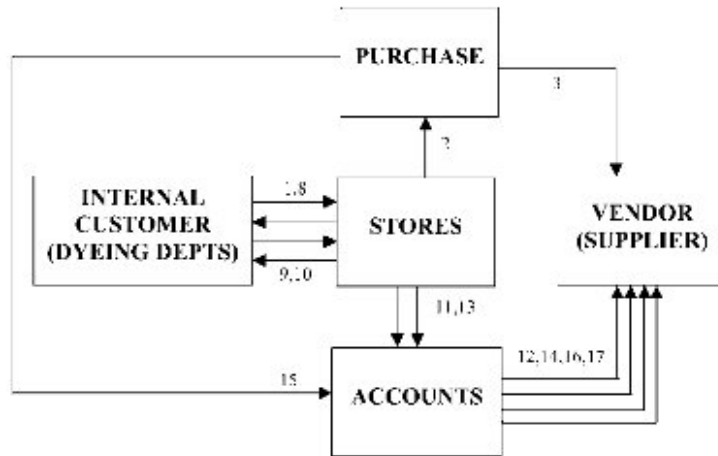


Figure 2. Departmental interrelationship for procurement

Measures and Issues

On the basis of the information collected from indent/enquiry/quotation/P.O./GRN/invoice/challan, the following measures were carried out (see Tables 3, 4 and 5).

- (1) Estimation of mean and variance through frequency distribution of activity completion time.

Table 2. Description of KPIVs and CTQs

KPIV	Activity No.	Activity description	CTQ (Time/duration, in general)
X_1	1	Raising of indent and sending to stores	Difference between date of requisition and date of receipt by Stores
X_2	2	Checking the completeness of indent, materials availability in stores and sending indent to purchase	Difference between date of receipt of indent by Stores and date of receipt by Purchase
X_3	3	Floating enquiry after receiving the indents	Difference between date of receipt of indents by Purchase and date of inviting tender/enquiry
X_4	8	Preparation of GRN after the receipt of goods & sending it to User depts.	Difference between date of GRN preparation and date of receipt by User depts.
X_5	9	Inspection and approval of materials from the date of GRN	Difference between date of GRN preparation and date of approval on GRN
X_6	10	Physical issue of materials to User departments from the date of approval	Difference between date of approval on GRN by User depts. and date of receipt of mats on Issue note by the User depts.
X_7	11–17	Payment (general, advance, cash purchase) process	Difference between date of billing and date of physical payment through cash/cheque

Table 3. Summary statistics of CTQs of KPIVs

Sl. No.	KPIV	Min	Max	Avg	sd	t_c
1	X_1	0.5	18	2.53	4.35	1.08
2	X_2	1	19	5.33	3.31	2
3	X_3	1	21	6.60	5.44	3
4	X_4	0.5	5	2.16	1.41	1.08
5	X_5	1	11	6.06	1.83	2.33
6	X_6	1	12	3.36	2.15	2
7	X_7	6	98	44.75	28.26	12.83

Note: t_c , obtained from Table 4.

- (2) Estimation of average expected time and its variance, using the PERT technique based on Most Pessimistic (t_p), Most Optimistic (t_o), Most Probable (t_m) times as perceived by the management.
- (3) Computation of Defect rate [$D(X)$, i.e. DPU], Performance rate [$P(X)$], DPMO etc for each KPIV.

Sigma Rating and Baseline Measure

Using the findings of defect rates, $D(X)$, for each KPIV, as obtained in the earlier section, the Sigma level of the entire system performance was estimated as follows.

Total number of units checked in the system = 395

Total number of defects observed in the system = 150

Number of opportunities = 1

$$\Rightarrow \text{DPO} = \text{number of defects}/(\text{the number of units} \times \text{the number of opportunities}) \\ = 150/(395 \times 1) = 0.379747$$

$$\Rightarrow \text{DPMO} = \text{DPO} \times 10^6 = 379747$$

$$\Rightarrow \text{Sigma level} \approx 1.8$$

Thus, the baseline sigma level for the existing process performance was found to be 1.8.

Table 4. Estimation of average expected time (t_c) and variance

Sl. No.	KPIV	t_o	t_m	t_p	t_c	S_t	Variance
1	X_1	0.5	1	2	1.08	0.25	0.0625
2	X_2	1	2	3	2	0.33	0.1089
3	X_3	1	3	5	3	0.67	0.4489
4	X_4	0.5	1	2	1.08	0.25	0.0625
5	X_5	1	2	5	2.33	0.67	0.4489
6	X_6	1	2	3	2	0.33	0.1089
7	X_7	7	10	30	12.83	3.83	14.6689
Total	–	12	21	50	24.32	–	15.9095

Notes: $t_c = (t_o + 4t_m + t_p)/6$; $S_t = \text{sd. of } t = (t_p - t_o)/6$

Total expected length (T_c) = $\sum t_c = 24.32$ days with variance ≈ 16 days.

Table 5. Computation of Defect rate [D(X), i.e. DPU], Performance rate [P(X)], DPMO

Sl. No.	KPIV	Sample (Unit)	No. of units checked	No. of defects	Defect rate (DPU)	Performance rate {P(X)}	DPMO
1	X ₁	Indent	109	25	0.2294	0.7706	229358
2	X ₂	Indent	109	37	0.3394	0.6606	339450
3	X ₃	Indent/Tender	15	6	0.4000	0.6000	400000
4	X ₄	GRN	35	13	0.3714	0.6286	371428
5	X ₅	GRN	35	24	0.6857	0.3143	685714
6	X ₆	Issue Note	64	28	0.4375	0.5625	437500
7	X ₇	Bill/Payment advice	28	17	0.6071	0.3928	607143
Total	–	–	395	150	0.379747	0.6203	–

Target Completion Time

Based on the findings on the performance of the identified activities w.r.t. time of completion and the most expected time, as perceived by the management, the target completion time for the combined seven KPIVs has been fixed at 25 days (i.e. average expected time), on average, with a fluctuation of ± 8 days at 95% level of confidence.

Analyse Phase

It has been found that the overall sigma level for the process is 1.8. In the analyse phase, attempts were made to identify the root causes of this problem and find out the contribution of each cause.

The primary objectives of the analyse phase were

- to identify all possible causes contributing to the system discrepancy,
- to estimate the contribution of each cause, and
- to segregate the most critical causes (vital few) for remedial measures.

Identification and Contribution of Causes through PFMEA techniques

The potential causes (reasons for delay) under each KPIV were listed using the concept of PFMEA and ranked on the basis of occurrence [O], severity [S] and detectability [D]. The scales for [O-S-D] were discussed with the management and fixed as shown in Table 6.

In a brainstorming session, all causes were assigned an individual Risk Priority Number (RPN = [O] \times [S] \times [D]). The geometric mean of RPNs for each KPIV were calculated to realize the significance of them relating to the overall system discrepancy (delay) for the procurement process. The higher the RPN value, the higher the contribution of the particular cause for delay in the procurement of materials.

Altogether 24 causes for delay in procurement (see Table 7) were identified, allotted [O-S-D] scale values and ranked in descending order of magnitude, based on RPN values. A total of 11 causes corresponding to the KPIVs X₁, X₃, X₅ and X₇ and leading

Table 6. Interpretation of [O-S-D] scales

Occurrence [O]	Detectability [D]	Severity [S]
Estimates the probability that the failure mode will occur due to the cause given	Estimates the ability to detect the failure mode before it reaches to the customer	Estimates the effect of the failure experienced by the customer
Remote (1)	Very High (2)	Minor (3)
Low (2–4)	High (3)	Major (6)
Moderate (5–6)	Moderate (4–5)	Critical (9)
High (7–8)	Low (6–7)	
Very High (9)	Remote (8–9)	

to a high (unexpected) level of average time along with a high variability in completing the activities were considered for the next phase of the study, where RPN scores were found to be above 100.

Improve Phase

The objective of this phase was to work on the root causes (identified in the analyse phase, and see Table 8) and eliminate them so as to achieve lasting improvement. The steps undertaken in this direction were as follows.

The following actions were decided by the management for the possible improvement of the procurement process:

Activity description (X₁: Raising indent and sending to Stores)

The user departments were instructed to use a general indent as an 'urgent' indent only after understanding the actual need of the materials. It was decided to make all the respective users aware of the effective interrelationship between production planning and the procurement plan. Further, the user departments were provided with the list of the lead time for enquiry, ordering and procurement, which will match the actual urgency, procurement type, destination (local/out-stationed) of the supplier and the subsequent processing of the indent to ultimately reach the Purchase department.

Activity description (X₃: Floating enquiry after receiving the indents)

It was decided to review the status of the presence of complete specifications of each material, including its code number, and then make it available online to the Purchase department to reduce unnecessary paper work. The Purchase department was instructed to update the list of all approved suppliers after every six months through their periodic assessment based on quality, delivery, price and other service commitments. This list must accompany the materials' details supplied by those suppliers and be available online to Purchase and Stores departments. The existing supplier assessment system has been modified through a quantitative approach.

Table 7. Contribution of causes of delay

Sl. No	Failure mode (KPIV)	Causes of failure (delay)	O	D	S	RPN	Geometric mean of RPN
1.	X_1	C1. variation in indent type	7	4	5	140	172.68
		C2. absence of clarity in authority	5	3	4	60	
		C3. need misunderstood	6	8	5	240	
		C4. lack of knowledge w.r.t. lead time	9	7	7	441	
2.	X_2	C5. incomplete delivery time, not duly signed, missing dates etc.	6	3	5	90	92.95
		C6. stock mismatch (physical vs. on-line SAP)	3	4	8	96	
3.	X_3	C7. not updated approved vendor list	7	5	7	245	159.56
		C8. delay in indent grouping	6	3	4	72	
		C9. unnecessary paper work	5	5	5	125	
		C10. lack of knowledge w.r.t. material specs.	6	7	7	294	
		C11. absence of invoice/challan copy	2	3	6	36	
4.	X_4	C12. mismatch between P.O. & invoice/challan	3	4	7	84	128.96
		C13. delay in unloading of materials	4	2	4	32	
		C14. lack of communication	5	6	5	150	
		C15. manpower problem	6	4	4	96	
5.	X_5	C16. lack of communication	7	7	6	294	61.30
		C17. error in the process of sampling, testing etc.	4	7	7	196	
		C18. absence of date of approval	5	2	5	50	
		C19. manpower trouble	4	4	4	64	
6.	X_6	C20. delay in paper work in stores (indent/GRN/stock register/Bin card etc.)	4	6	5	120	227.41
		C21. storage and handling issue	2	5	3	30	
7.	X_7	C22. late approval of mats. by the user depts.	7	5	6	210	227.41
		C23. late receipt of P.O. by Stores from Purchase	5	5	5	125	
		C24. lack of proper control at bill passing section	8	8	7	448	

Activity description (X_5 : Inspection and approval of materials from the date of GRN)

A lack of communication between Stores and user departments regarding the receipt of materials, which eventually delayed the process of inspection and approval, was sorted out. Adoption of a scientific bulk sampling inspection scheme for the most critical categories of dyes and chemicals was thought of to reduce the time of decision making for approval of materials due to taking samples in an ad-hoc manner and thereby increasing

Table 8. Description of root causes

Sl. No.	Avg	t_e	Cause of failure (delay)	RPN
X_1	2.53	1.08	C1. variation in indent type	140
			C3. need misunderstood	240
			C4. lack of knowledge w.r.t lead time	441
X_3	6.6	3	C7. not updated approved vendor list	245
			C9. unnecessary paper work	125
			C10. lack of knowledge w.r.t material specs.	294
X_5	6.06	2.33	C16. lack of communication	294
			C17. error in the process of sampling, testing etc.	196
X_7	44.8	12.8	C22. late approval of mats by the user depts.	210
			C23. late receipt of P.O. by Stores from Purchase	125
			C24. lack of proper control at bill passing section	448

variation of the performance level. Documentation such as rejection report, date of notification of approval, inspection status through colour tags were decided to put in a proper place to improve the process of communication.

Activity description (X_7 : Payment process)

It was observed in the measure phase that 60% of bills had taken more than a month to pass. The following actions were decided.

- Advance payment.* After receipt of authorized payment advice from the Purchase department through Stores, the Accounts department must issue the cheques within three days (instead of five days).
- General payment.* Suppliers must send their invoice copy/challan to the Purchase department within three days, mentioning the code numbers of materials and suppliers. After sending payment advice from Stores within ten days (instead of fifteen days), the Accounts department must issue cheques for payment within five days. Some other activities, like material approval, sending copies of P.O. etc, were streamlined.
- Cash purchase bills.* The Purchase department will send these within three days from the date of incurring the expenditure after being duly approved by the concerned authority.
- Freight and Octroi bills.* These must be made within three days (instead of five days).

Status of Improvement

After taking the actions on the above problems, along with holding the stability of the other activities, information on activity completion time was collected in the same manner, for the next two quarters. The collected data were scrutinized to verify the status of improvement, if any. Tables 9 and 10 give a comparative picture on the findings observed.

As can be observed, the discrepancy of the entire system is approximately 24%. In other words, the system's performance (yield) is about 76%. Thus, there is a significant

Table 9. Improvement status

Sl. No.	KPIV	t_e	Before improvement		After improvement Quarters-(1 + 2)	
			Avg	sd	Avg	sd
1	X_1	1.08	2.53	4.35	1.5	2.04
2	X_3	3	6.60	5.44	3.8	3.29
3	X_5	2.33	6.06	1.83	4.5	2.08
4	X_7	12.83	44.75	28.26	25.8	19.52

improvement of process performance from the level of 62% (earlier, Table 5). The improved sigma level based on the reduction in defect rate (DPO or DPMO) from the level of 38% to 24% was computed theoretically and found to be around 2.4.

It may be concluded from the above findings of the Improve phase of this study that all the activities (KPIVs) in the entire process of procurement of materials have been more or less affected by taking necessary actions on the significant (root) causes of the four KPIVs, namely X_1 , X_3 , X_5 and X_7 . The average time taken in completing the activities along with its variability has been improved (reduced) satisfactorily.

The next phase, i.e. the Control phase of this study aims at 'holding the gains' obtained through the improve phase.

Control Phase

In this phase, the management has started restructuring the indenting process, Stores and Purchasing process, material inspection and approval process and the bill passing process through implementation of the following control schemes in a structured manner.

- (i) increasing awareness about the lead time of all materials by the relevant personnel,
- (ii) stringent monitoring of indent for proper fulfilment while raising the indent,
- (iii) reviewing and updating the supplier approval list in every quarter,

Table 10. Improved defect rate and DPMO [two quarters combined]

Sl. No.	KPIV	Sample (Unit)	No of units checked	No of defects	Defect rate (DPU)	DPMO (present)	DPMO (previous)
1	X_1	Indent	67	9	0.1343	134328	229358
2	X_2	Indent	67	15	0.2238	223880	339450
3	X_3	Indent/Tender	10	2	0.2000	200000	400000
4	X_4	GRN	22	6	0.2727	272727	371428
5	X_5	GRN	22	9	0.4091	409091	685714
6	X_6	Issue Note	36	12	0.3333	333333	437500
7	X_7	Bill/ Payment advice	16	5	0.3125	312500	607143
Total	–	–	240	58	0.2417	241667	379747

- (iv) evaluating the effectiveness of training provided to the inspectors on the scientific sampling process and testing methods,
- (v) assessing suppliers' delivery performances from time to time,
- (vi) ensuring all types of payment in schedule time,
- (vii) knowledge about the expected required time for each activity in the whole procurement process and working upon it accordingly,
- (viii) strengthening the internal communication process along with the necessary reporting structures among the personnel/departments engaged in material procurement.

Conclusions

It is observed from the results obtained from this study that there is further scope for improvement, in general, with respect to the total time of completing the critical activities of procurement, as identified. Hence, by identifying specific unaddressed issues, if any, and maintaining the present level of stability of the system, studies can be initiated by selecting critical items from each of the different categories, like general, spare parts, building, packing, dyes & chemicals and capital. However, to start with, the expected required time to be taken, the responsibility and other criticality details of each activity should be known a priori to every concerned department for procurement. The study will be based on lead time enlisted for each item as standard by the company. However, the management has started thinking of adopting Six Sigma philosophy as a bottom line improvement strategy for other critical business processes in the organization.

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