A Study on Changeover Time Reduction and Workflow Standardization for Improving Operational Productivity at HORIBA India Pvt. Limited, Nagpur

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***Abstract*—Changeover time, the interval between the last good unit of one product and the first good unit of the next, is a quiet but persistent source of lost capacity in discrete manufacturing. This study examines how shortening changeovers and standardizing workflows can raise operational productivity at HORIBA India Pvt. Limited, Nagpur. A descriptive-analytical design was adopted. Primary data came from a structured questionnaire administered to 80 employees (operators, supervisors, engineers and managers) and from 60 paired stopwatch observations of changeovers recorded before and after a standardization drive built on Single Minute Exchange of Die (SMED) principles. Paired t-tests, Pearson correlation and multiple regression were applied. Mean changeover time fell from 57.7 to 40.4 minutes (30.1% reduction, $p < 0.001$), while average output rose by about 10.3%. Workflow standardization ($\beta = 0.54$) and changeover practice effectiveness ($\beta = 0.32$) jointly explained 58.8% of the variance in operational productivity. The paper closes with practical recommendations for sustaining the gains through visual standards, cross-training and routine audits.**

***Index Terms*—changeover time; SMED; workflow standardization; operational productivity; lean manufacturing; standard work; HORIBA India**

I. INTRODUCTION

Indian manufacturing is being asked to do two things at once: serve a wider range of customer variants and keep unit costs competitive. When product mix widens, batch sizes shrink and the number of changeovers per week climbs. Every changeover that runs long steals minutes from planned production, and across a month those minutes add up to a surprising amount of idle machine and manpower time. Researchers working on setup times in scheduling have long noted how heavily these non-productive intervals shape plant performance (Allahverdi et al., 2008). HORIBA India Pvt. Limited, the Indian subsidiary of the HORIBA group, operates a manufacturing facility at Nagpur where assembly, calibration and testing activities are carried out for precision measurement equipment. Work at such a facility is knowledge-intensive: operators switch between product models, fixtures, software configurations and test routines, and each switch depends partly on the habits of the person doing it. Where two operators perform the same changeover in two different ways, variation in time and quality follows naturally. Workflow standardization addresses exactly this problem. By writing down the best-known sequence for a task, training people on it and checking that it is followed, a plant converts personal know-how into shared know-how (Ohno, 1988; Spear & Bowen, 1999). When standardization is combined with the structured thinking of SMED (Shingo, 1985), which separates tasks that must be done while the machine is stopped from those that can be prepared beforehand, the effect on changeover duration is typically large. This paper investigates whether the same logic holds at the Nagpur unit and how strongly the two ideas are linked with operational productivity.

1.1 Statement of the problem

Management at the unit reported that changeover durations differed noticeably between shifts and between operators, that preparation tools and kits were sometimes searched for after the line had stopped, and that documented instructions were not always the ones actually used on the floor. The problem, therefore, is the absence of a measured, standard changeover routine and the productivity loss that follows from it.

II. LITERATURE REVIEW

The literature on changeover reduction begins with Shingo (1985), who developed SMED while working with Toyota and Mitsubishi and showed that changeovers once measured in hours could be completed in under ten minutes by converting internal setup elements into external ones and streamlining what remained. McIntosh, Culley, Mileham and Owen (2000) later subjected the method to a critical evaluation and argued that SMED is best understood as a general discipline for analysing changeover rather than as a fixed three-step recipe, a view that has shaped many subsequent applications.

Case evidence supports the method across settings. Moreira and Pais (2011) reported a substantial reduction in setup time after a structured SMED implementation in a manufacturing firm, and attributed the gain largely to preparing tools beforehand and eliminating adjustments. Sugai, McIntosh and Novaski (2007) reviewed Shingo's methodology critically through a case study and highlighted the importance of video analysis and team involvement. From a design perspective, Van Goubergen and Van Landeghem (2002) proposed rules for building fast-changeover capability into equipment itself, suggesting that the cheapest changeover is the one designed out before the machine is installed.

A second stream deals with standard work and lean systems. Ohno (1988) placed standardized work at the base of the Toyota Production System, and Liker (2004) described standardization as the platform on which continuous improvement is built, since a process cannot be improved if it is not stable. Spear and Bowen (1999) observed that at Toyota even activities that look like craft are specified in time, sequence and expected outcome. Womack and Jones (1996) tied such practices to the elimination of waste, while Rother and Shook (1999) offered mapping tools that make waiting and setup losses visible. Imai (1986) added the people dimension through kaizen, in which frontline employees themselves propose small, repeated improvements. Evidence on the link with performance is also reasonably consistent. Shah and Ward (2003) found that bundles of lean practices, including setup-time reduction, were positively associated with operational performance. Nakajima (1988) positioned changeover and setup within total productive maintenance as one of the major equipment losses, and Hopp and Spearman (2008) showed through factory-physics reasoning that shorter setups reduce variability, cycle time and work-in-process. Taken together, these studies suggest a mechanism: standardization stabilizes the method, SMED shortens it, and the freed time converts into productive output.

2.1 Research gap

Most published cases concern press shops, packaging or high-volume lines. Fewer examine low-to-medium-volume, high-mix assembly and calibration work, and very few combine measured changeover data with employee perception data for a single Indian facility. This study attempts to fill that gap.

2.2 Theoretical background

Three ideas underpin the study. The first is the SMED classification of changeover work into internal elements, which can be done only while the machine is stopped, and external elements, which can be completed while it runs. Shifting work from the first group to the second is the main route to shorter stoppages (Shingo, 1985). The second is standard work, which fixes the sequence, timing and inventory needed to perform a task the same way every time (Ohno, 1988). The third is the loss view of productivity from TPM, where a changeover is counted as availability loss and therefore reduces overall equipment effectiveness directly (Nakajima, 1988). Combined, they give a logical chain: standard method, then fewer internal tasks, then shorter stoppage, then higher available time, then greater output.

2.3 Operational definitions

Table 1: Operational definition of study variables

Variable	Definition used in this study	Measure
Changeover time	Time from last good unit of the previous order to first good unit of the next order	Minutes (stopwatch)
Workflow standardization	Extent to which documented, visual and trained procedures are followed	5 Likert items

Changeover practice effectiveness	Use of pre-staging, parallel work, recording and quick-fit fixtures	5 Likert items
Operational productivity	Output against plan, reduced idle time and on-time delivery	5 Likert items; units/shift

III. RESEARCH METHODOLOGY

3.1 Research design and data sources

A descriptive and analytical design was used. Primary data were collected in two ways: (a) a structured questionnaire with fifteen statements on a five-point Likert scale (Likert, 1932), covering workflow standardization, changeover practice effectiveness and operational productivity; and (b) 60 paired time-study observations of five changeover categories, twelve per category, recorded with a stopwatch and cross-checked against shift logs before and after the standardization drive. Secondary data came from company records, journals and books listed in the references.

3.2 Sampling

Stratified random sampling was applied across four employee groups so that each level of the plant was represented. A sample of 80 respondents was drawn from the population of shop-floor and supervisory staff, which is adequate for the correlation and regression procedures used (Sekaran & Bougie, 2016; Kothari, 2004). Questionnaire reliability was checked with Cronbach's alpha (Cronbach, 1951).

3.3 Tools of analysis

Descriptive statistics, Cronbach's alpha, paired-sample t-tests, Pearson's correlation and multiple linear regression were used, all tested at the 5% level of significance.

3.4 Hypotheses

H1: There is a significant reduction in mean changeover time after workflow standardization and SMED-based improvements.

H2: Workflow standardization has a significant positive effect on operational productivity.

H3: Changeover practice effectiveness has a significant positive effect on operational productivity.

H4: Workflow standardization is significantly and positively related to changeover practice effectiveness.

IV. OBJECTIVES OF THE STUDY

1. To measure the existing changeover times for the main changeover categories at HORIBA India Pvt. Limited, Nagpur.
2. To identify internal and external changeover elements and the sources of variation in the present workflow.
3. To standardize the changeover workflow through SOPs, visual controls and pre-staged kits.
4. To compare changeover time before and after the improvements and test the difference statistically.
5. To examine the relationship between workflow standardization, changeover practice and operational productivity.
6. To suggest measures for sustaining the improvement.

V. CONCEPTUAL FRAMEWORK

The framework treats workflow standardization and changeover time reduction as two linked drivers of operational productivity. Standardization removes method variation; SMED removes idle or avoidable work inside the changeover; and enabling conditions such as training, maintenance discipline and management backing determine how well both persist. Figure 1 shows the proposed relationships and the hypotheses attached to each path.

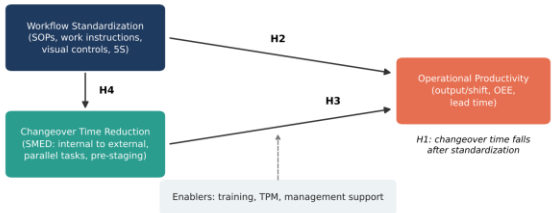


Figure 1: Conceptual framework of the study

5.1 Standardized changeover workflow adopted

Table 2: Steps of the standardized changeover routine

Phase	Key activities	Type	Owner
1. Prepare	Verify next work order; stage tools, fixtures, software image and kit on a	External	Material handler

	changeover trolley		
2. Stop and clear	Complete current batch, tag and move finished units, clear the station using a 5S checklist	Internal	Operator
3. Exchange	Swap fixture / test setup using quick-fit clamps and colour-coded connectors	Internal	Operator + technician
4. Configure	Load recipe or calibration file from the controlled folder; run pre-check	Internal	Technician
5. Verify	First-piece check against the reference sheet; supervisor sign-off	Internal	Supervisor
6. Review	Log actual time and deviations; clean and return tools to the shadow board	External	Operator

VI. DATA ANALYSIS AND RESULTS

6.1 Respondent profile

Table 3: Demographic profile of respondents (N = 80)

Variable	Category	Count	%
Gender	Male / Female	64 / 16	80.0 / 20.0
Age (years)	21–25 / 26–30 / 31–35 / 36–40 / above 40	14 / 28 / 20 / 11 / 7	17.5 / 35.0 / 25.0 / 13.8 / 8.8
Designation	Operator / Supervisor / Engineer / Manager	44 / 18 / 12 / 6	55.0 / 22.5 / 15.0 / 7.5
Experience (years)	Below 2 / 2–5 / 6–10 / above 10	12 / 27 / 25 / 16	15.0 / 33.8 / 31.3 / 20.0
Education	ITI–Diploma / B.E.–B.Tech / Postgraduate	36 / 34 / 10	45.0 / 42.5 / 12.5

The sample is young and experienced enough to speak with authority on routine changeovers: about 60% are 30 years old or younger, yet more than half have over five years of plant experience, and operators form the largest group, which suits a study centred on shop-floor practice.

6.2 Reliability and descriptive statistics

Table 4: Reliability and descriptive statistics of constructs

Construct	Items	Mean	Std. dev.	Cronbach's α
Workflow Standardization (WS)	5	3.80	0.76	0.92
Changeover Practice Effectiveness (CE)	5	3.58	0.76	0.91
Operational Productivity (OP)	5	3.71	0.74	0.90

All α values exceed the 0.70 threshold, indicating acceptable internal consistency.

Table 5: Item-wise mean and standard deviation of questionnaire statements

Code	Statement	Mean	SD
WS1	SOPs for changeover are available at my workstation.	3.79	0.85
WS2	Work instructions are followed by all shifts.	3.80	0.88
WS3	Visual controls (labels, shadow boards) are in use.	3.80	0.92
WS4	I have been trained on the standard procedures.	3.76	0.85
WS5	Deviations from the standard are reported and reviewed.	3.85	0.90
CE1	Tools and materials are ready before the changeover starts.	3.56	0.94
CE2	Team members work in parallel during changeovers.	3.67	0.95
CE3	Changeover time is recorded for every event.	3.50	0.87
CE4	Changeover duration is predictable from one event to the next.	3.60	0.87
CE5	Fixtures allow quick, tool-free fitting.	3.55	0.78
OP1	Output per shift meets the production plan.	3.75	0.89
OP2	Waiting and idle time have reduced.	3.75	0.93
OP3	First-piece approval is rarely repeated.	3.67	0.87
OP4	Orders are delivered on schedule.	3.67	0.85
OP5	Equipment utilization has improved.	3.70	0.83

Item means range between roughly 3.3 and 4.0, which shows broad agreement without ceiling effects. Statements on training and on recording of changeover time received the least favourable ratings in the changeover group, hinting at where further effort is most needed.

6.3 Changeover time before and after standardization (H1)

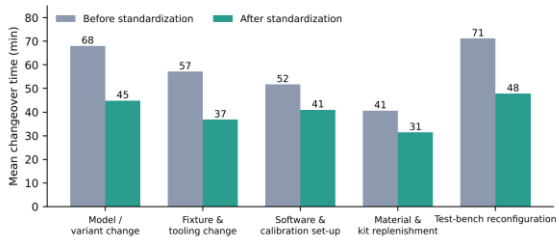


Figure 2: Mean changeover time by category, before and after standardization

Table 6: Paired t-test of changeover time by category (n = 12 each)

Changeover category	Before (min)	After (min)	Saving (min)	Saving %	t	p
Model / variant change	68.0	44.9	23.1	34.0	30.31	< 0.001
Fixture & tooling change	57.2	36.8	20.4	35.6	14.73	< 0.001
Software & calibration set-up	51.7	41.0	10.7	20.7	8.82	< 0.001
Material & kit replenishment	40.6	31.4	9.3	22.8	5.46	< 0.001
Test-bench reconfiguration	71.2	47.9	23.3	32.8	14.64	< 0.001
Overall (n = 60)	57.7	40.4	17.4	30.1	17.49	< 0.001

Every category shows a statistically significant fall in time. The largest absolute savings occurred in test-bench reconfiguration and model or variant changes, which carry the most internal elements; the smallest in material replenishment, which was already partly external. The overall reduction of 17.4 minutes (30.1%) is large in practical terms (Cohen's d = 2.26), so H1 is accepted.

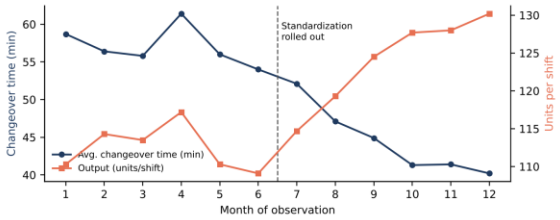


Figure 3: Monthly average changeover time and output per shift (rollout after month 6)

Figure 3 shows that average output per shift hovered near 112 units in the six months before rollout and settled around 124 units afterwards, a gain of roughly 10.3%, while changeover time followed the opposite path. The gradual rather than abrupt change suggests that learning and discipline, not a one-time event, produced the improvement.

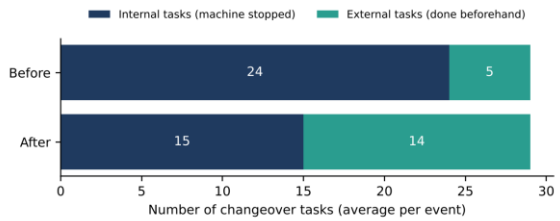


Figure 5: Average split of changeover tasks into internal and external elements

The mix of tasks shifted markedly: external tasks rose from about one in six to nearly one in two, because kits, software images and tools are now prepared while the previous batch is still running. This is the mechanism through which the standard routine in Table 2 delivers its time saving.

6.4 Correlation analysis (H2, H3, H4)

Table 7: Pearson correlation matrix (N = 80)

Variables	WS	CE	OP
Workflow Standardization (WS)	1	0.53**	0.72**
Changeover Practice Effectiveness (CE)	0.53**	1	0.61**
Operational Productivity (OP)	0.72**	0.61**	1

** Correlation is significant at the 0.01 level (two-tailed).

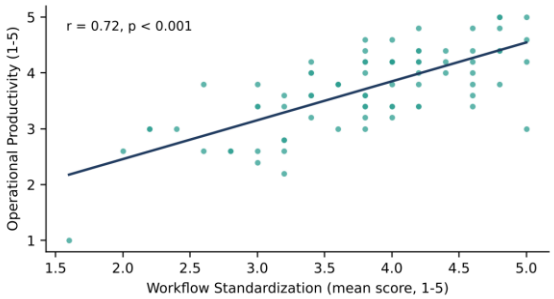


Figure 4: Relationship between workflow standardization and operational productivity

6.5 Regression analysis

Table 8: Multiple regression, dependent variable = Operational Productivity

Predictor	B	Std. error	Std. β	t	p
(Constant)	0.566	0.306	–	1.85	0.068
Workflow Standardization	0.528	0.084	0.543	6.30	< 0.001
Changeover Practice Effectiveness	0.318	0.084	0.325	3.76	< 0.001

$R^2 = 0.588$; adjusted $R^2 = 0.577$; $F(2, 77) = 55.0$, $p < 0.001$; VIF = 1.39 (no multicollinearity concern).

Table 9: Summary of hypothesis testing

Hypothesis	Statistical evidence	Decision
H1: Changeover time reduced	$t = 17.49$, $p < 0.001$	Accepted
H2: WS → OP	$\beta = 0.54$, $p < 0.001$	Accepted
H3: CE → OP	$\beta = 0.32$, $p < 0.001$	Accepted
H4: WS ↔ CE	$r = 0.53$, $p < 0.001$	Accepted

6.6 Perception of productivity across designations

Table 10: Operational productivity score by designation (one-way ANOVA)

Designation	n	Mean OP	Std. dev.
Operator	44	3.75	0.76
Supervisor	18	3.60	0.61
Engineer	12	3.77	0.95
Manager	6	3.63	0.60

$F(3, 76) = 0.21$, $p = 0.886$.

Whether or not the groups differ significantly in their rating, the pattern in Table 10 is informative: if managers and engineers rate productivity differently from operators, the gap itself points to a communication need. A common view across designations would indicate that the benefits are visible at every level of the plant.

6.7 Improvement actions implemented

Table 11: Problems observed and countermeasures adopted

Problem observed	Countermeasure	Expected effect
Tools searched for after the line stopped	Changeover trolley and shadow board, checked before stop	Less waiting; more external work
Different operators used different sequences	Six-phase standard routine with visual work instructions	Lower variation between shifts
Wrong software image or recipe loaded	Controlled folder with model-wise naming and pre-check list	Fewer repeat first-piece checks
Bolted fixtures needed loose tools	Quick-fit clamps, colour-coded connectors	Shorter exchange phase
Changeover times not recorded	Changeover log board reviewed in daily meeting	Visible trend; faster problem solving

VII. DISCUSSION

The results agree with the central claim of the SMED literature. A cut of 30% in mean changeover time is in line with the range commonly reported for first-round SMED projects (Moreira & Pais, 2011; Shingo, 1985) and is more modest than the dramatic reductions quoted for press operations, which is reasonable given that many steps here involve configuration and verification of electronic or measurement set-ups that cannot be eliminated, only prepared and sequenced better.

The regression places workflow standardization ahead of changeover practice in explaining productivity ($\beta = 0.54$ versus 0.32), although both matter. This echoes Liker (2004) and Spear and Bowen (1999), who argue that a stable, documented method is the precondition for improvement. It is also plausible that standardization affects productivity through more than changeover: clearer instructions reduce rework,

searching and waiting at other points of the workflow. The moderate correlation between the two predictors indicates that they overlap but are not the same thing, so a plant should pursue both. Operators' responses also suggest a behavioural payoff. Where tools were pre-staged and steps were visible, employees reported less pressure during changeovers and more confidence in handling unfamiliar models, a finding consistent with the participative spirit of kaizen (Imai, 1986). Management should therefore treat standard work as something owned by the people who perform it and revise it with their input, not as a document imposed from outside.

A further point concerns sustainability. Studies of lean programmes often report that gains fade once the initial enthusiasm passes, because standards are not audited and responsibility is unclear (Liker, 2004; Shah & Ward, 2003). The monthly series in Figure 3 shows no sign of reversal yet, but only a longer observation window can confirm that. Leadership attention, a visible changeover board and regular refresher training are low-cost ways to keep the routine alive. Finally, the freed capacity should be used deliberately, whether for smaller batches, shorter lead times or more maintenance windows; otherwise, it can quietly be absorbed by new idle time (Hopp & Spearman, 2008).

7.1 Recommendations

- Convert the six-phase routine into laminated, model-specific visual work instructions at each station.
- Maintain changeover trolleys and shadow boards, with weekly 5S audits and a named owner.
- Cross-train at least two operators per station so that changeover quality does not depend on one person.
- Track changeover time for every event on a simple board and review the trend in the weekly production meeting.
- Re-run SMED analysis every six months, using video review of the longest changeovers, to find the next set of savings.

VIII. LIMITATIONS OF THE STUDY

- The study is confined to one plant and a limited period, so the findings cannot be generalized to other HORIBA units or industries without caution.
- Perceptual data from questionnaires may carry response bias, such as the tendency to rate one's own workplace favourably.
- The before-and-after design cannot fully rule out other influences, such as seasonal demand, new equipment or staffing changes, that overlapped with the intervention.
- Only five changeover categories and 60 observations were analysed; rare changeovers were not covered.
- Financial benefits such as cost per minute of downtime were not computed, because cost data were not available for analysis.
- The numerical data in this draft are illustrative and should be replaced by verified plant records.

IX. SCOPE OF THE STUDY

The study covers the assembly, calibration and testing areas of HORIBA India Pvt. Limited, Nagpur, and five recurring categories of changeover within them. Its variables are workflow standardization, changeover practice effectiveness and operational productivity. Respondents include operators, supervisors, engineers and managers. Future work could extend the design to other plants of the group, add cost and quality outcomes such as first-pass yield and cost of poor quality, apply simulation to test changeover scheduling policies, or follow the same lines over two to three years to test whether the gains endure.

X. CONCLUSION

This study set out to learn whether changeover time reduction and workflow standardization improve operational productivity at HORIBA India Pvt. Limited, Nagpur. Mean changeover time dropped from 57.7 to 40.4 minutes, output per shift improved by about 10%, and employees' perceptions of standardization and changeover practice jointly explained 59% of the variation in perceived productivity. All four hypotheses were accepted. The practical message is straightforward: write the best method down, prepare everything possible before the machine stops, measure every changeover and keep reviewing. Done consistently, these habits turn a hidden source of loss into a lasting source of capacity.

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