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PRODUCTIVITY IMPROVEMENT IN A TRUCK CHASSIS LONG MEMBER MANUFACTURING COMPANY IN PITHAMPUR: A CASE STUDY

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Abstract

In the fiercely competitive manufacturing landscape, optimizing productivity is paramount. This research paper focuses on enhancing productivity in a truck chassis long member manufacturer located in Pithampur, Madhya Pradesh. The study employs various methodologies and tools related to industrial engineering such as time study, Single Minute Exchange of Die (SMED) and work sampling to identify and address key constraints and inefficiencies. It explores critical issues such as machine breakdowns, worker idleness, and operator activities. The time study on the Press machine results in providing management with standard time for the current production model. SMED implementation reduces coil changeover times, boosting productivity by 51.5% and 64% in specific machines. The work sampling activity provides insights into downtime causes and their duration, worker idleness time and operator activities, facilitating maintenance prioritization and targeted training. Overall, this study significantly improves production efficiency, laying the foundation for further enhancements in standard time calculations, tool storage optimization, and worker training. These findings offer potential for long-term productivity growth and provide a basis for developing Standard Operating Procedures (SOPs) as the company plans for expansion.

Keywords: Productivity, Work Study, Time Study, Single Minute Exchange of Die, Work Sampling, Downtime

INTRODUCTION

In today's fiercely competitive business landscape, achieving optimal performance within minimal time has become a paramount objective for organizations. In manufacturing, this drive for efficiency has left little room for flexibility in production schedules, rates, delivery timelines, and quality standards. In manufacturing, cycle time represents the total time a product or part spends within the production system, encompassing the interval between the departure of two consecutive parts or the time spent as a work-in-progress [Panneerselvam, R., 2012]. Efforts to improve productivity involve aligning existing resource productivity with forecasted demand while optimizing the utilization of analysed manufacturing resources. Such analyses focus on enhancing productivity through efficient machine use within specified timeframes, but they must also consider the economic and operational efficiency of additional workstations [Trojanowska J. et al., 2018]. Maximizing a resource's manufacturing capacity can pose challenges, as reaching 100% utilization at a workstation may lead to increased breakdowns and production delays due to resource downtime. Bottlenecks in manufacturing can disrupt processes, causing inventory accumulation and downtime [Banga, H., K., et al., 2020]. Thus, when striving to boost manufacturing productivity, it's crucial to ensure well-organized processes at bottleneck stations. Numerous approaches are available to reduce cycle time and minimize waste in various processes, as revealed in systematic literature surveys. One renowned method for reducing cycle time is the Toyota Production System (TPS), celebrated for its positive impacts on product quality, cost reduction, and lead time reduction [Kumbhar et al., 2014]. Common waste categories include overproduction, unnecessary inventory, waiting times, excessive transportation, needless processing, wasted motion, defective parts, underutilized human resources and facilities [Sreelekshmy et al., 2013]. One technique used to address these issues is SCAMPER, which stands for "substitute, combine, adapt, modify, put, eliminate, reverse." SCAMPER helps substitute components or processes, combine related tasks, adapt practices to save time, modify ineffective processes, assign the right workers, eliminate unnecessary elements, and reverse actions when needed [Taifa et al., 2018]. Long cycle times pose challenges for manufacturing industries, particularly those not considered world-class. Researchers advocate integrating various techniques to address industrial problems and achieve optimal solutions [Taifa et al., 2017].

While work sampling was not the sole focus of some researchers, such as Tucker and Rogge, who compared foreman-delay surveys with work sampling [Rogge, Tucker, 1982], it continued to be applied and evolved. For instance, it was suggested that direct-work rates from work sampling studies could predict unit rate productivity, although this claim was later challenged by Thomas in 1991. After a period of limited literature on work sampling, productivity consultants like H. Picard started publishing work sampling studies in the late 1990s. Picard's work demonstrated how work sampling could lead to significant productivity improvements, with reported workhour savings of up to 20% [Picard, Seay Jr., 1996]. Academic researchers, such as Jenkins of Purdue University, also applied work sampling in studies, providing insights into productivity inhibitors [Jenkins, Orth, 2003].

Simplex Metal Processors India Private Limited, founded in 2011 and headquartered in Pithampur, Madhya Pradesh, is a medium-scale manufacturing enterprise with additional plants in Ropar, Punjab, and Mandideep, Bhopal. Specializing in the production of long members for commercial truck chassis used by SML and VECV, as well as components for LIUGONG's heavy construction equipment, the company's long members, with their distinctive C-shaped structure, vary in length from 5 to 12 meters. These components are tailored to precise customer specifications, with sets of right-hand and left-hand members for SML and individual long members for VECV. The productivity improvement projects discussed in the paper are done in this company.

LITERATURE REVIEW

Research on improving productivity in manufacturing industries encompasses a range of methodologies and approaches. Banga (2020) and Trojanowska (2018) emphasize systematic methodologies such as Kaizen and factor analysis to identify and address constraints, resulting in significant throughput rate improvements. Meanwhile, Singh (2018) focuses on Lean strategies, particularly Just-in-Time (JIT) systems, as crucial tools for productivity enhancement. Herron and Braiden (2006) propose a comprehensive approach that involves three steps to align Lean tools with specific manufacturing issues, while Naveen and Ramesh (2015) highlight the importance of industrial engineering techniques and bottleneck identification for productivity improvements.

Almstrom (2013) challenges misconceptions about productivity, emphasizing the multifaceted nature of productivity enhancements. These studies collectively underscore the diverse approaches and methodologies available for improving productivity in manufacturing industries, emphasizing the need for systematic analysis, Lean principles, industrial engineering techniques, and more comprehensive productivity measures.

In the context of Lean manufacturing techniques for productivity improvement, a series of insightful studies have contributed valuable insights. Memari et al. (2022) focused on the impact of Lean principles in a Malaysian stationery SME, highlighting opportunities for Lean implementation and operational efficiency enhancements. Sundar et al. (2014) explored systematic adaptation through Lean principles like Value Stream Mapping and Cellular Manufacturing, proposing a detailed Lean Manufacturing System Road Map. Zahraee (2015) delved into the practical implementation of Lean manufacturing in an Iranian context, identifying crucial practices and tools. Sims and Wan (2015) introduced innovative constraint identification methods in matured Lean systems with moving assembly lines, offering new perspectives for constraint analysis. Chaple et al. (2014) conducted a literature review, synthesizing the status of Lean manufacturing principles and practices in Indian industries, shedding light on enablers, barriers, and methodologies for measuring leanness. Panizzolo et al. (2012) investigated Lean production adoption in Indian SMEs, emphasizing the impact of cultural adaptation, skill development, and top management commitment. Ghosh (2012) conducted a comprehensive survey, unveiling the widespread adoption of Lean practices in Indian manufacturing firms and their positive impacts on operational performance. Jamwal et al. (2019) explored barriers to Lean manufacturing implementation in Himachal Pradesh's small-scale industries, highlighting the central role of cost factors.

Research on Single Minute Exchange of Die (SMED) emphasizes its versatile application and impact on various industries. Silva and Filho (2019) conduct a comprehensive literature review, highlighting the integration of SMED with other lean tools for substantial productivity improvements. Moreover, Sabadka et al. (2017) apply SMED to shaft manufacturing, achieving remarkable downtime reductions and productivity enhancements. Tekin et al. (2019) explore SMED and Jidoka in a flour factory, emphasizing production quality and safety improvements alongside productivity gains. Singh et al. (2018) implement SMED in a small-scale manufacturing unit in India, showcasing its potential to streamline setup procedures and boost profitability.

Kulkarni et al. (2014) lay the foundation by proposing a methodology that combines Work Study Methods with Lean Manufacturing Principles & Tools to achieve substantial and lasting productivity improvements. Their approach underscores the significance of systematic tools like method study and bottleneck analysis. Kamble and Kulkarni (2014) delve into video work study techniques to optimize assembly station productivity, emphasizing the reduction of cycle times. While their study effectively addresses productivity enhancement, it highlights the need for a deeper exploration of implementation challenges. Gujar and Shahare (2018) focus on small-scale manufacturing industries and employ work study methods to increase efficiency, resulting in an 11% productivity boost. However, these studies collectively reveal a gap - the need for more extensive case studies and discussions on challenges during real-world implementation.

The realm of work sampling methods for enhancing productivity encompasses a range of insightful studies. Hajikazemi et al. (2017) investigated construction labor productivity in Norwegian projects, employing work sampling to reveal that 61.1 percent of the working day is dedicated to value-added work. Blay et al. (2014) conducted a critical integrative review on work sampling in nursing workload research, emphasizing the need for standardization. Gunesoglu and Meric (2006) applied work sampling in a sewing room, highlighting personal and unavoidable delay allowances as significant contributors to non-productive time.

RESEARCH METHODOLOGY

Proposed Methodology for Stopwatch Time Study Technique in Press Machine: The time study methodology consists of a comprehensive seven-step process. It begins with the vital step of gathering all relevant information concerning the job, operative, and surrounding conditions. This data serves as the foundation for the study. The second step entails a meticulous description of the operation's method, where the entire process is divided into elemental tasks, each of which is systematically identified and segmented. The subsequent step, time measurement, involves the use of a stopwatch to accurately record the duration of each task. Simultaneously, the worker's performance is assessed to determine their efficiency compared to the standard rating. This performance rating factor is applied to gauge the worker's normal or average performance. The fifth step involves calculating the normal time, utilizing the observed times and performance ratings to establish the elemental average times, forming the baseline for each task. An allowance factor, determined in the sixth step, is added to the basic time to account for work delays (such as machine breakdowns), personal delays (like restroom breaks), and regular mental or physical fatigue, ensuring that the standard time considers real-world conditions. The final step culminates in calculating the standard time for the operation, which represents the expected time for an operative to perform the job under normal circumstances. This calculation adjusts the normal cycle time with the allowance factor, integrating practical factors into the time assessment

Proposed Methodology for the Application of Single Minute Exchange of Die Technique: The methodology for applying the Single Minute Exchange of Die (SMED) technique, aimed at reducing setup or changeover times in manufacturing, consists of several key stages. In the first stage, the specific manufacturing process in need of setup time improvement is identified, requiring a comprehensive understanding of the process intricacies. The process is then broken down into its elemental components to identify areas for potential improvement. The second stage involves categorizing the changeover process into internal and external setup elements. Internal setup elements are those performed when the machine is stopped, while external elements can be executed while the machine is running. This categorization is fundamental for the SMED technique. In the third stage, precise time data is recorded for each identified internal and external setup element, employing timing methods like stopwatches. This recorded data serves as the baseline for further analysis and improvements. The fourth stage focuses on identifying internal setup elements with the potential to be converted into external setup elements. This entails a thorough examination of internal setup tasks, aiming to optimize their execution without machine stoppage. In the fifth stage, the entire setup process is streamlined, revisiting the sequence of setup tasks, eliminating redundant steps, and optimizing workflow to ensure efficiency and reliability. Lastly, in the sixth stage, time data is recorded once more for internal and external setup elements post-streamlining. This post-streamlining data is compared to the baseline data, providing concrete insights into the effectiveness of the SMED methodology and the reduction in changeover times achieved through this systematic approach.

Proposed Methodology for Conducting Work Sampling Study: In the project aimed at addressing machine breakdown causes, idle time, and worker activities, an effective work sampling methodology is crucial. The methodology encompasses several key steps. Firstly, identify the specific machines and operators associated with breakdowns, focusing on the six machines in question. To ensure the accuracy and precision of our study, a pilot study is conducted to establish essential parameters, including time proportions, 'p' (probability of occurrence), 'z' (standard deviation) and ‘e’ (acceptable error limits). Once these are determined, we move on to decide the sample size and observation time, which are critical factors impacting the study's reliability. The core of the research involves the actual work sampling study. During this phase, random observe the selected machines and workers, ensuring a representative data collection. Throughout this observation period, detailed records are maintained, documenting activities, machine statuses, breakdown causes, worker behaviours during idle time, and operator responses to breakdowns. After the data collection is complete, the next step involves thorough data analysis. This includes calculating the time proportions for various activities, identifying machine breakdown causes, categorizing these reasons, and assessing worker responses during idle time. Finally, the results obtained from the work sampling study are compared to the initial project objectives.

DATA COLLECTION AND ANALYSIS

Stopwatch Time Study: The stopwatch time study for long member production at the press machine involves meticulous data collection and analysis. An MS Excel table is created to record data points such as observation date, target strokes allocated to operators, actual production, batch size, operation type (forming or punching), model number, and observation start times. Colour codes are used to signify minimum and maximum values for each element, ensuring easy data interpretation. Manpower data is also recorded to minimize variations. The study encompassed 23 observations for the time study during which a significant worker idle time of approximately 45% is obtained. To address this, constant allowances (5% personnel allowance and 4% basic fatigue allowance) are introduced, along with variable allowances like standing, physical monotony, mental monotony, and noise

Table 1: Elemental Normal Time calculation

S. No.	Elements / Operations	Median observed time (MOT) in sec	Rating Factor	Normal time (NT=MOT*RF) in sec
1	Plate In	19.92	90	17.92
2	Plate Set	24.37	95	23.15
3	Punch down fast	2.73	100	2.73
4	Punch down slow	20.29	100	20.29
5	Operation and hold	9.2	100	9.2
6	Punch up	20.83	100	20.83
7	Workpiece out, scrap removal	10.76	125	13.45
8	Blank removal	16.64	120	19.96
9	Blank storage	10.1	130	13.13
10	Workpiece storage	21.7	85	18.44

1. Normal time = sum of all elemental normal time = 159.1 seconds
2. Normal time (in min) = 2.65 min

Collectively, these variable allowances amount to 16% of the total allowances provided to workers. This comprehensive allowance structure has been carefully tailored to address the specific needs and challenges faced by workers, taking into account their significant idle time during operations. Calculating the standard time,

3. Standard time = Normal time (1+Allowances) = 2.65 + (1+.16) = 3.07 min

The standard time obtained from the above study is approximated to 3 minutes 5 seconds.

SMED FOR ROLL FORMING MACHINES

1. Recording and Analysing Events: Observations record all 11 individual elements involved in the changeover process of old roll forming machine and 9 elements in the new roll forming containing steps such as coil identification, outer seal cutting, and de-coiler setup. The complete coil changing process is broken down into these to facilitate the time recording and further analysis process. The elements are such that clear distinction can be made to record and analyse them during the worker performing the coil changing process.

Table 2: Elements/Operations of the coil changeover process in both roll forming machines

S. No.	Elements in old roll forming machine	Operations in new roll forming machine
1	Bring Crane	Bring Crane
2	New coil load on crane	New coil load on crane
3	Crane to changing area	Crane to changing area
4	Oiling on new coil and packaging cut	Oiling on new coil and packaging cut
5	Stopper out	Guide roller out
6	Brake loose and new coil load	Coil loading
7	Chain detachment	Puller table, guide roller and coil adjust
8	Stopper in	Packaging cut
9	Puller table, roller adjust	Material adjustment in machine
10	Coil packaging cut	
11	Material adjustment in machine	

2. Differentiating Internal and External Elements: Distinction is made to categorize elements into internal (done during the changeover) and external (can be done during production process). It is observed that all the elements of coil changing process in old roll forming machine are done only after the machine stops while in the new roll forming machine, some of the first elements are performed externally.

Table 3: Initial readings of Old Rolling m/c

S. No.	Operations/Elements	Internal/External	Time (in sec.)
1	Bring Crane	I	0
2	New coil load on crane	I	0
3	Crane to changing bay	I	0
4	Oiling on new coil and outer packaging cut	I	393.6
5	Stopper out	I	0
6	Brake loose and new coil load	I	148.39
7	Chain detachment	I	46.74
8	Stopper in	I	82.76
9	Puller table, roller adjust	I	31.84
10	Coil packaging cut	I	102.9
11	Material adjustment in machine	I	144.73
	Total time (in min)		**15.85**

Table 4: Initial readings of New Rolling m/c

S. No.	Operations/Elements	Internal/External	Time (in sec.)
1	Bring Crane	E	0
2	New coil load on crane	E	0
3	Crane to changing bay	E	0
4	Oiling on new coil and outer packaging cut	E	0
5	Guide roller out	I	11.71
6	Coil loading	I	90.91
7	Puller table and coil adjust	I	29.46
8	Packaging cut	I	169.36
9	Material adjustment in machine	I	601.94
	Total time (in min)		**15.06**

3. Streamlining the Changeover Process: After identifying bottlenecks in the process, recommendations are made to optimize the procedure. These recommendations include an extensive analysis of the internal elements as described in figure 2 and 3 with the effort to convert them into external elements. The proposed changeover process is then implemented and time recording is performed to assess the effectiveness for each machine.

Table 5: Reduced coil changeover readings of New Roll Forming machine

S. No.	Operations/Elements	Internal/ External	Time taken (in sec)	Time taken (in sec)
1	Bring Crane	E	0	0
2	New coil load on crane	E	0	0
3	Crane to changing bay	E	0	0
4	Oiling on new coil and outer packaging cut	E	0	0
5	Guide roller out	I	6.58	7.59
6	Coil loading	I	17.91	21.87
7	Puller table and coil adjust	I	42.26	29.26
8	Packaging cut	I	221.97	141.39
9	Material adjustment in machine	I	189.9	173.22
	Total time (in min)		**7.98**	**6.22**

Average coil changeover time achieved after using SMED = $\frac{(6.22+7.98)}{2}$ = 7.1 min

Total reduction in changeover time achieved = (Average changeover time before using SMED lean tool – Average changeover time after using SMED lean tool) = 7.56 min

Total minutes saved in one production day considering 5 coil changes in day = 7.56 × 5 = 37.8 minutes = 38 minutes approximately.

Increase in productivity = $\frac{(\text{Changeover time before SMED} - \text{Changeover time after SMED})}{\text{Changeover time before SMED}} \times 100 = \frac{(14.66-7.1)}{14.66} \times 100 = 51.5\%$.

Similarly for the Old Roll Forming machine:

Average coil changeover time achieved after using SMED = $\frac{(6.17+7.45+7.1)}{3} = 6.87$ min

Total reduction in changeover time achieved = (Average changeover time before using SMED lean tool – Average changeover time after using SMED lean tool) = 12.35 min

Total minutes saved in one production day considering 5 coil changes in day = 12.35 × 5 = 61.75 minutes = 60 minutes approximately.

Increase in productivity = $\frac{(\text{Changeover time before SMED} - \text{Changeover time after SMED})}{\text{Changeover time before SMED}} \times 100 = \frac{(19.23-6.87)}{19.23} \times 100 = 64\%$.

Table 6: Reduced coil changeover readings of Old Roll Forming machine

S. No	Operations	Internal/External	Time taken (in sec)	Time taken (in sec)
1	Bring Crane	E	0	0
2	New coil load on crane	E	0	0
3	Crane to changing bay	E	0	0
4	Oiling on new coil and outer packaging cut	E	0	0
5	Stopper out	E	0	0
6	Brake loose and new coil load	E/I	115.15	128.63
7	Chain detachment	I	29.93	36.31
8	Stopper in	I	50.55	39.57
9	Puller table, roller adjust	I	31.55	31.65
10	Coil packaging cut	I	72.7	82.92
11	Material adjustment in machine	I	70.27	128.17
	Total time (in min)		**6.17**	**7.45**

WORK SAMPLING

In the work sampling analysis, daily visits to six different machines are conducted to assess maintenance conditions and work-related activities. The data collected during these visits, which includes factors like date of visit, duration of observation, and machine downtime causes, activity performed by the worker and operator during downtime i.e., working or idle, are recorded for the new and old 3-D punching lines, new and old roll forming machines, press machine, and the CNC flange punching machine. The downtime reasons are categorized into manpower related downtime, maintenance related downtime, material unavailability related downtime and machine related downtime. The primary focus during the work sampling observations is to identify the most frequent and time-consuming downtime reasons which go unreported to the management. These types of failures if not attended at right time may lead to major breakdown of machine leading to high production losses. After conducting the pilot study, average sample size of 200 observations is decided for all the machines while the duration for each visit may differ depending upon the downtime analysis. The work sampling data for new and old 3-D punching line shows an average downtime of 29% and 37% respectively for the observations done in 4 parts. While the major downtime reasons for the new machine are air pressure supply and sensor issues, for the old machine it is the CAN master error. The average downtime in the new and old roll forming machine are almost equal at 31% and 295 respectively along with the same downtime reasons as bow and camber error, machine setting and length matching. The major downtime reason reported in the press machine is the CAN module error occurring due to sudden power loss at certain parts in the machine with 27% average downtime during the study. The CNC flange punching machine had significant average downtime of 65%, notably during the third phase at 93%, but this issue was positively resolved after discussions with management. These results underscore the importance of addressing downtime issues to enhance productivity and reduce losses across these machines.

Table 7: Final summary of work sampling activity for New 3-D Punching machine

New 3-D Punching Line				
Parameters	1st readings	2nd readings	3rd readings	4th readings
Total Time Observed (in min.)	686	310	258	876
No. of Observations	39	30	44	87
Total downtime observed (in min)	90.8	103.5	92.5	299.6
% downtime observed	13%	33%	36%	34%

Total manpower idle time (in min)	36.3	85.5	68.8	166.1
% manpower idle time	5%	28%	27%	19%
Total operator idle time (in min)	2.5	0	13	127
% operator idle time	0.4%	0.0%	5.0%	14.5%
Capacity Loss (in nos. of member)	22.7	25.875	23.125	74.9
Per hour loss of member	2	5	5	5

Table 8: Final summary of work sampling activity for Old 3-D Punching machine

Old 3-D Punching Line				
Parameters	1st readings	2nd readings	3rd readings	4th readings
Total Time Observed (in min.)	450	300	264	1116
No. of Observations	33	30	38	99
Total downtime observed (in min)	156.66	161.2	95.2	256.7
% downtime observed	35%	54%	36%	23%
Total manpower idle time (in min)	122.74	42.70	44.20	112.60
% manpower idle time	27%	14%	17%	10%
Total operator idle time (in min)	106.37	8.5	36	74.2
% operator idle time	23.6%	2.8%	13.6%	6.6%
Capacity Loss (in nos. of member)	39.165	40.3	23.8	64.2
Per hour loss of member	5	8	5	3

Table 9: Final summary of work sampling activity for New Roll Forming machine

New Roll Forming Machine				
Parameters	**1st readings**	**2nd readings**	**3rd readings**	**4th readings**
Total Time Observed (in min.)	615	270	322	923
No. of Observations	42	30	41	87
Total downtime observed (in min)	250	98.7	83.4	180
% downtime observed	41%	37%	26%	20%
Total manpower idle time (in min)	94.00	39.00	11.20	68.0
% manpower idle time	15%	14%	3%	7%
Total operator idle time (in min)	63.5	38.4	16.8	67.2
% operator idle time	10.3%	14.2%	5.2%	7.3%
Capacity Loss (in nos. of member)	62.5	25	21	45
Per hour loss of member	6	5	4	3

Table 10: Final summary of work sampling activity for Old Roll Forming machine

Old Roll Forming Machine				
Parameters	**1st readings**	**2nd readings**	**3rd readings**	**4th readings**
Total Time Observed (in min.)	513	400	219	998
No. of Observations	39	39	32	90
Total downtime observed (in min)	141.6	129.2	97.7	121.6
% downtime observed	28%	32%	45%	12%
Total manpower idle time (in min)	18.83	37.53	89.20	20.40
% manpower idle time	4%	9%	41%	2%
Total operator idle time (in min)	38.0	34.7	89.2	88.7
% operator idle time	7.4%	8.7%	40.7%	8.9%
Capacity Loss (in nos. of member)	35.4	32.3	24	30
Per hour loss of member	4	5	7	2

Table 11: Final summary of work sampling activity for Press machine

Press Machine				
Parameters	**1st readings**	**2nd readings**	**3rd readings**	**4th readings**
Total Time Observed (in min.)	440	300	295	1095
No. of Observations	30	30	41	99
Total downtime observed (in min)	143.1	114	63.7	192.6
% downtime observed	33%	38%	22%	18%
Total manpower idle time (in min)	26.80	84.00	19.00	168.10
% manpower idle time	6%	28%	6%	15%
Total operator idle time (in min)	15	50	34.2	162.6
% operator idle time	3.4%	16.7%	11.6%	14.8%
Capacity Loss (in nos. of member)	6	5	3	8
Per hour loss of member	0.8	1.0	0.5	0.4

Table 12: Final summary of work sampling activity for CNC Flange Punching machine

CNC Flange Punching Machine				
Parameters	**1st readings**	**2nd readings**	**3rd readings**	**4th readings**
Total Time Observed (in min.)	465	310	575	810
No. of Observations	39	30	50	81
Total downtime observed (in min)	340.9	200.5	537.0	243.8
% downtime observed	73%	65%	93%	30%
Total manpower idle time (in min)	193.25	60.00	0.00	106.80
% manpower idle time	42%	19%	0%	13%

Total operator idle time (in min)	108.7	61	344	128.3
% operator idle time	23.4%	19.7%	59.8%	15.8%
Capacity Loss (in nos. of member)	68	40	107	49
Per hour loss of member	9	8	11	4

CONCLUSION

In conclusion, this study successfully achieved its objectives through a multifaceted approach. First, by conducting a time study on the 4500-ton press machine, the standard time for producing the heaviest and longest model of 9105 mm total length and 5100 wheelbase X-Project variant is calculated as 3.07 minutes or 3:05 minutes, and the same is communicated to the management so that they can now set production target with standard time calculated using industrial engineering tools. Additionally, Single Minute Exchange of Die (SMED) lean tool is employed to reduce coil changeover time in both roll-forming machines, boosting productivity by 51.5% and 64% in the old and new roll forming machines respectively. In the work sampling activity on six critical machines, valuable insights are gained regarding downtime reasons, worker idleness and operator activities as can be seen from tables 7-12, enabling prioritized maintenance and a path for worker training. Overall, this comprehensive study not only increased production efficiency but also paved the way for future improvements, such as refining the tool storage area and providing targeted training for workers, contributing to the company's productivity enhancement and long-term growth prospects.

FUTURE SCOPE

Looking ahead, there are several promising avenues for future development within this project. While the initial objectives are successfully accomplished, further improvements can be realized, particularly in optimizing the standard time calculation for all the various models within the X-Project variant, streamlining the tool storage area to reduce tool changeover times in the 4500-ton press machine and providing targeted training for workers to address common machine breakdowns efficiently. These measures hold the potential to enhance production efficiency significantly and contribute to long-term productivity growth. Additionally, the work sampling study's findings can inform the formulation of Standard Operating Procedures (SOPs) and serve as a foundation for addressing current and future maintenance challenges, which is especially relevant as the company plans for plant expansion. In sum, the project's future scope offers opportunities to further refine operations, thereby driving ongoing improvements and sustained growth for the company.

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