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REDUCING CHANGEOVER TIME IN THE PRINTING PROCESS

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ABSTRACT

This study explores strategies to reduce the changeover time in the printing process. The current changeover time is affecting the operational efficiency of the offset unit. The research focuses on a comprehensive analysis of the current changeover process, identifying inefficiencies and recommending strategies to reduce changeover time. Data was gathered through observations, unstructured interviews, and production logs, and analysed with tools such as Root Cause Analysis, Value Analysis, and Single-Minute Exchange of Die (SMED). The paper also presents recommendations through the implementation of ECRS (Eliminate, Combine, Rearrange, and Simplify), SMED, and 5S methodologies and suggestions for improvements that significantly reduce the overall changeover time. Beyond the printing industry, this study offers valuable insights for various industries that seek to optimise changeover processes. The structured methodologies presented here can serve as a framework for reducing changeover time, minimising waste, and improving workflow efficiency across diverse industrial contexts, thereby lowering operational costs and boosting productivity.

Keywords: ECRS, Printing, Reduction in Changeover, SMED.

1. Introduction

Printing is a fundamental process used in various industries, including publishing, advertising, packaging, manufacturing, and art (Chinpakdee et al., 2023). It allows for the mass production of materials and is essential for the dissemination of information and the creation of visual and printed communication. Aside from its traditional uses, printing plays a huge role in current production processes mainly through the generation of product labels and packages ensuring successful branding and advertising of a product and enabling product distribution by offering appropriate information about the product. There is always a need for packaging design that appeals to the target market in addition to facilitating identity recognition, flyers, postcards, and business

posters are among the various materials when used in the marketing of goods and services (Nurwahidin, et al., 2017).

The changeover time which is referred to as the time taken in switching from one job to another is one of the challenges facing the printing industry. It is clear that the changeover times significantly influence output and productivity in industries involving high production such as packaging and commercial print. This process includes removing material such as ink, printing plates, ink foils, and machine settings regards to previous job. The time taken to changeover process depends on the complexity of the job, the tools used, and the capacities of the operators and workers in production (Indrawati et al.,2017). It is important to reduce changeover time to increase production throughput and reduce operational costs (Niekurzak et al.,2023).

Printcare PLC was founded in 1979 and has grown to become a highly respected provider of printing, packaging, and digital media solutions in South Asia. The company is proud to own one of the most technologically advanced manufacturing plants in Asia and serves customers on five continents. Printcare PLC has also expanded its services to multiple locations to offer convenience and flexibility to its customers (Printcare PLC, 2023). Though changeover time is a critical task it does not directly add value to neither the customer nor the organization. Reduction in changeover time would result in increased productivity, cost reduction, and better-quality control which would be a competitive advantage in the end for the organization, not only in the local market but in the global market as well.

1.1. Scope of the Problem

The research aims to address the problem of "How to reduce the changeover time in the XL machine in the offset printing plant of Printcare PLC." Optimizing the changeover process/reducing changeover time in offset printing units is a challenge, where the existing 80-minute transition time is a bottleneck for operational efficiency. Here we defined the changeover time as the duration required to remove all materials from the previous job including data, ink, and printing plates, until registering the print. There are numerous inefficiencies that cause extended changeover time including unnecessary movements, repetitive activities, and tasks that could be completed before the changeover but are performed during it. These inefficiencies reduce the capability of the company to meet deadlines, reduce costs, and quality of prints apart from slowing down production. An ineffective changeover process affected important operational factors. Excessive changeover time results in low output rates and profits while increasing costs in terms of labor, energy, and material. Breakdowns can also affect quality since they cause rushed setups, and reworks. Ultimately those causes may

compromise the competitive advantage of the organization. Within the offset department, there are two main printing machines the XL106 (with a capacity of 18,000 per hour) and the CD 1026 (with a capacity of 15,000 per hour). Among these two machines, we selected the XL106, which has the highest capacity to conduct the research.

1.2. Objectives

The following three objectives are expected to be achieved through the research.

01. Conduct a comprehensive analysis of the changeover process.

This objective focuses on thoroughly understanding the changeover process of the XL 106 printing machine. It involves identifying each changeover activity, calculating the time allocated to each task, and verifying the standard/reported changeover times for accuracy and consistency.

02. Explore the reasons that affect excessive changeover time.

Following data collection on the current changeover process, the analysis aims to identify the underlying reasons for prolonged changeover times, pinpointing specific inefficiencies or delays.

03. Provide recommendations for reducing changeover time.

Through evaluating various strategies, the goal is to develop actionable recommendations to enhance worker productivity, minimize idle times and unnecessary movements, and streamline the changeover process on the XL machine. The target is to achieve at least a 10% reduction in the current changeover time.

2. Literature Review

Considerable research has been conducted across various industries in an attempt to analyze methodologies that could help in optimizing operational efficiency, with the main goal of minimizing changeover time for better production processes, cost-effectiveness, and overall performance. Several research articles done about the printing industry, the research that has been done to reduce the changeover time in many industries, research articles have researchers about the tools used to reduce the changeover time reduction, and the articles about the ECRS method will be reviewed in this section.

There are several research articles done about the printing industry most of them in the printing industry much research has taken place to improve quality, reduce cost, implement sustainable practices in the factories, etc. According to the research on Cost reduction and quality improvements in the printing industry, they have implemented methodology in the printing industry resulting in significant improvements and cost savings. The results were obtained through time savings, cost savings, decreased nonconformity cost, equipment performance, overall equipment effectiveness, and improved product

quality (Moreira, et al., 2018).

Here focus on the research that has been done to reduce the changeover time in many industries. Many research has been done to reduce changeover time in many industries. According to the research done by Deros et al. (2011), discusses the application of single-minute exchange dies (SMED)techniques to reduce setup time in an automotive battery assembly line. The study aims to detect 4 bottlenecks, provide solutions, and reduce machine setup time by 35% (Deros, et al., 2011).

Changeover times can be reduced to improve manufacturing efficiency, particularly in batch production. The authors of this article have proposed a broad framework integrating the DMAIC and DMADV Six Sigma methods. They emphasize a formalised approach toward identifying, measuring, and optimizing changeover processes. The article also underscores different types of quick changeover methodologies, such as SMED, that have been implemented in a wide range of industries, all with considerable time and cost savings. This contribution to the literature on operational efficiency enhances previous work by providing practical solutions to the problems of manufacturing changeover and the article focuses on how a structured approach, incorporating various established methodologies, can bring down effectively the changeover time and improve the production efficiency with sustained improvement in batch production facilities (Eldardiry, El-Dardiry, & Nada, 2021).

Under following research articles have researchers about the tools used to reduce the changeover time reduction according to the research done by Janez Kusar, Tomaz Berlec, Ferdinand Zefran, and Marko Starbek. The article presents a procedure for reducing machine setup time in manufacturing companies. The procedure is based on teamwork and utilizes the SMED method, which aims to gradually reduce setup time to less than 10 minutes (Kusar, Berlec, Zefran, & Starbek, 2010). The concept of SMED is the widely used technique in the field of changeover time reduction.

According to the above articles, SMED methodology has been important in many industries' attempts at reducing set-up times, increasing efficiency, and raising productivity. For example, 35% can be shaved off machine setup times on an automotive battery assembly line by applying SMED, which is an effective way to solve bottlenecks (Deros, et al., 2011). Similarly, another work conducted by Trovinger and Bohn in 2005 applied SMED to reduce setup times in high-speed printed circuit board assembly machines used in the electronics industry. Another article emphasized teamwork in applying SMED to achieve a setup time of less than 10 minutes. These works indicate that SMED is integrally important in minimizing the times of changeover (Kusar, et al.,2010).

This research article focused on the ECRS method that they use

to improve the process in production. The research on minimising waste using lean manufacturing and the ECRS principle in the Indonesian furniture industry discusses the reduction of waste in the Indonesian furniture industry using Lean Manufacturing and the ECRS Principle. In this research, Value Stream Mapping is applied to find the wastes, and 5W1H techniques and Kaizen, ECRS principles are used to improve processes in production. The result showed that the lead time was reduced by 4.79%, with a significant improvement in efficiency and workload balance. This study shows that small changes bring high outputs regarding efficiency gain and productivity increase without workforce addition (Suhardi, Anisa , & Laksono, 2019).

Considering the researchers' historical background of changeover time, printing industry-related research, and changeover time reduction in different industries, the time taken to conduct a changeover becomes essential to raise productivity and efficiency in most sectors, including the printing industry. Reducing the changeover time allows organizations to decrease downtime, reduce costs, and gain more overall performance. The studies related to different methodologies, including SMED, highlighted that setup process simplification can be dramatically improved, thus yielding a 35% reduction in setup times in automotive battery assembly lines apart from cost savings (Deros, et al., 2011). These strategies not only reduce cost but also improve product quality and equipment performances and prove that effective management of changeover time is critical for sustainable growth and competitiveness.

3. Methodology

This explicates the way of accomplishing the research objectives and it includes the data analysis tools, data collection methods, and research process. This focuses on qualitative aspects such as the importance of various activities, their contribution to organisational and customer value, waste management, optimising the sequence of activities, and reorganising workstations to reduce the changeover time.

Since this is a qualitative study, the research used an exploratory approach, which is appropriate for identifying the inefficiencies in the changeover process (Stevens et al., 2022). This approach helps to get a deeper understanding of the factors affecting prolonging changeover time without being limited to predefined hypotheses (Stevens et al., 2022).

To accomplish objectives, researchers must carefully select the /appropriate data collection techniques they will use that align with the objectives. Inappropriate research technique selection might provide faulty conclusions and inaccurate study findings (Mwita, 2022). Three methods were used to collect primary data, which are as follows:

1. Observation - Monitoring the changeover process in real-time, identifying the sequence of the activities, and interactions among the

workers to identify inefficiencies.
2. Memo motion study - A camera is used in this technique, commonly referred to as spaced-shot photography, to evaluate a prolonged procedure (Taherdoost, 2021). It is conducted by recording the parallel activities, movements, and time durations of workers and identifying unnecessary motions.
3. Unstructured interviews - The unstructured interviews are conducted with the various stakeholders including executives, the offset plant manager, and the workers who are directly involved in the changeover process to get a deeper understanding of the changeover process.

Under secondary data, we used production logs such as Standard Operating Procedures (SOP) and Systems, Applications & Products (SAP) to gather documented details regarding the changeover.

Using the collected data, data analysis was conducted using Value Analysis and SMED. Value-added analysis is a core principle of lean manufacturing, which aims to create more value with fewer resources by eliminating waste (Shou et al.,2019). SMED is considered a core lean manufacturing technique that helps eliminate waste and promote continuous improvement in a production environment and manufacturing companies can significantly reduce downtime. SMED is vital for reducing changeover times, which in turn enhances production efficiency, flexibility, and cost-effectiveness (Deros, et al., 2011).

Further explanations of these methods are provided in the research process outlined below. The research process outlines the step-by-step approach taken to achieve the objectives.

3.1. Research Process

Objective 1- Comprehensive analysis of the changeover process

Step 01: Identify the main activities

The first step is to identify the main activities in the changeover process in the XL 106 machine and document them. We identified the activities by refereeing the SOP and observing the activities while engaging with workers. Activities are classified based on the significant impact on overall changeover time, impact on the quality of the print, and complexity of the activity.

Step 02: Identify the sub-activities related to the main activities

To make a more comprehensive analysis of the current process, the identified main activities are broken down into sub-activities. This identification reveals the inefficiencies and bottlenecks that are causing excessive changeover time that could not be revealed at the border level.

Step 03: Divide the activities into VA, BVA, and NVA

The third step is to divide the activities into Value Added (VA), Business Value Added (BVA) and Non-Value added (NVA)) activities to do the Value Analysis. Activities that are directly related to changeover and ensure product quality are considered as VA (Shou, et al.,2019). For

example, color matching and plate preparation. BVA activities are supportive activities, they don't directly add value to the product but smooth the operation (Shou, et al.,2019). Unnecessary motions, such as moving between different units without a reason, can be mentioned as NVA activities (Shou, et al.,2019). Categorizing activities into VA, BVA, and NVA helped in achieving the objective of a comprehensive analysis of the changeover process by identifying inefficiencies and streamlining the process. This kind of work allows us to concentrate on eliminating NVA activities, which increases overall efficiency. In addition, this categorization guarantees that essential tasks are given priority, and unnecessary activities are minimized.

Step 04: Identify the activities as internal or external

In the SMED analysis, the collected data was divided into two categories internal and external activities. The primary goal of this categorization is to convert the internal activities into external activities to reduce the machine's idle time.

Step 05: Calculate the time spent on each activity

In the SMED analysis, the collected data was divided into two categories internal and external activities. The primary goal of this categorisation is to convert the internal activities into external activities to reduce the machine's idle time. We observed three distinct changeovers to get accurate time spent on each activity. The time study helped to determine whether workers work within the allocated time and to reveal the waste and inefficiencies for elimination. Then for the observed changeovers, we created Gantt charts using collected times and activities.

Objective 02- Explore the reasons that affect excessive changeover time

Step 06: Compare the collected time against the company standard/expectations. Comparing actual changeover time against the company's 80-minute standard changeover time helps to identify the discrepancies and offers insights into inefficiencies.

Step 07: Identify the inefficiencies in changeover time

In this step, we identified inefficiencies that are caused by excessive changeover time through the time study, Gantt charts, and root cause analysis. This Gantt chart provides a detailed visualization of the current changeover process, showing all activities along with their respective durations. It will not only show who is responsible for each task but also highlight the activities that are performed in parallel, helping to identify areas where time can be saved through parallel execution.

Through root cause analysis, the underlying reasons for the prolonged changeover time were uncovered.

Objective 03- Provide recommendations for reducing changeover time

Step 08: Explore the several methods
To identify the strategies to reduce changeover time we explore several methods including the ECSR method, SMED, and 5S.
Step 09: Give recommendations to address the identified issues
Based on the exploration, targeted recommendations were provided to reduce changeover time by 10% (from 80 minutes) in the offset plant. These recommendations focused on minimizing inefficiencies, reducing waiting times, eliminating unnecessary movements, and optimizing worker utilization to ensure maximum productivity.

3.2. Data Analysis

Objective 1- Comprehensive analysis of the changeover process
The study aimed to identify and calculate the time spent by workers on the XL machine in the offset department at Printcare PLC. Data was collected from three changeovers held on 27th February 2024, 15th May 2024, and 16th May 2024. The current changeover process was chosen due to resource availability and time constraints. The data was analysed using a timesheet, Gantt chart, and graphical representation. The study was conducted without prior knowledge or complexity.
Step 01: Identify the main activities involved in the changeover process
The comprehensive analysis of the XL 106 machine changeover process involved identifying 30 main activities. By interacting directly with workers and referring to SOP, we were able to observe and document the following main activities involved in the XL 106 machine changeover. This identification is crucial for value-added analysis and SMED application, as it provides a clear map of the whole process (Chivatxaranukul, 2019). Using the attached link can get the best idea about the main activities that we identified through the collected data.
Link: https://shorturl.at/Pe4HE
Step 02: Identify the sub-activities involved in the changeover process
To optimize the changeover process, breaking down major activities into sub-activities is crucial. This provided a comprehensive view of the entire process and identified individual actions that cause delays or inefficiencies. This examination helped identify hidden bottlenecks and redundant steps, often overlooked in broader assessments (Pawłyszyn, Stachowiak, & Hadas, 2014). For example, we divided the printing plate setting main activity into sub-activities. Such as Taking the new plates to the unit, keeping them in the relevant unit, taking a new plate, and inserting it into the plate guard. The following link will show the observation related to 653 sub-activities, including the individuals responsible for each task and the purpose of these activities.
Sub activities link: https://shorturl.at/3j3rp
Step 03: Divide the activities into VA, BVA, and NVA
In this step, we observed the main and sub-activities data and divided these into three main categories based on observations: VA, BVA, and

NVA activities. VA activities directly contribute to meeting customer needs and expectations, adding value to the product. In the XL 106 machine changeover process context, VA activities prepare the machine for the next print job, satisfy client needs, and guarantee product quality. BVA activities support process compliance but do not directly affect product quality. NVA activities are considered waste and should be minimized or eliminated to improve efficiency and reduce costs. Here is the link to the value analysis sheet to get the best idea about the value analysis and we have justified the reasons for dividing the activities into VA, BVA, and NVA.
Value analysis link: https://shorturl.at/PmPIb

For example, some of the VA, BVA, and NVA activities that we identified from the observations through data are in the following table 1.

Table 1: Example of Value Analysis.

VA Activities	BVA Activities	NVA Activities
Remove excess paint in the unit	Loose sides locks and nuts	Go to units
Apply the color to the roller	Clean the working table.	Wipe hands
Insert new plates into the plate guard	Remove previous job ink foil	Again, clean the Ductor roller

According to the pie chart in Figure 1, out of 653 activities based on observations, 85 (13%) are value-adding activities, 226 (35%) are BVA, and 342 (52%) are NVA. NVA and BVA do not directly add value to the product. Therefore, we are planning on eliminating them or converting them into VA.

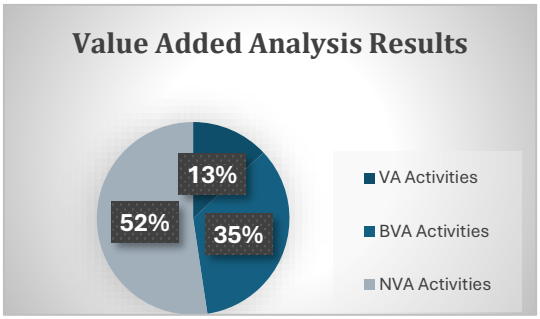

Figure 1: Value Analysis.

Step 04: Identify the activities as internal or external
The study analyzed changeover activities in a machine using observations, unstructured interviews, and production logs. It is part of the Single-Minute Exchange of Die (SMED) technique, which aims to reduce changeover times by separating internal and external activities.

Internal activities are also performed while the machine is stopped and these are necessary for the changeover process and cannot be completed during the printing process, impacting machine downtime (Ulutas, 2011). External activities, on the other hand, can be performed while the machine is running, and printing sheets, minimizing changeover time (Ulutas, 2011). The study found that 95% of the activities were internal, while 5% were external. The following link displays all our observed activities, categorized into external and internal.
Internal and external activity link: https://shorturl.at/bZD1M

For example, some of the internal and external activities that we identified from the observations, unstructured interviews, and production logs through data are as follows.

Table 2: Examples of Internal and External Activities.

Internal Activities	External Activities
Go to the ink processing area	Take the new plates to the unit
Pick relevant ink buckets	Check the printing sheet with the sample
Keep the ink buckets in the relevant unit.	Feed more sheets to the machine

Step 05: Calculate the times spent on each activity
The data collected for the changeover process at Printcare PLC's offset plant was analysed using time sheets and Gantt charts. The standard time for a changeover is 80 minutes, and each employee was measured individually who did the relevant work and how much actual time he spent using a time sheet. We drew time sheets and Gantt charts to calculate the actual time spent for the main activities and sub-activities mentioned in step 1 and step 2 above.
Timesheet link: https://shorturl.at/P97aO

Table 3: Actual Times of the Changeover Processes.

	Actual Time
Day 1	86 minutes 31 seconds
Day 2	167 minutes 55 seconds
Day 3	156 minutes 45 seconds

A Gantt chart was created to visualize the time spent across different activities, separating waiting times and parallel and overlapping activities. The chart was divided into four columns for operator, assistant, 3rd position, and 4th position.
Gantt charts link: https://shorturl.at/KtCGw

We applied the color codes in the Gantt chart for respective activities to identify differences between these.

Table 4: Color Codes of the Gantt Chart.

Waiting	Movements	Breaks	Discussions	Previous job workings	Absent

Objective 02 - Explore the reasons that affect excessive changeover time

Step 06: Compare the collected time against the company standard/ expectations

This step was crucial for assessing the accuracy of the provided changeover times and identifying any discrepancies between the stated and actual times observed during the data collection period. We observed three different changeovers. All three changeovers were taking more than standard time.

Table 5: Gap of the Changeover Processes.

	Standard time	Actual time	Variance	Reason
Day 1	80 minutes	86 minutes 31 seconds	6 minutes 31 seconds	Due to the customer's color requirement not arriving
Day 2	80 minutes	167 minutes 55 seconds	87 minutes 55 seconds	Due to the need for a change in jobs, longer discussions among plant managers and workers, and issues in coordination
Day 3	80 minutes	156 minutes 45 seconds	76minutes 45 seconds	Due to cutting a new blanket for the XL machine, previously done by the CD machine

From these three changeovers, we choose the first changeover to analyze the current changeover process. Based on the first changeover, we drew a Gantt chart for a current changeover. It is the one that can be taken as a general changeover with fewer exceptions.

Through the process of identifying and analyzing the reasons for any discrepancies, we can acquire important insights into areas that lead to deviations from the company's desired standards.

Step 07: Identify the inefficiencies in changeover time

In this step, we evaluated the drawn Gantt charts and identified stages with excessive waiting times or unnecessary movements. After that, the root cause analysis was done as follows (Figure 2).

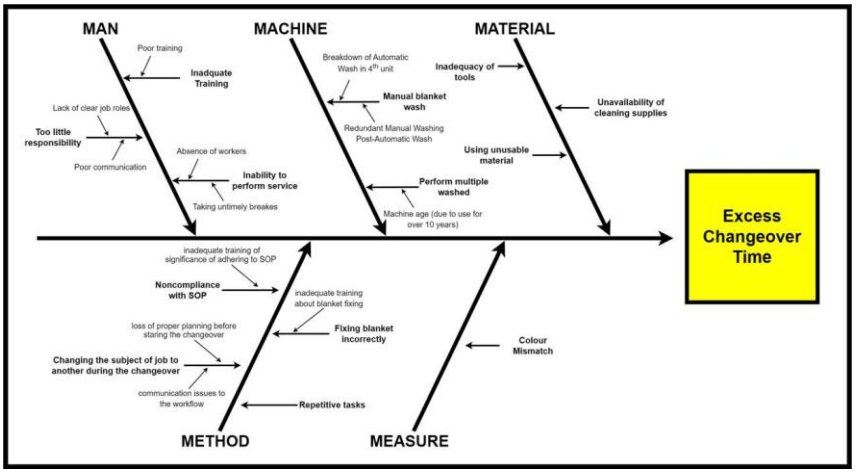

Figure 2: Fishbone Diagram.

Material:

- Unavailability of cleaning supplies: Materials needed to clean the foils, paint locks, and ink knives like pieces of cloth, and roller wash are not available on the working table. The same thing happens when they want them to clean the rollers, causing excessive time spent changing supplies. Because of these issues, the workers have to walk around.
- Inadequate Tool of XL machine: Tools like keys and funnels are not accessible, causing workers to walk for specific tasks, as seen in Changeover 01 where a worker had to use a CD machine to pick up a funnel to pour roller wash.
- Using unusable material: The worker repeatedly did the same task due to the use of damaged ink foils, causing extensive time spent changing them, as they had to remove the ink from the duct roller to replace the ink foil.

Machine:

- Manual blanket wash: The XL machine can automatically wash blankets. We observed that one blanket was washed manually due to an issue with the 4th unit blanket wash. Furthermore, even while using the automatic wash, workers frequently wipe the blankets manually afterward. Blanket cleaning is essential for removing debris and producing clean photos (Sinha & Achenie, 2003). Automatic washing takes only 1 minute and 17 seconds, while manual washing takes 9 minutes and 12 seconds.
- Perform multiple washes
  - Machine age: This issue happens due to the machine age, which has been in use for over 10 years. According to data gathered through unstructured interviews with workers, when the machine was new, a single wash was sufficient to

remove the colors from the previous job, which requires four or more washes to fully clean the colors and effects excess changeover.

Man:

- Inadequate Training: Poor implementation of changeover processes can lead to employees at the lowest level, such as the 4th position, taking longer to fix ink foil compared to other employees, resulting in changeover 3, others taking 23 sec and 4th position taking 50 sec.
- Too little responsibility
  - Lack of clear job roles: Employees are spending excessive time during the changeover process, not performing their assigned tasks according to SOP, leading to inefficiencies and unnecessary walking.

Table 6: Inefficiencies and Unnecessary Walking.

	Operator	Assistant	3rd Position	4th Position
Day 1 walking	2 min 08 sec	4 min 18 sec	5 min 2 sec	4 min 13 sec

  - Poor communication: Due to poor communication between employees during the changeover process, excess time is spent carrying out the process, The operator must click on CPC panel buttons and walk again to relevant units to say that it has been clicked and tell other workers to start tasks. Also, it causes unnecessary walking.
- Inability to perform service
  - Absence of workers: Four workers are assigned to handle the XL machine changeover in the offset plant. If an Assistant is absent from work, the day 03 changeover took the excess time than the standard time.
  - Taking untimely breaks: Untimely breaks during the XL machine changeover in the offset plant resulted in excess time, as analyzed during the three changeovers.

Table 7: Untimely Breaks during Changeovers.

	Operator	Assistant	3rd Position	4th Position
Day 1	18 min 39sec	12 min 09sec	25 min 18sec	-
Day 2	24 min 22sec	11 min 28sec	29 min 34sec	-
Day 3	23 min 15 sec	- (absence)	-	16 min 48sec

- Measure Colour mismatching: The XL 106 machine changeover process has led to time-wasting issues, with 20.17 minutes of

excess time spent on day 01 due to mismatching colors with samples.

Method

- Noncompliance with SOP: Factors contributing to non-compliance include inadequate training, awareness of the importance of adhering to SOPs, and inadequate monitoring, as workers may stop adhering to tasks without regular supervision.
- Changing the job to another job during the changeover: During a changeover, job changes led to significant inefficiencies, requiring the team to hold current processes, review new requirements, and make adjustments. The loss of proper planning before starting the changeover and communication issues with the workflow caused excessive time will be spent when changing the job.
- Incorrect blanket fixing: During changeovers can cause unalignment, leading to excessive time and potential damage to the blanket. Workers spent an additional 4.42 minutes fixing a blanket due to unalignment, which could potentially increase the risk of damage.
- Repetitive task: During the changeover process, the same task is repeated multiple times. For example, when cleaning, the foil, paint locks, and other items are taken multiple times to clean them. Similarly, waste sheets are placed on the working table two or three times. This causes a significant waste of time.

4. Recommendations

After considering the factors like cost, and ease of implementation we divided the recommendations into long-term and short-term as follows.

Short-term recommendations:

1. To reduce the walking time of workers, we recommend **providing each worker with the tools** they need to do their respective tasks. For example, provide keys, blades, and spanners to the 3rd Position and 4th position since they are involved in tasks where these tools are needed. Also having tools assigned to the unit like nut wrenches and a funnel is important. Otherwise, the workers have to walk to the CD 106 machine or around to pick up the needed tools.
2. Having **cleaning supplies** like roller wash, and pieces of clothing **near every unit** reduces the time of walking to collect them. Also having two buckets for roller wash and alcohol on the working table eliminates the time of cleaning the roller wash bucket to add alcohol after usage.

3. To eliminate the time of replacing the unusable ink foil with a usable one, we recommend the workers **check the foils before they are fixed** in the first place.
4. Having a clear communication system for all employees during the changeover process can reduce the time they spend walking to notify information about tasks. To reduce the time of movement, **walkie-talkies** or dedicated communication systems can be introduced.
5. The organization can have **a contingency plan** to solve in case the problem of employees being absent. Adding another employee to replace the absent employee helps reduce the changeover time. In doing so, payment should be made to the employees involved in providing the service in addition to their salary to eliminate the reluctance of employees to serve without benefit.6. **A clear schedule** can be created for each employee to take breaks to coincide with the changeover. Currently, they take longer breaks during the changeover. To improve this, breaks should be taken separately during the printing period, after the changeover is completed.
6. Daily scheduling of jobs should **adhere to the updated schedule** to ensure operational efficiency and consistency. In instances where immediate job changes due to a customer's request, should be promptly communicated to the workflow before starting the changeover. It reduces the excessive time in changeover.
7. Instead of repeatedly carrying items like ink, foil, and ink stones one by one, we recommend using **an equipment box** to carry everything at once.

Long-term recommendations:

1. Prioritize the **repair of the 4th unit's broken automated washes**. This minimizes manual washes performed to verify the proper operation of each unit so that all can go through auto-washes. Since manual washes are more time-consuming and not as effective, it would indeed be advantageous in the long term to allow every single unit the chance to perform automated washing, to reduce changeover time.
2. As we observed, the rubber used in the roller and ink kitchen are different, and also the impression used in the ink kitchen is different from the roller's impression since it is done by hand. Because of these issues the ink percentages to be put to the unit differ in the real scenario. Therefore, we recommend having **technology in the long term that can give the exact percentages of ink** that need to be put since it would reduce the excessive time spent on color matching.

3. The rollers of every unit have not been replaced since the date the machine was fixed, which is around 10 years. Therefore, recommending replacing **the rollers** would be a benefit for the company in the long run since it would eradicate the necessity to manually clean the rollers after every job and also the need for 4th or 5th wash.

According to the recommendation, we conducted ECRS. It has the potential to eliminate 105 activities by eliminating some NVA and business-value-added (BVA) activities. In the datasheet, these eliminated activities are indicated in red.

Then the remaining activities can be categorized into two: internal and external. Through this analysis, we identified 55 internal activities that can be converted into external activities, allowing these tasks to be performed either before the changeover or after the machine is back in operation. In the datasheet, these rearranged activities are indicated in green. We considered activities that were done several times but can be done as a single step. Considering these activities can combine those into one single activity (simplify) to reduce unnecessary movements and effort. The combined activities are indicated in blue while simplified activities are indicated in yellow.

Due to these efforts, the proportion of external activities has the potential to achieve an increase of up to 22% of total activities, while the proportion of internal activities has the potential to drop to 78%, indicating a notable improvement in the changeover process (Figure 3).

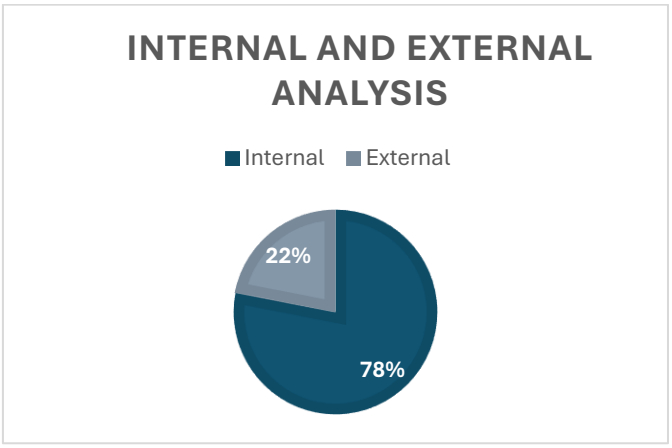

Figure 3: Internal and External Analysis after Recommendations.

The following link provides a detailed analysis of the ECRS method - ECRS. After considering all these recommendations we created a work schedule (Figure 4) for the four workers, giving clearly defined

responsibilities by removing unnecessary movements, idle time, and rearranging the sequence of the process. By adhering to these steps, it is expected to reduce the changeover time to 45 minutes, which would be a 43.75% reduction in the changeover time. All the times entered in the work schedule are taken from observing the real time taken to complete each task. Therefore, there is a high credibility to complete the tasks according to the new schedule.

Operator	Assistant	3rd Position	4th Position				
Ink zero and first wash							
Varnish unit wash	Remove excess paint, locks, foils (Unit 5,6)	Remove excess paint, locks,foils (Unit 2,1)	Remove excess paint, locks, foils (3rd & 4 th units)	7 min			
2nd Wash Wipe the 10 th & 7 th unit roller (UV)	Clean ductor roller (unit 6,5,4,3,2,1)	Clean 3 pair of paint locks and clean 3 knives	Bring the equipment box and Clean the 3 pair of paint locks and 3 knives	4min			
3rd Wash Prepare the delivery system and clean the control station	Fix paint locks ,Ink foil and ink filling (Unit 1,2)	Fix paint locks. Ink foil and ink filling (unit 3,4)	Fix paint locks. Ink foil and ink filling (unit 5,6)	5 min			
4th Wash				2 min			
Blanket wash (Automatic)	Printing Plate setting(2,1)	Printing Plate setting ((unit 4,3)	Printing Plate setting (unit 6,5)	1 min			
Click a button to lift the old plates		Blanket wash (Manually) Unit 2,1	Blanket wash (Manually) - Unit 4		2 min	1 min 10 sec	
Change the 10th roller	Change the 10th roller				0.42 sec	1 min 30 sec	
Remove Varnish Packing (Unit 7)	Remove Varnish Packing (Unit 7)	Remove old plate & new plate fixing (unit 1,2,3)	Remove old plate & new plate fixing (unit 4,5,6)	6 min 30 sec	1min 30 sec	50 sec	
Change the rollers (Unit 7 to 10)	Change the rollers (Unit 7 to 10)	Remove the varnish chamber & tray (Unit 7)	Remove the varnish chamber & tray (Unit 10)		0.50 sec	3 min	6 min 30 sec
Changing the Varnish Packing (Unit 10)	Changing the Varnish Packing (Unit 10)	Bring the 7th unit chamber and fix it to 10th unit after fixing the tray	Bring the 7th unit tray and fix it to 10th unit		0.48 sec (chamber)		
					0.40 sec (tray)	6 min 30 sec	
Clean the UV roller under the 10th unit	Clean the UV roller under the 10th unit	Clean the UV roller under the 7th unit	Clean the UV roller under the 7th unit	2 min 30 sec			
					1min (w/pan)		
Go to CPC (click button to pump varnish)	Pump Varnish	Clean the water pan roller (Unit 3,2,1)	Clean the water pan roller (Unit 6,5,4)	4 min	3 min 32 sec (pump)		
Click buttons to Pre-inking		Feeder setting			1min 14 sec feeder		
Click buttons to start printing after setting feeder	Check the readiness of the Units		Go to delivery area to help the operator	13 min			
Register	Go to the delivery area and help to operator and 4th position to refeed		Go to the feeder and Refeed the waste sheets				
				45 min			

Figure 4: Work Schedule.

Work schedule can be accessed by the following link - Work Schedule. Printcare PLC can significantly reduce its changeover time by implementing these adjustments into practice. Process simplification and downtime are reduced by converting internal tasks and eliminating those NVA and BVA activities. This optimization makes it possible to use time more effectively, which eventually results in faster changeovers and improved productivity.

When implementing the above recommendations, resistance to change of the workers is expected since their breaks will be shortened and might have to work for the absent workers. Also, the company would have to spend a significant amount of money in order to achieve long-term implementations. To address these issues, we plan on clarifying the importance of the time reduction in the changeover to the workers and discussing with the administration to provide an incentive to motivate the workers who would work overtime to fill the gaps. Further, we can provide a cost-benefit analysis to the administration of the company to enlighten them regarding the importance of implementing the long-term recommendations.

5. Conclusion

In conclusion, the project aimed at reducing the changeover time in the offset printing plant, specifically focusing on the XL 106 machine at Printcare PLC, Kelaniya. To begin with, we identified the main sub-activities involved in the changeover process by conducting observations, memo studies, unstructured interviews, and analyzing production logs over three days. Through this process, we identified 30 main activities and 653 sub-activities. These were then analyzed through

value-added and internal-external analyses, which revealed significant inefficiencies, with 87% of NVA and BVA and 95% being internal activities.

To further explore, we calculated the time spent on each activity, finding that while the standard changeover time was 80 minutes, the actual time often exceeded this time. Using tools such as Gantt charts and root cause analysis, we explored the reasons for excessive changeover time. This analysis led us to focus on streamlining the process and reducing these inefficiencies.

By applying the ECRS method, SMED for externalizing internal activities, and 5S, we developed a revised changeover process. These recommendations aimed to eliminate unnecessary steps, reduce worker idle time, and address the root causes of prolonged changeovers. As a result, we proposed a changeover process of 45 minutes, a 43.75% reduction in the changeover time. Significantly reducing the time from the current process and making the operations more efficient.

Ultimately, this research holds the potential to significantly impact not only the printing industry but also other industries by providing a structured approach to reducing changeover times, eliminating unnecessary activities, minimizing idle times, and streamlining processes. This methodology can be applied across various sectors to enhance operational efficiency, reduce costs, and improve overall productivity. By adopting similar strategies, companies can optimize their workflows, reduce waste, and achieve more efficient production, ultimately leading to a stronger competitive advantage in their respective markets.

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