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Process Optimization of Make-Ready Time in Offset Printing for Higher Operational Efficiency

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Abstract: Make-ready time is a key factor in determining turnaround time, production cost, and overall operational efficiency in the offset printing sector. The objective of this study is to find possibilities for optimization by providing a thorough examination of the make-ready time in an offset printing machine. Ink setting, paper alignment, registration, colour matching, blanket and roller washing, plate mounting, and other common make-ready tasks are reviewed to enhance the efficiency in offset printing. With the assistance of skilled staff, real-time data has been collected from an established printing company. Two widely used offset printing machines, KBA RAPIDA 106 and Heidelberg SM 105 are chosen to measure the make-ready times for various printing jobs. After analysis, findings indicate that registration stability and colour calibration are the most persistent barriers to achieving consistent make-ready performance throughout the ten jobs analysed on both machines. These results highlight the potential of minimizing the overall make-ready time, which would improve press utilization, minimize material wastage, and increase overall production.

Keywords: Make-ready, Registration, Colour calibration, Printing plates, offset process.

1. Introduction

The printing industry is under pressure to meet rising expectations for competitive pricing, faster delivery, and consistent product quality. Fulfilling these demands requires more control over make-ready efficiency and equipment performance [1]. Prior work emphasizes that operators must resolve routine quality issues at the press and ensure stable setup parameters to limit unnecessary adjustments [2]. Printed output is the primary medium through which information is visually communicated, the final product must transfer content accurately while conveying the required level of quality. At the same time, production must remain cost-effective, fast, and stable. Consequently, most press-optimization strategies focus on minimizing startup waste, improving energy and substrate efficiency, and reducing unnecessary environmental impact. These improvements support predictable, reproducible print quality and contribute to lower carbon emissions [3]. Increasing press speed, new materials, and higher run lengths also heighten the importance of substrate behaviour, as print performance depends on the interaction among ink, dampening solution, and paper. Ensuring consistent, high-quality reproduction from design to final print remains the main objective of printing-process optimization (Amon-Tran et al., 2012). Productivity remains a central metric, shaped not only by output volume but also by the reliability of machine operations. In practice, inadequate maintenance planning often contributes to extended downtime and reduced throughput. A structured maintenance strategy can mitigate failures, enhance utilization, and stabilize production flow. The present study evaluates productivity, effectiveness, utilization, failure likelihood, risk factors, and sigma levels within a risk-based maintenance framework [4]. Persistent challenges such as failure-related downtime, avoidable idle time, prolonged make-ready, and associated production losses continue to constrain performance in many offset printing facilities [5].

The shift in market expectations has altered the operational landscape for commercial offset presses. Although traditionally designed for high-volume production, these systems are now required to perform efficiently in medium- and small-lot scenarios with shorter delivery cycles. Meeting these requirements demands more control over make-ready performance, particularly through reducing start-up waste and shortening the interval between consecutive jobs. Conventional drive configurations and centralized control architectures offer limited flexibility for such rapid transitions [6].

In response, modern offset presses have adopted shaftless configurations and independent drive motors, enabling finer control over unit synchronization and operating conditions. The increasing diversity of customer requirements and the rapid introduction of new technologies compel printing firms to adapt quickly and refine both organizational and technical practices. Effective competitiveness now depends on streamlined production workflows that account for the sector's unique constraints, simultaneous handling of numerous orders, frequent changes in substrates and consumables, and the need to deliver products in varied formats with distinct finishing pathways. Optimizing these workflows requires a clear understanding of production demands and a systematic analysis of the end-to-end process [7].

Modern offset presses support this effort through integrated control systems capable of monitoring and adjusting critical print variables in real time. Leading manufacturers such as Heidelberg, Komori, MAN Roland, and KBA have developed platforms that use press-mounted cameras to scan full images or selected regions, detect defects, and trigger corrective actions. In advanced configurations, the system can automatically mark or remove defective sheets, allowing operators to maintain consistency without interrupting production [8]. Figure 1 illustrates the schematic of a single-colour offset process.

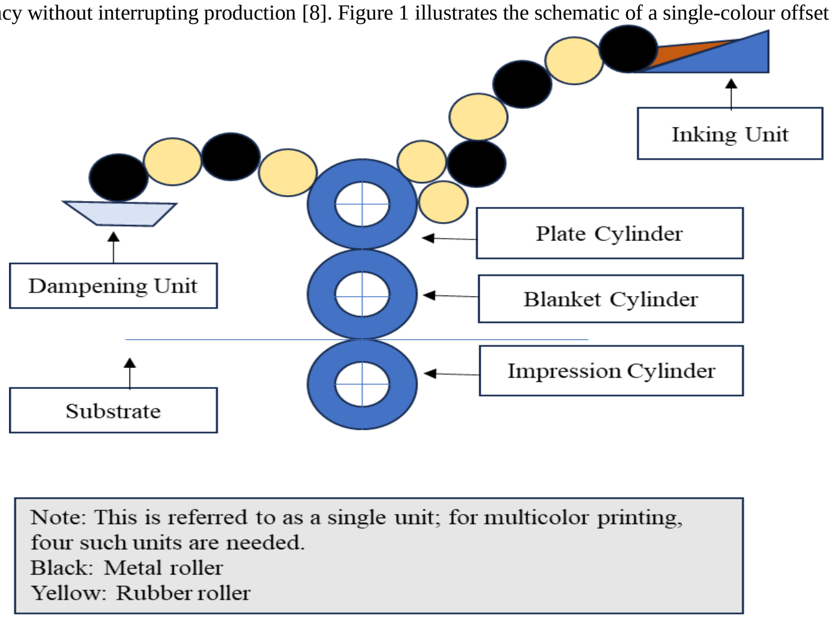

Fig.1. Schemtaic of single colour offest process

Time reduction of make-ready activities in offset press offers significant operational and financial benefits i.e., jobs can be completed and delivered to the customers more quickly that improving customer satisfaction. Faster make-ready reduces the number of test sheets needed, that directly reduce material cost and environmental impact. Increasing productivity, lower material waste and reduce labour costs, directly boost in profitability [9]. During analysis, Registration is the factor that is the main cause of making delay. By duly check the registration by skill operators it can be reduced. As a result, this increases overall manufacturing efficiency and output, allowing the business to take on more jobs and produce more finished product in the same amount of time.

The organization of the manuscript is as follows: Section 2 represents the make-ready procedure in offset press operator. Research methodology used in the process is presented in section 3. Section 4 shows the evaluation results and discussion about the results. In last, paper is concluded as section 5.

2. Make-ready Procedure in Offset Press Operations

The make-ready sequence comprises a series of coordinated tasks that prepare the press for stable and high-quality production. Fig. 2 gives the step-by-step the stages of the Make-ready Procedure [10]. Key activities include the following:

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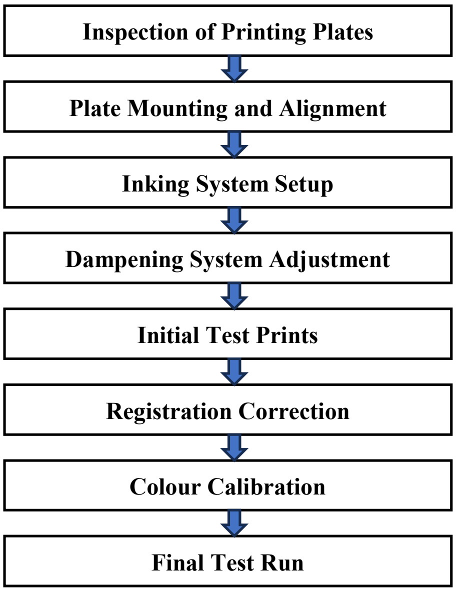

Fig. 2. Sequence of make-ready operations

2.1. Inspection of Printing Plates: Each job requires dedicated plates to transfer image and text information to the substrate. Operators begin by examining the plates for scratches, dents, or contamination that could compromise tonal accuracy or detail reproduction.

2.2. Plate Mounting and Alignment: After inspection, cylinders are cleaned to remove residual ink or debris. Plates are then positioned uniformly across the plate cylinders and secured to ensure accurate contact and consistent image transfer.

2.3. Inking System Setup: During make-ready, inks are loaded into dedicated fountains, each corresponding to a specific colour. Operators adjust fountain keys and roller settings to achieve the required ink density and maintain uniform distribution across the plate surface.

2.4. Dampening System Adjustment: A separate roller train supplies the dampening solution, which must be evenly applied to maintain clean non-image areas and prevent toning. Operators regulate the ink–water balance to sustain image sharpness and stable adhesion throughout the run.

2.5. Initial Test Prints: Once plates, ink, and dampening systems are set, the press is run at low speed to generate initial test sheets. These provide an early indication of colour consistency, tonal accuracy, and mechanical stability.

2.6. Registration Correction: Test sheets help verify whether colour separations are aligned. Operators adjust lateral and circumferential plate positions as needed to establish precise four-colour register.

2.7. Colour Calibration: Based on the test prints, operators fine-tune ink density and the ink water ratio to ensure that colour reproduction matches the proof and remains consistent across the sheet.

2.8. Final Test Run: After completing all corrections, a final series of test prints is produced. Minor adjustments may still be implemented while the press is operating. Once print quality meets the required criteria, the press is accelerated to production speed and the main run begins.

3. **Comparative Analysis of Job, their roles and Evaluation Findings**

3.1 Research Methodology

The methodology combines quantitative time motion analysis with direct process observation to identify the principal contributors to make-ready duration. Insights from these assessments inform targeted interventions aimed to improve overall operational efficiency. Although numerous variables influence make-ready performance, eight high-impact activities were selected for detailed evaluation: roller wash, blanket wash, plate change, ink change, paper loading, sheet travel, registration, and colour matching. Fig 3. Shows the make-ready activities analysed during this study. These activities consistently account for the largest share of make-ready time and therefore offer the greatest potential for improvement.

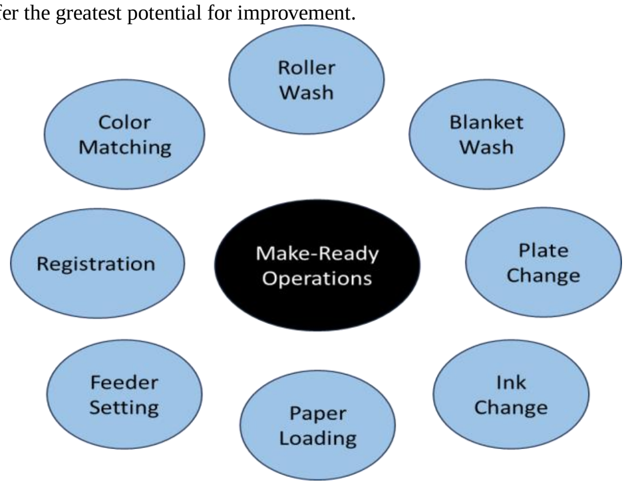

Fig.3. Make-ready activities analysed during this study

Performance assessments are conducted using two commercially significant offset machine models, i.e., Heidelberg SM 105 and KBA Rapida 106, chosen for their comparable automation capabilities, technological maturity, and extensive industrial use. The Heidelberg SM105 is a six-colour conventional press with a coater, whereas the KBA Rapida 106 is a seven-colour UV press equipped with a coater. Although a wide range of tasks can influence make-ready time, this study focuses on recurrent activities most likely to introduce delays. Ten representative jobs are analysed on both models, and for each activity, the actual time consumed is compared against the corresponding standard make-ready time to quantify deviations and identify key inefficiencies.

3.2 Data Collection and Analysis

The make-ready times for all ten jobs are recorded through daily observations on the Heidelberg SM 105 and KBA Rapida 106 presses. The collected data is then compared with the standard time allowances for each activity to assess deviations and identify sources of delay. For Job I, the ink-change operation exceeded its standard time by approximately three minutes. The sheet-travel or paper-path check took two minutes more than expected, while blanket washing required

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an additional 1.5 minutes. Plate change, registration adjustment, and colour matching each exceeded their respective benchmarks by about one minute. In total, the make-ready duration for Job I was 57.25 minutes, roughly ten minutes more than the prescribed standard indicating multiple minor delays that cumulatively contributed to the extended setup time.

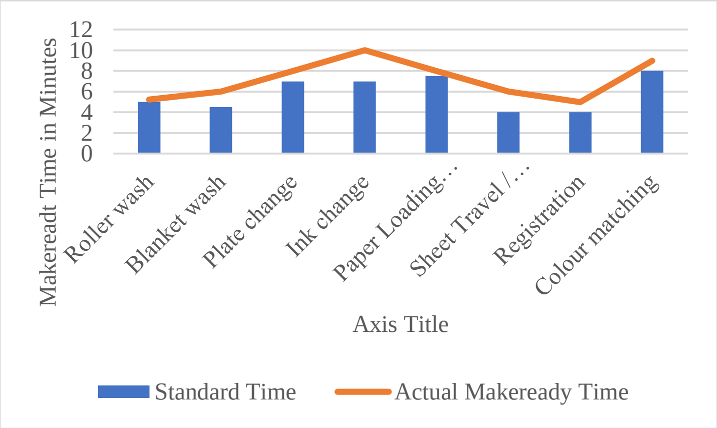

Fig. 4. Make-ready time of Job-I

For Job II, the total make-ready duration was 52 minutes, exceeding the standard allowance by approximately five minutes. The most significant deviation occurred in the colour-matching stage, which takes 14 minutes, that are about six minutes more than the prescribed limit. Roller washing also exceeded its benchmark by three minutes, while both the sheet-travel check and registration adjustments each ran one minute longer than expected. Paper loading and alignment contributed an additional 1.5-minute delay. Collectively, these overruns indicate that colour calibration and preliminary handling tasks were the primary contributors to the extended make-ready time for this job.

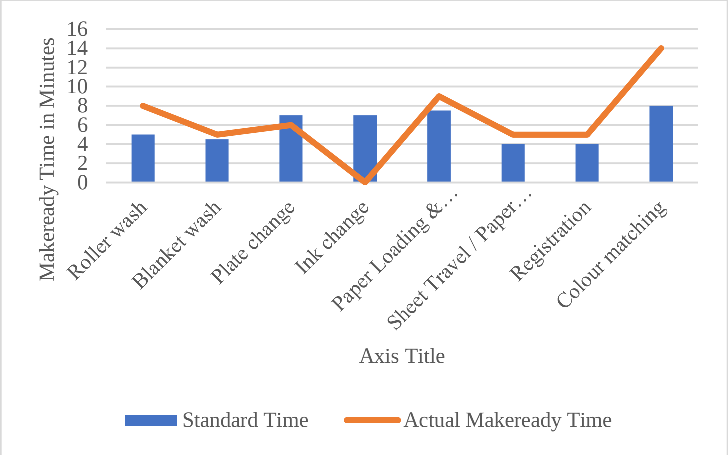

Fig. 5. Make-ready time of Job-II

For Job III, the most pronounced deviation was observed in the color-matching stage, which exceeded its standard allowance by more than twelve minutes. Both blanket washing and registration adjustments required approximately six additional minutes, indicating instability in ink–water balance and alignment during early test runs. The sheet-travel inspection also ran about 1.5 minutes longer than expected. In total, the make-ready process required 66.5 minutes, roughly 19.5 minutes beyond the prescribed standard, reflecting cumulative delays concentrated in colour calibration and image-stability adjustments.

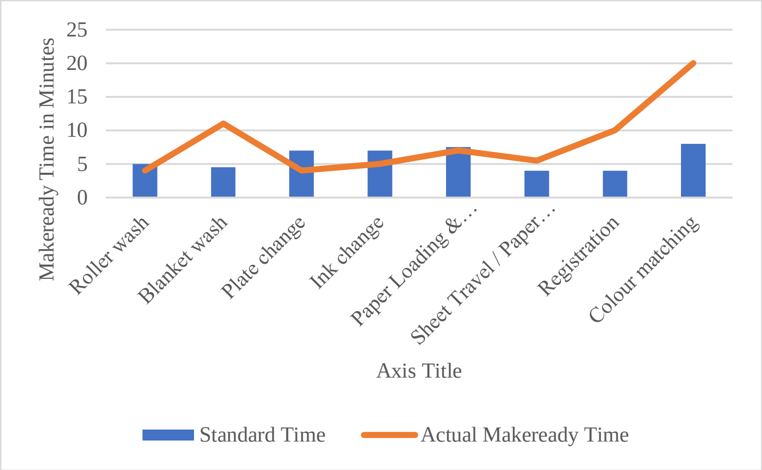

Fig.6. Make-ready time of Job-III

For Job IV, the most substantial delay occurred during the plate-change operation, which required 27 minutes, approximately 20 minutes beyond the allocated standard. Blanket washing exceeded its benchmark by 1.5 minutes, and the sheet-travel or paper-path check required an additional minute. The ink-change activity also ran one minute longer than expected. Overall, the make-ready process totalled 66 minutes, representing a 19-minute overrun and indicating that plate handling and related preparatory tasks were the primary contributors to the extended setup time.

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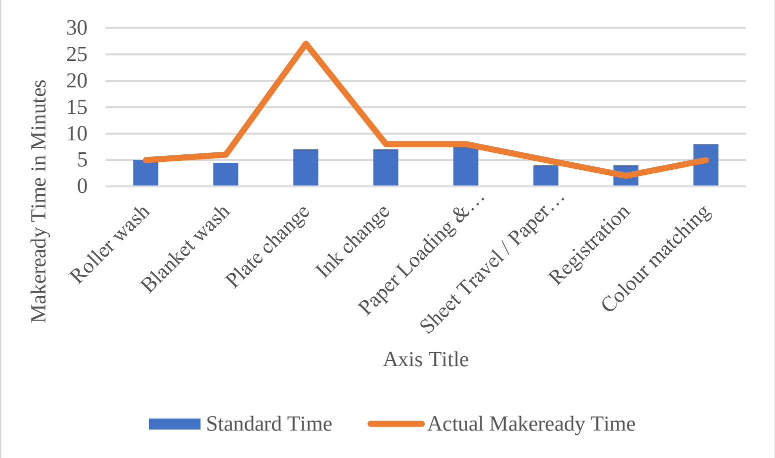

Fig.7. Make-ready time of Job-IV

For Job V, registration adjustments accounted for the largest deviation, requiring five minutes more than the standard allowance. Blanket washing exceeded its benchmark by 3.5 minutes, while plate change ran one minute more than expected. Both roller washing and the sheet-travel check added an additional two minutes each. Despite these individual overruns, the total make-ready time reached 47 minutes, closely aligning with the standard duration and indicating that the delays were relatively minor in aggregate.

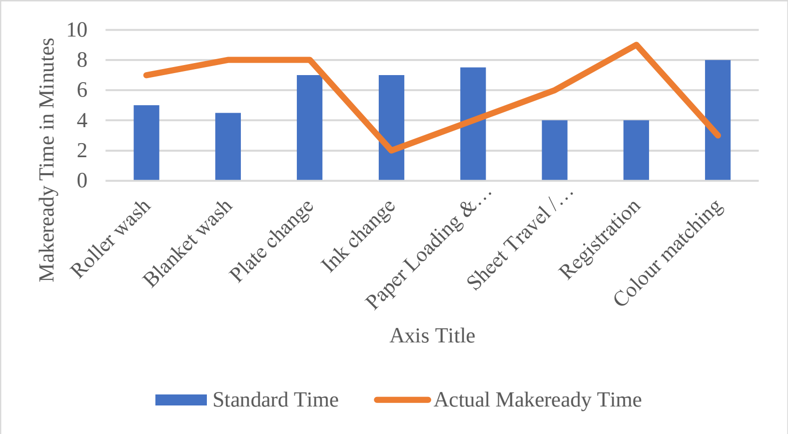

Fig.8. Make-ready time of Job-V

For Job VI, ink matching represented the most significant source of delay, requiring approximately ten minutes beyond the standard allowance. Registration adjustments also exceeded expectations by nearly five minutes. The sheet-travel or paper-path check is completed within its standard four-minute duration, indicating stable substrate handling for this task. Blanket washing, however, added an additional 2.5 minutes. Overall, the make-ready process required 64 minutes, about 17 minutes longer than the prescribed standard, driven primarily by extended colour calibration and alignment activities.

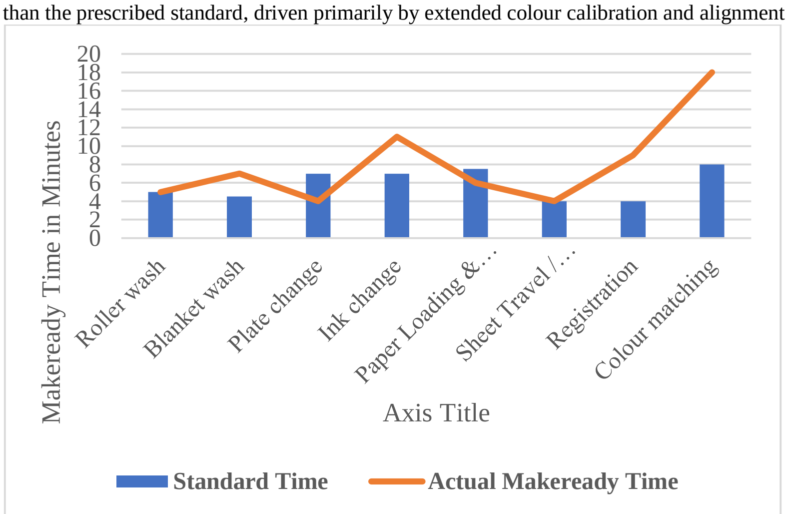

Fig.9. Make-ready time of Job-VI

For Job VII, blanket washing accounted for the largest deviation, requiring eight minutes, approximately 3.5 minutes beyond the standard allowance. Registration adjustments also exceeded expectations, taking seven minutes and running three minutes over the benchmark. Ink change required one additional minute, while paper loading and alignment added another 1.5 minutes. In total, the make-ready duration for Job VII is 49 minutes, only two minutes longer than the prescribed standard, indicating relatively contained delays despite multiple small overruns.

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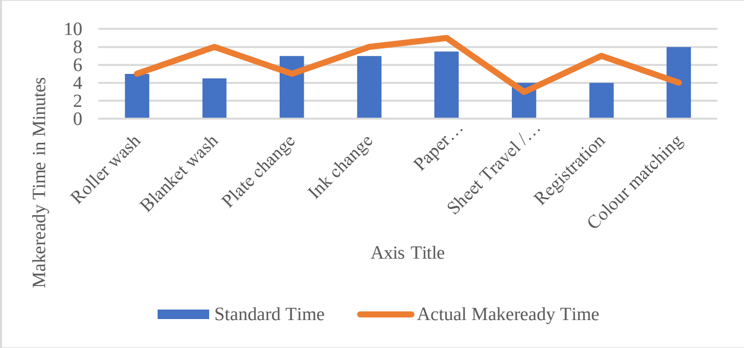

Fig.10. Make-ready time of Job-VII

For Job VIII, both colour matching and ink change exceeded their standard times by slightly more than three minutes. Blanket washing required six minutes, representing a 1.5-minute overrun. Registration adjustments and the sheet-travel check each contributed nearly two minutes of delay. Cumulatively, the make-ready process required 54 minutes, about seven minutes longer than the standard, suggesting moderate inefficiencies concentrated in colour calibration and preliminary handling tasks.

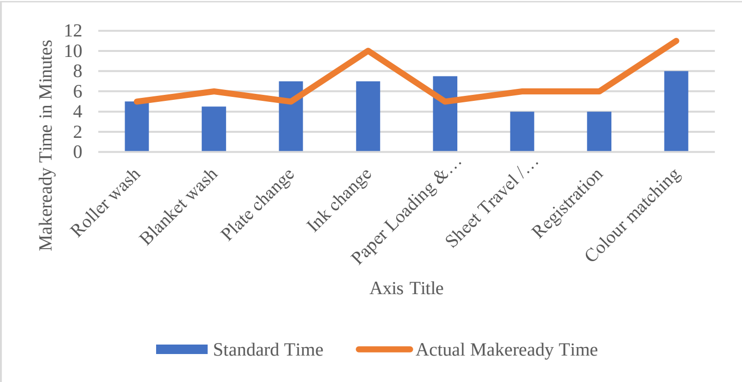

Fig.11. Make-ready time of Job-VIII

The total make-ready duration for Job IX was 61.5 minutes, approximately 14.5 minutes above the standard time. The biggest delay is due to the ink change, which took 16 minutes, nine minutes longer than the benchmark. Registration adjustments and the sheet-travel inspection also run five and three minutes longer than expected, respectively. Colour matching exceeded its standard allowance by one minute. These combined deviations indicate that Job IX experienced substantial delays across both colour-related and mechanical preparation tasks.

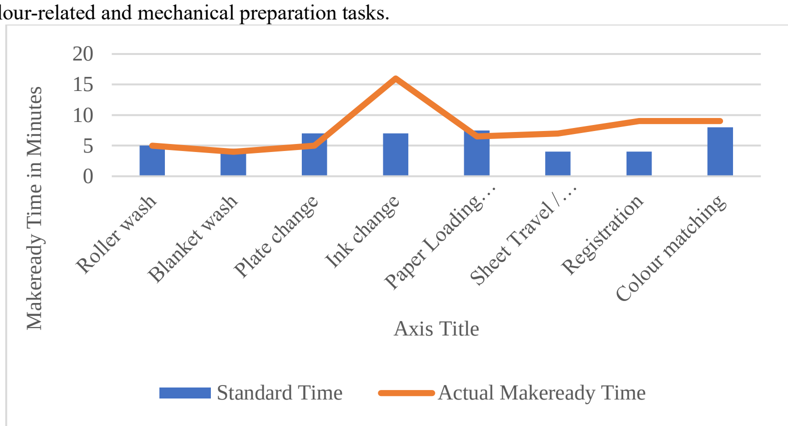

Fig.12. Make-ready time of Job-IX

For Job X, registration required roughly seven minutes more than the prescribed limit. Roller washing took 11 minutes, an overrun of six minutes, while blanket washing exceeded the standard time by more than 6.5 minutes. As a result, the total make-ready duration reached 60 minutes, approximately 13 minutes longer than the benchmark. These findings highlight extended cleaning and alignment operations as the primary drivers of delay for this job.

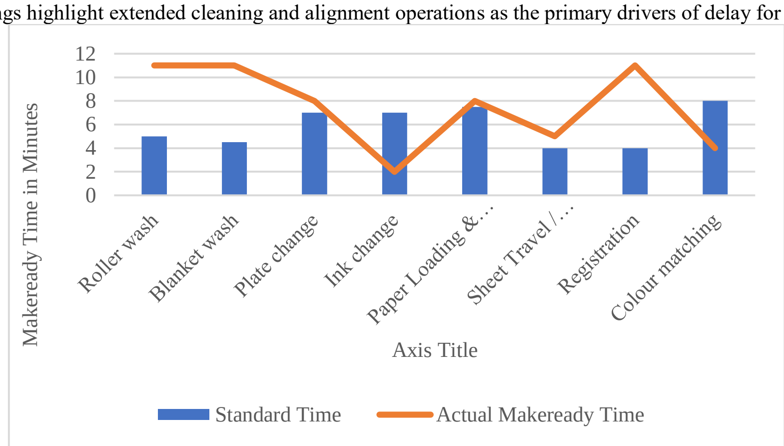

Fig.13. Make-ready time of Job-X

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4. Results and Discussion

Across the ten observed jobs on the Heidelberg SM 105 and KBA Rapida 106 presses, real-time measurements are used to quantify deviations in key make-ready activities relative to their standard allowances. The analysis shows that only four jobs experienced delays in roller washing, with an average overrun of approximately one minute. Blanket washing exhibited the highest frequency of delay, occurring in nine jobs and averaging 2.7 minutes beyond the benchmark. Plate-change deviations were recorded in four jobs, each with an average delay of about one minute. Ink-change activities exceeded their allotted time in six cases, reflecting variability in colour preparation and ink-handling routines. Paper loading and alignment consistently required less time than the standard allowance, indicating procedural efficiency in this stage. In contrast, eight jobs experienced delays in the sheet-travel or paper-path check, with an average overrun of 1.25 minutes. These findings highlight that inconsistencies in cleaning activities and sheet-handling verification constitute the most recurrent contributors to extended make-ready times.

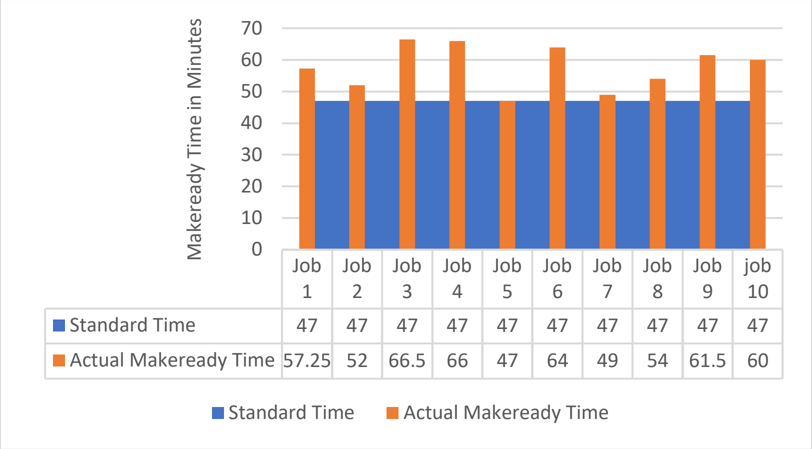

Fig.14. Comparative analysis of actual Make-ready time of ten jobs

Delays in registration were observed in nine of the ten jobs, with an average overrun of 3.3 minutes, making it one of the most consistently affected activities. Colour matching also exhibited notable variability, with six jobs requiring additional time and an average delay of 1.7 minutes. Among the ten observed jobs, only one was completed within the prescribed make-ready duration. Two jobs finished with delays of five minutes or less, while another two exceeded the standard time by up to ten minutes. The remaining five jobs experienced delays greater than ten minutes. These findings indicate that registration stability and colour calibration remain the most persistent constraints to achieving predictable make-ready performance across the ten observed jobs on the Heidelberg SM 105 and KBA Rapida 106. Paper is the most significant consumable in offset printing and typically represents the largest share of material costs. Waste generated during the make-ready stage often constitutes the majority of non-hazardous waste produced in a printing facility. The volume of this waste is largely influenced by the efficiency of quality-control adjustments required to achieve stable printing conditions, particularly through precise ink-density control and accurate registration. Consequently, reducing paper waste depends on optimizing these adjustments and maintaining consistent process control. Monitoring the relationship between waste sheets and acceptable output enables printers to evaluate material efficiency more accurately and identify opportunities for improvement during both make-ready and full production runs.Registration accuracy can be improved through systematic maintenance of rollers, grippers, and feeder mechanisms, along with proper calibration of impression and pressure settings according to the substrate characteristics. Static electricity should be controlled using appropriate antistatic measures, while automated inspection tools such as CPC systems or scanning devices—can facilitate rapid correction during pull-sheet evaluations. Gray-balance control fields should be employed for colour calibration, allowing operators to adjust ink densities to maintain neutral grays. Spectrophotometric measurements can support this process by ensuring colour deviations remain within an acceptable range ($\Delta E < 2–3$).

Closed-loop control technologies further enhance efficiency by enabling automatic pre-setting of ink zones using CIP3 data, which can reduce make-ready sheet consumption by approximately one third. Operator training also plays a critical role; adherence to standardized operating procedures including verification of packaging uniformity and proper pre-inking practices helps stabilize printing conditions. In addition, workflow automation tools, such as integrated press features available in Heidelberg systems, support faster plate mounting and efficient OK-sheet determination. Finally, maintaining stable environmental conditions and ensuring substrate consistency are essential to minimize misregistration caused by variations in moisture, dimensional stability, or web tension.

5. Conclusion

This study demonstrates the significant influence of make-ready duration on the operational performance of offset presses. By separating standard procedural tasks from mechanical elements, the analysis provides a clearer view of where time losses occur during press setup. Findings indicate that mechanical delays most of which are avoidable account for nearly half of total make-ready time, reinforcing the importance of preventive maintenance and consistent equipment monitoring. Variability in how operators execute standard make-ready tasks further suggests that clearer procedural definitions and focused skill training can reduce inconsistencies and associated downtime. The optimization measures proposed structured checklists, operator training modules, and strengthened maintenance routines show the potential to decrease make-ready time by up to 28%. Such reductions directly enhance press utilization, lower production costs, and shorten job turnaround cycles.

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References:

[1] R. Abdullah, M. N. Abd Rahman, I. Halim, N. Omar, and Y. Yusuf, "Lean Six Sigma Approach for Labor Productivity Improvement at Final Test Semiconductor Manufacturing," *Science International (Lahore),* vol. 26, no. 5, pp. 1817-1820, 2014.

[2] P. Korytkowski, A. Olejnik-Krugly, and O. Zaikin, "A Framework for a Quality Assurance in Offset Printing," *IFAC Proceedings Volumes,* vol. 42, no. 4, pp. 1875-1880, 2009/01/01/ 2009.

[3] D. Bratić, P. Miljković, D. Jurečić, and T. Grabarić, "AI-Driven Random Forest Model and the Six Sigma Approach for Enhancing Offset Printing Process and Product Quality," *Applied Sciences,* vol. 15, no. 5, p. 2266, 2025.

[4] G. Chatzistelios, E. P. Kechagias, G. A. Papadopoulos, and S. P. Gayialis, "From scientific research to industrial application: a Lean Six Sigma system for improving the bill of materials of the packaging process," *International Journal of Productivity and Quality Management,* vol. 41, no. 1, pp. 110-127, 2024.

[5] A. Kar and A. K. Pal, "An Implementation of ANOVA and Six-Sigma for Productivity Improvement in Printing Machines," *Management and Production Engineering Review,* vol. 15, no. 2, 2024.

[6] S. MAKINO, M. AKATSUKA, T. FUJIKAWA, S. SENOO, and H. KOBARA, "Quick Start Print System of Commercial Offset Press," *Mitsubishi Heavy Industries Technical Review,* vol. 41, no. 2, 2004.

[7] L. Berculescu, E. Bălan, C. Mohora, and C. Dogariu, "Some Aspects Of Optimization For Printing And Finishing Offset Processes," *Annals of the Academy of Romanian Scientists Series on Engineering Sciences,* vol. 10, no. 2, pp. 5-18, 2018.

[8] B. Kushlyk, "Adjustment of Ink and Water Supply in Offset Printing," *Journal of Materials Science and Engineering. B,* vol. 3, no. 8B, p. 545, 2013.

[9] J. Hadiwijaya, A. Situngkir, and Y. Yerta, "Optimizing The Role of Inking Unit in Offset Printing Machine," *Kreator,* vol. 6, no. 2, pp. 96-103, 07/30 2021.

[10] M. A. Saryatmo, H. J. Kristina, and R. P. Putra, "Production Quality Improvement of Duplex Carton Packaging for AA Products Using the Six Sigma and Seven New Quality Tools Methods," in *Proceedings of the 8th North American International Conference on Industrial Engineering and Operations Management*, Houston, Texas, USA, 2023: IEOM Society International.