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IMPLEMENTATION OF A CLOUD-BASED DESIGN AND MANUFACTURING SYSTEM FOR BATIK SMES IN INDONESIA

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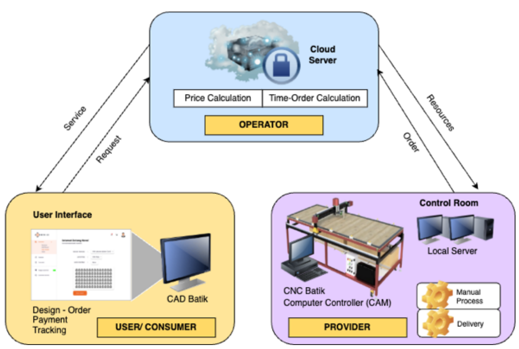
Graphical abstract



Abstract

The adoption of Industry 4.0 technologies among small and medium-sized enterprises (SMEs) in the creative sector remains limited due to resource constraints and the manual nature of production processes. This study addresses this challenge by implementing a cloud-based design and manufacturing (CBDM) system specifically developed for SMEs in the Indonesian batik industry. The system integrates a web-based Computer-Aided Design (CAD) platform, automatic cost estimation, production scheduling, and remote CNC batik fabrication. The main problem addressed in this research is the lack of efficient, scalable, and customizable digital manufacturing systems for low-volume, high-variation craft industries such as batik. The system was evaluated based on three key performance metrics: design similarity between digital and physical products, production time, and scheduling accuracy. Experimental testing was conducted on eight traditional batik motifs and 30 customer orders. The results showed an average similarity score of 71%, average production time of 18 minutes, and 86,7% scheduling accuracy. Additionally, the system achieved 89,29% operational reliability over 22 hours of production. These findings demonstrate that CBDM can effectively support custom production in traditional industries while improving efficiency and responsiveness. The system contributes to increased competitiveness, reduced production time, and greater product customization, while preserving cultural heritage through modern engineering solutions. The implementation offers a practical solution for digital transformation among ASEAN creative industries and shows potential for replication in similar SME settings across the region.

Keywords: Batik, Cloud-Based Manufacturing, Custom Design, Industry 4.0, SMEs

1.0 INTRODUCTION

Small and medium-sized enterprises (SMEs) in the creative sector, such as the batik industry in Indonesia, play a vital role in preserving cultural heritage and contributing to local economies [1], [2]. However, these enterprises often face challenges in adapting to technological advancements due to limited access to capital, infrastructure, and digital literacy [3], [4]. As consumer preferences shift toward customization and faster delivery times [5], [6], [7], [8], traditional batik production methods struggle to meet these evolving demands. A more efficient design-to-manufacturing workflow is essential.

Industry 4.0 offers opportunities for transformation through technologies such as cloud manufacturing, Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), and Computer Numerical Control (CNC) machines. By incorporating technology into batik manufacturing, both creativity and operational performance can be significantly improved [9], [10]. Yet, the adoption of these technologies among artisanal industries remains low in Southeast Asia. There is a growing need to bridge traditional production techniques with digital manufacturing systems in a way that is both accessible and culturally respectful.

Cloud-Based Design and Manufacturing (CBDM) is a service-oriented paradigm that virtualizes and delivers design and production resources over the internet [11], [12], [13], [14]. CBDM enables collaborative product development by decoupling physical manufacturing resources from geographical constraints. It supports "design anywhere, manufacture anywhere" (DAMA) scenarios by offering design platforms and fabrication tools as services through the cloud [15]. In practice, CBDM involves CAD, CAM, CNC, and cloud-based scheduling integrated into a single platform. These systems have been successfully applied in various industries such as additive manufacturing [16], ceramic production [17], and mold fabrication [18], [19]. However, applications in artisanal or culturally rooted industries remain limited.

CMfg extends CBDM by introducing a broader infrastructure layer that connects distributed resources (e.g., machines, software, human expertise) as services [20], [21], [22], [23], [24], [25], [26]. CMfg conceptualized as a manufacturing model utilizing cloud computing, Internet of Things (IoT), and Service-Oriented Architecture (SOA) to offer scalable and flexible resource management. Software-as-a-Service (SaaS) is a core component of CMfg, enabling user access to applications through browsers without requiring local installation. SaaS-based CAD systems have enhanced collaborative design and real-time data synchronization. These developments provide the technological basis for implementing integrated design-to-manufacturing systems in creative industries.

Despite the growing body of literature on CBDM and CMfg, few studies have applied these concepts to low-volume, high-variation production environments such as the batik industry. Existing research tends to focus on large-scale manufacturing or purely technical demonstrations, lacking real-world deployment and empirical validation in small-scale traditional sectors. Moreover, little is known about system performance metrics—such as similarity accuracy, scheduling reliability, or production time—in these contexts.

This study addresses that need by implementing and evaluating a CBDM system in a real-world Indonesian batik SME setting, referred to as "Batik 4.0" system. It aims to demonstrate that custom batik production can be digitally enabled to improve efficiency, product customization, and scalability. By providing a case study with performance data, the study offers a model for broader adoption of Industry 4.0 in ASEAN creative sectors.

2.0 METHODOLOGY

2.1 System Architecture

The proposed system is based on a Service-Oriented Architecture (SOA) composed of three core layers:

1. Front-End Layer: A web-based CAD interface allowing customers to input design parameters, motif preferences, and order specifications.
2. Cloud Platform Layer: Hosts a SQL database, decision support algorithm, and process monitoring modules. It estimates costs and production time, generates G-code, and schedules orders based on machine availability.
   A Representational State Transfer (REST) Web API facilitates communication between system components, consists of API payment gateway and shipping costs.
3. Manufacturing Execution Layer: Connects the cloud system to centralized control room and CNC Batik machines via local area network (LAN). CAM software and microcontroller units interpret G-code for physical execution.

The proposed CBDM framework of this project is illustrated in Figure 1, where every step of the workflow can be seen clearly. Given that batik craftsmanship adheres to the Indonesian National Standard (SNI) for batik, the integration of modern technology must align with traditional craftsmanship principles. This research introduces a novel approach by fostering collaboration between technology and manual processes (such as: dyeing, manual *canting*, etc), aiming to enhance the performance of the SMEs batik industry while preserving local traditions.

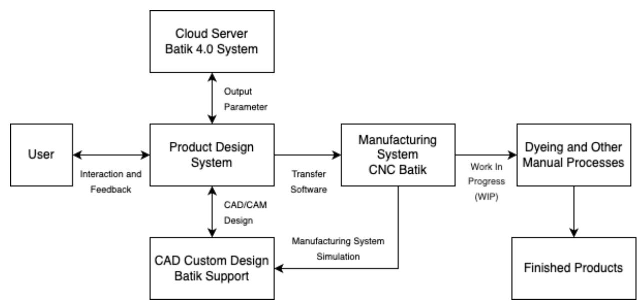


Figure 1 The framework of the proposed CBDM system (Batik 4.0)

The manufacturing system includes a centralized control room that serves as the hub for data monitoring, scheduling, and production control. The control room schema is illustrated in Figure 2. All computers in the control room (CR1 and CR2) are connected to the production floor machines via a LAN network in Figure 3, ensuring seamless data integration. Incoming orders are processed through the cloud platform and forwarded to CR1, an internet-connected computer. The cloud system automatically calculates production time, updating the estimated completion duration. Design data is then distributed from CR1 to the CNC machines based on the scheduling system. CR2 ensures the readiness of each machine, including the *canting* tools and fabric, before production begins.

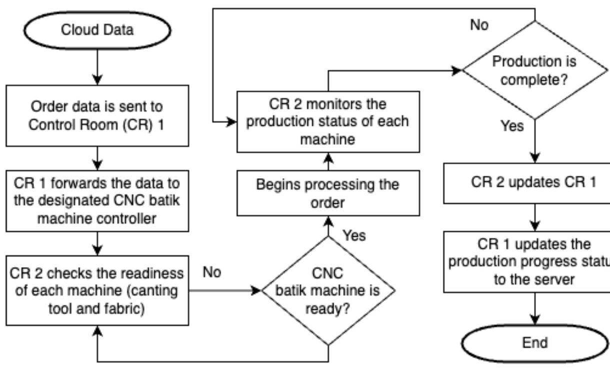


Figure 2 Control Room Schema Diagram

Figure 3 Control room and manufacturing process

2.2 Experimental Setup

The system was deployed in a batik SME facility using CNC Batik machines (model FTS-3421) with PC-based controllers. A total of eight batik motifs were selected for performance testing, ranging in complexity. For system reliability analysis, 30 customer orders were processed over a production period of 22 hours using three machines (M3, M8, and M11). The CNC batik technology shown in Figure 4.

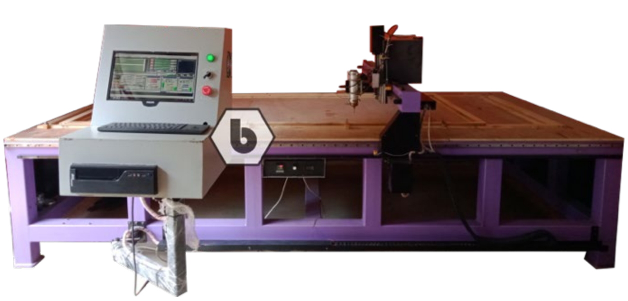


Figure 4 CNC Batik (Butimo) included Batik Frame [9]

A web-based CAD platform was developed [27], [28], [29] to enable customers or operators to create motif designs directly in-browser using vector drawing tools. Once a design is finalized, the system automatically performs cost and time estimation based on key parameters such as motif complexity, stroke length, and colors. This estimation algorithm leverages a pre-calibrated database linked to the CNC machine profiles and historical processing data, allowing users to receive real-time feedback on expected production time and associated costs before placing an order. The resulting motif file is converted to G-code and queued for scheduled manufacturing.

2.3 Evaluation Metrics

System performance was evaluated based on three major aspects: effectiveness, efficiency, and reliability. These metrics offer a comprehensive view of technical performance according to ISO/IEC 25010:2023 [30].

1. Effectiveness measured using design similarity (%), calculated via cosine similarity between digital and physical motif contours. Higher similarity indicates better design reproduction accuracy.
2. Performance efficiency using on-time delivery (%), was measured by comparing estimated completion times with actual delivery timestamps across 30 orders.
3. System Reliability: Calculated as the percentage of uptime (actual operating hours) over the total scheduled hours, accounting for downtime events including software crashes, power interruptions, and mechanical faults.

3.0 RESULTS AND DISCUSSION

3.1 Business Process and System Deployment

The Batik 4.0 system was successfully deployed in an SME facility with CNC-based batik production equipment. Customers accessed the design platform through a web application, created motif specifications (size, pattern, number of colors), and submitted orders through a cloud interface. The system automatically generated G-code, performed scheduling, and initiated remote CNC batik fabrication. The implementation and evaluation of a full-stack CBDM system in a batik SME in Yogyakarta, Indonesia.

The sequence of business processes for Cloud Manufacturing services as Software as a Service (SaaS) is explained using a Business Process Diagram (BPD) as shown in Figure 5. From this there are 3 parties that carry out business interactions with this CMfg service, namely: Users (clients), Service provider, and Payment system. The user is the person who will access this cloud service, the service provider is the party who has the right to control the service on the server, while the payment system is a third party that deals with online payments system.

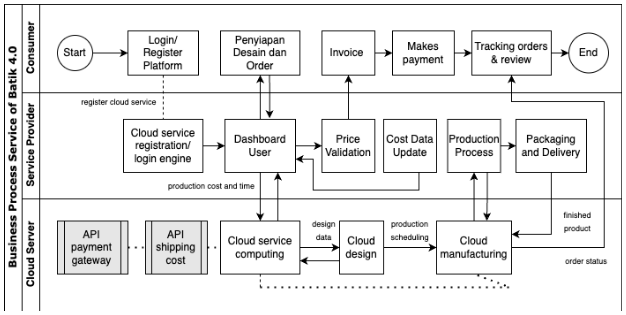


Figure 5 Business Process Custom Batik Production (Swimlane Diagram)

The business process steps can be explained as follows:

1. User registration and login, fill in biodata. 4.3.2. Users log in to the software by entering their registered Username and Password (Figure 6). Access is granted after verification by the service provider.

Figure 6 User Login

2. Users (customers) input product specifications (Figure 7) and create custom batik designs (Figure 8).

Figure 7 Website interface with SQL database for the design–manufacturer connection (English Version)

Batik 4.0 begins with customer input, where specifications such as size, pattern, color, and dyeing type. This allows for easy visualization of the product design. Within the cloud platform, each order is organized under a specific customer catalogue, and an administrator verifies any manufacturing constraints.

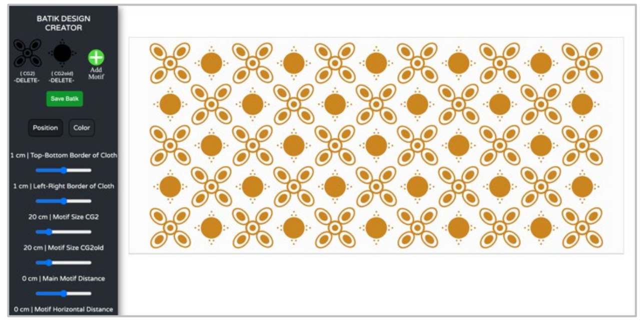


Figure 8 Create Custom Batik Designs

3. Users (customers) place orders (Figure 9)

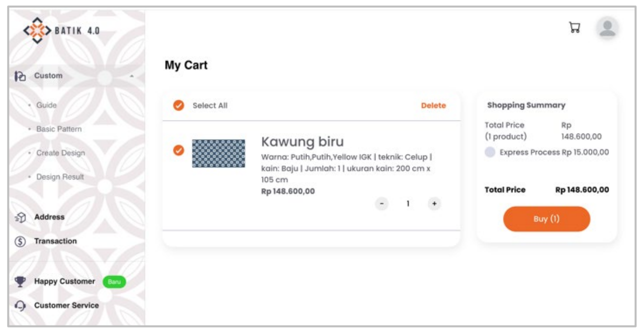


Figure 9 Place Orders

4. User makes payment, integrated with API 1 payment gateway & API 2 shipping cost (Figure 10)

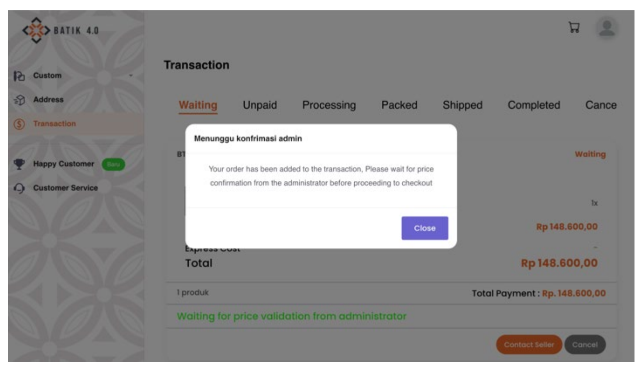


Figure 10 Makes Payment

5. After successfully completing the payment process, clients were able to track their orders in real time. Upon receiving the finished product, also provide feedback (ratings and reviews) through the platform. The Batik 4.0 for custom batik design, along with available menus and functions. The CMfg service includes functions for managing data such as saving, opening, downloading, uploading, and deleting files.

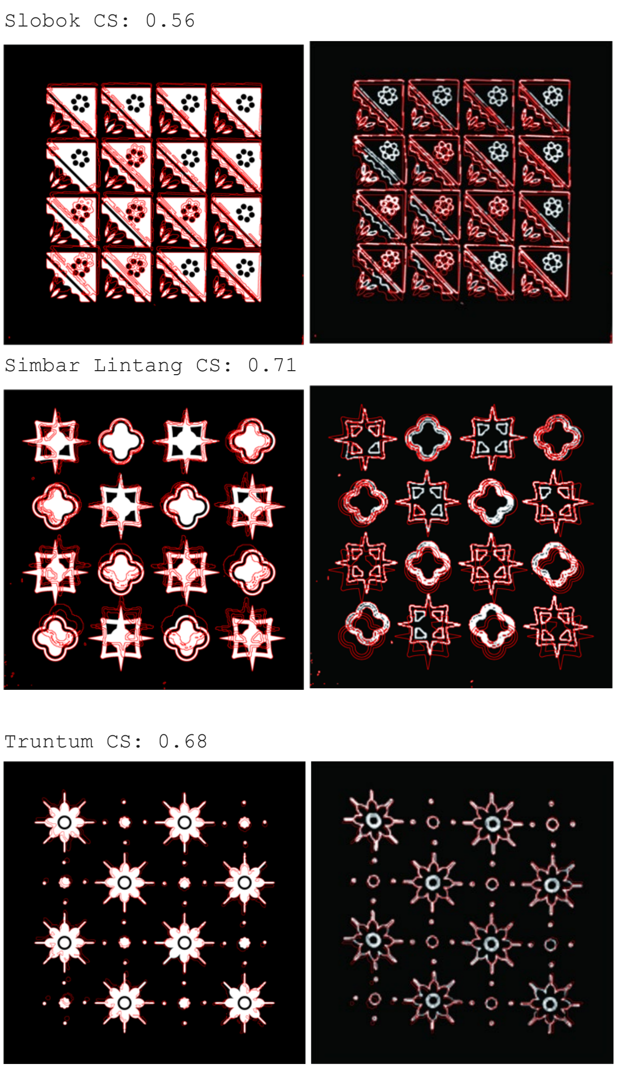
3.2 Design Similarity (Effectiveness) Evaluation

Similarity between digital designs and final products was evaluated on 8 batik motifs using a Cosine Similarity (CS) metric. As shown in Table 1, similarity scores ranged from 54% to 87%, with an average of 71%. The highest alignment was achieved for the Kawung motif (87%), while the lowest was for Nitik Sekar (54%). Higher motif complexity tended to improve similarity due to increased edge information and alignment accuracy.

Table 1 Design-Manufacture Similarity and Production Time

Motif Name	Similarity (%)	Production Time (min)
Kawung	87	20
Truntum	68	12
Ceplok Grompol	86	18
Ceplok Bintang	64	22
Nitik Sekar	54	12
Slobog	56	18
Cakar Ayam	82	22
Simbar Lintang	71	20

The average production time per motif was 18 minutes, with simpler patterns requiring 12 minutes and more complex designs up to 22 minutes. With the Batik 4.0 system, 8 batik motif design were manufactured, as shown in Figure 11.



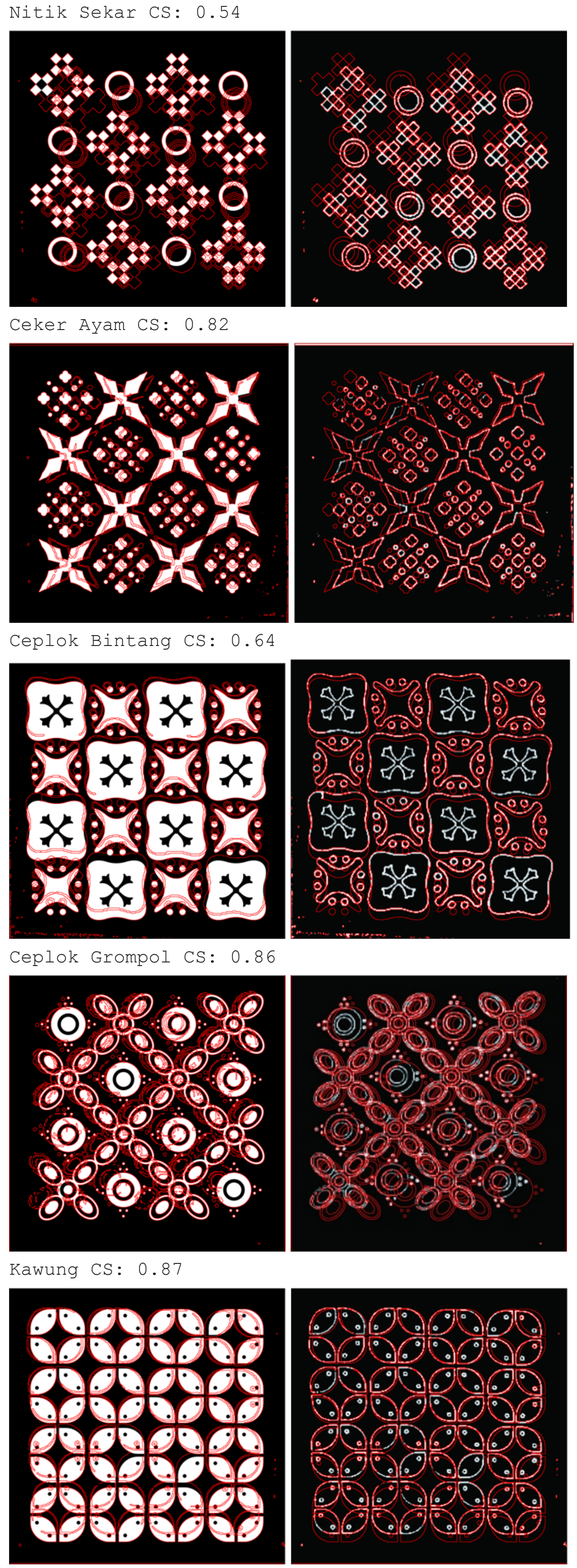


Figure 11 Batik Design and Manufacturing Results (using Batik 4.0)

The comparison was conducted by overlaying binary contour images with white pixels representing the original digital design and red overlays for output of the CNC-manufactured batik motif. The analysis focused on the outline or "*klowong*" area of the motif, which represents the outermost visual boundary typically drawn manually in traditional batik. The similarity measurement was implemented using a custom-developed Python application that utilizes image processing libraries to calculate cosine similarity between pixel vectors of the two overlapping images, as shown in Figure 12.

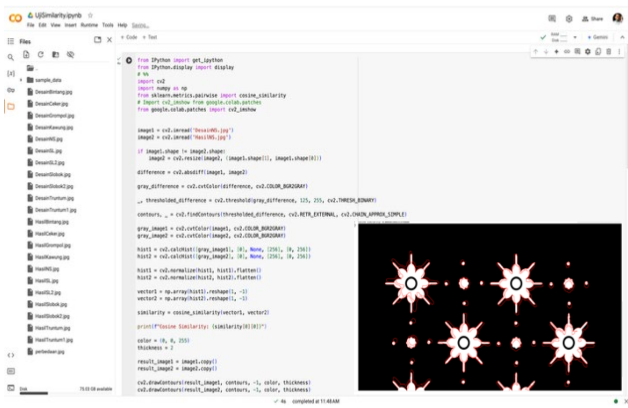


Figure 12 Similarity measurement using a custom-developed Python

This method detects the degree of alignment between contours, where perfectly matching outlines would result in a similarity value of 100%. These findings indicate that simpler or less complex designs may struggle to achieve high similarity levels, despite being more efficient in production time. The results highlight the scalability of the system for custom production scenarios.

3.3 Performance Efficiency Evaluation

A second evaluation was conducted by comparing the predicted and actual completion times of production orders. A total of 30 customer orders from various regions in Indonesia were tested using three out of eight available machines (Machines 3, 8, and 11), as the remaining five were in use for non-Batik 4.0 orders.

The on-time performance accuracy was calculated using the following equation (Eq.1):

$$= \frac{OnTime\ Orders}{Total\ Orders} \times 100\% \qquad \text{(Eq.1)}$$

$$= \frac{26}{30} \times 100\% = 86{,}7\%$$

The results, presented in Table 2, show that 26 of the 30 orders were completed on time according to the system's schedule predictions. This demonstrates that the Batik 4.0 scheduling system achieved an accuracy rate of 86,7%. The system proved effective and valid, surpassing the expected performance threshold. It indicates that Batik 4.0 can be relied upon as a scheduling solution, as it improves delivery punctuality, overcomes human limitations, and optimizes resources to deliver faster, more accurate, and flexible results.

Table 2 Machine Time Production Data

No	Order Code	Estimated Completion	Actual Completion
1	BTK-6-RK	26-Nov 2024 12:30	26-Nov 2024 12:30
2	BTK-8-RK	26-Nov 2024 15:30	26 Nov 2024 15:30
3	BTK-9-RK	26-Nov 2024 15:30	26-Nov 2024 15:30
4	BTK-30-RK	05-Dec 2024 16:36	04-Dec 2024 20:14
5	BTK-43-RK	25-Dec 2024 14:29	22-Dec 2024 09:31
6	BTK-39-RK	25-Dec 2024 14:29	19-Dec 2024 20:14
7	BTK-45-RK	25-Dec 2024 14:29	20-Dec 2024 10:01
8	BTK-44-RK	25-Dec 2024 14:29	20-Dec 2024 13:23
9	BTK-50-RK	23-Dec 2024 14:29	19-Dec 2024 16:57
10	BTK-51-RK	23-Dec 2024 14:29	23-Dec 2024 14:29
11	BTK-63-RK	25-Dec 2024 14:29	24-Dec 2024 12:15
12	**BTK-53-RK**	**23-Dec 2024 20:30**	**26-Dec 2024 20:30**
13	BTK-55-RK	23-Dec 2024 10:18	21-Dec 2024 10:18
14	**BTK-57-RK**	**23-Dec 2024 13:23**	**26-Dec 2024 13:23**
15	BTK-38-RK	24-Dec 2024 09:24	24-Dec 2024 09:24
16	BTK-58-RK	24-Dec 2024 14:33	24-Dec 2024 14:33
17	**BTK-59-RK**	**24-Dec 2024 11:49**	**27-Dec 2024 11:49**
18	BTK-61-RK	24-Dec 2024 11:23	24-Dec 2024 11:23
19	BTK-65-RK	21-Dec 2024 14:27	24-Dec 2024 14:27
20	**BTK-67-RK**	**21-Dec 2024 16:05**	**26-Dec 2024 13:23**
21	BTK-68-RK	21-Dec 2024 16:05	21-Dec 2024 16:05
22	BTK-69-RK	21-Dec 2024 15:07	21-Dec 2024 15:07
23	BTK-74-RK	27-Dec 2024 07:00	26-Dec 2024 13:23
24	BTK-75-RK	27-Dec 2024 15:59	27-Dec 2024 15:59
25	BTK-80-RK	27-Dec 2024 15:59	27-Dec 2024 15:59
26	BTK-60-RK	27-Dec 2024 13:46	24-Dec 2024 13:46
27	BTK-85-RK	28-Dec 2024 15:59	27-Dec 2024 15:59
28	BTK-88-RK	28-Dec 2024 13:23	26-Dec 2024 13:23
29	BTK-89-RK	28-Dec 2024 15:59	27-Dec 2024 15:59
30	BTK-92-RK	28-Dec 2024 10:39	27-Dec 2024 10:39

*) Western Indonesian Time – WIB Time Zone

All transaction processes were recorded in the Admin Dashboard under the "Production Process" menu, as shown in Figure 13. The system automatically updated the production status in real time according to the corresponding order code. This feature allowed administrators to monitor and ensuring traceability and alignment between the system records and actual production activities.

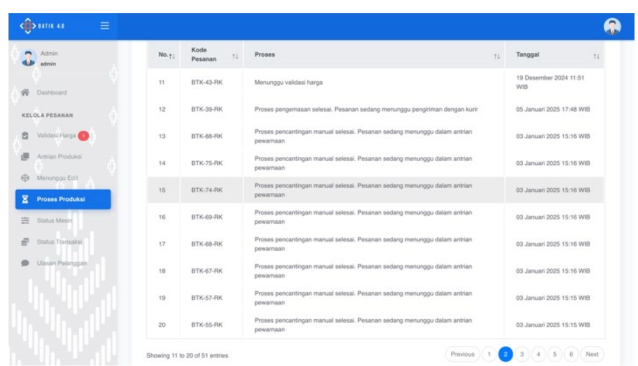


Figure 13 Production Process (Admin Dashboard)

3.4 System Reliability Testing

Reliability is a crucial aspect for online, real-time systems that are expected to operate continuously 24/7. Reliability testing was conducted to evaluate how dependable the Batik 4.0 system is in real operational conditions and to ensure its usability across various organizational levels and operational procedures. System reliability was evaluated based on recorded uptime and downtime during 22 hours of operation, as shown in Figure 14. Table 3 presents the reliability data collected from the production of ten batik products.

Table 3 System Reliability Testing

No.	Start	Finish	Duration (Hours)	Downtime (Minutes)
1	14.00	17.00	3	0
2	15.30	17.30	2	60
	08.30	10.45	2,15	0
3	09.00	13.00	4	30
4	09.00	12.25	3,25	0
5	09.00	12.15	3,15	30
6	13.55	15.55	2	30
7	13.55	16.20	2,25	0
8	13.50	15.42	1,52	30
9	15.55	18.00	2,3	0
10	10.27	12.40	2,13	0
	Total Time		22 hours	180 minutes (3 hours)

The system reliability was calculated using the following equation (Eq.2):

$$= \frac{Total\ Duration - Downtime}{Total\ Duration} \times 100\% \qquad \text{(Eq.2)}$$

$$= \frac{28-3}{28} \times 100\% = 89{,}29\%$$

This result indicates that the system achieved a reliability level (uptime) of 89,29%. The disruptions encountered during testing included ink bleeding in *"klowong"* results (machine configuration), CNC communication errors, web system errors/ software server delays, power outages, and weather-related issues. These were mitigated through backup servers and scheduled maintenance routines.

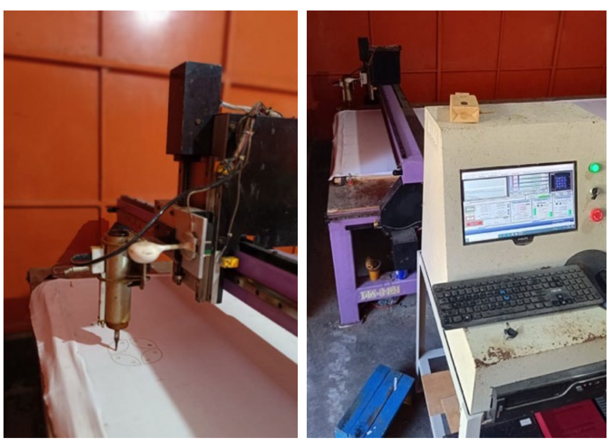


Figure 14 System Reliability Testing (Batik Manufacturing)

To improve future system reliability, these issues need to be addressed through targeted technical enhancements. For hardware reliability, preventive maintenance schedules and real-time machine diagnostics should be implemented to reduce unexpected failures. Web system errors can be mitigated through enhanced error logging and regular system updates. Furthermore, integrating an uninterruptible power supply (UPS) and implementing surge protection can help manage electrical disruptions. These improvements will be the focus of the next development phase to ensure more robust and consistent system performance in real-world conditions.

3.5 Discussion

The experimental results confirm that the Batik 4.0 system enables an effective application of cloud manufacturing concepts to traditional craft industries. With similarity scores above 70% for most motifs, the system proves capable of faithfully replicating complex manual designs through CNC automation. While the average production time of 18 minutes per unit is competitive, analysis shows that highly detailed motifs generally required more time and produced higher similarity. This suggests a trade-off between design complexity and replication accuracy, which could be addressed in future work through improved image preprocessing or AI-based optimization of tool paths.

The scheduling module achieved 86,7% accuracy despite limited machine resources, indicating a promising baseline for scalability. Further enhancements could incorporate heuristic optimization or reinforcement learning to dynamically adapt to job queues and maintenance schedules. This performance demonstrates the scheduling system's effectiveness in dynamic, multi-order environments with limited machine availability.

System reliability of 89,29% suggests reasonable robustness for continuous operation, though improvements in fault tolerance (e.g., auto-restart services, UPS) are needed for industrial-grade performance. Overall, the implementation validates that smart manufacturing technologies can be adapted to support high-variety, low-volume production models typical in artisanal contexts, bridging traditional techniques with advanced manufacturing frameworks.

3.6 User Feedback and Implementation Cost

To assess the usability and adoption potential of the Batik 4.0 system, a brief user evaluation was conducted involving three stakeholder groups: artisans (machine operators), administrators (managers), and customers (end-users). A questionnaire based on the System Usability Scale (SUS) was distributed, covering criteria such as interface clarity, ease of design input, order tracking, and satisfaction with automation performance. The SUS score averaged 78.2 across all groups, indicating high perceived usability. Artisans appreciated the simplification of motif replication, administrators valued the real-time monitoring and control room integration, while customers highlighted ease of order placement and design preview features.

In terms of implementation cost, the total cost for deploying the system (including server setup and three CNC machines) was estimated at approximately USD 7,500. This includes the local server (USD 500), three CNC batik units (USD 1,500 each), and software development for CAD platform and control dashboard. Compared to long-term labor costs and inefficiencies in manual production, the system is considered affordable and scalable for SMEs with moderate production volume.

4.0 CONCLUSION

This study presented the implementation and evaluation of a cloud-based design and manufacturing (CBDM) system in the context of the Indonesian batik industry. By integrating web-based design, automatic cost estimation, cloud scheduling, and CNC-driven production, the system successfully demonstrated how Industry 4.0 technologies can be applied to support digital transformation in creative SMEs.

More importantly, this research highlights how local creative industries, such as batik, can adopt Industry 4.0 technologies without compromising cultural values. By bridging traditional craftsmanship with modern engineering systems, this model supports digital transformation among ASEAN's artisanal SMEs. The Batik 4.0 system offers a scalable solution to promote innovation, efficiency, and competitiveness across creative sectors in Southeast Asia.

Key findings from experimental deployment in a live SME setting include:

1. The system achieved an average 71% similarity between digital motif designs and manufactured outputs, with peaks of up to 87%, validating the design fidelity of the CBDM approach. The average production time per motif was 18 minutes, confirming the system's viability for small-batch, rapid fabrication.
2. Automated production scheduling yielded 86,7% on-time completion across 30 customer orders, demonstrating reliability in managing resource-constrained operations.
3. An uptime of 89,29% was recorded over 22 hours of production, suggesting stable system performance with room for technical improvements.

Collectively, these results demonstrate that cloud-based design and manufacturing platforms can be effectively adapted for use in traditional craft industries, providing increased efficiency, accuracy, and scalability without sacrificing cultural authenticity. The following avenues are recommended for future research and system development:

1. CNC toolpath optimization by implement AI-based motif simplification and toolpath generation to improve accuracy and reduce production time.
2. Scalability and multi-site integration, expand the platform to support multi-site batik producers, enabling distributed manufacturing and collaborative via cloud infrastructure.
3. Real-Time quality control by integrate computer vision-based inspection systems for in-process quality assurance and adaptive correction mechanisms.
4. User experience studies by conduct usability testing with both artisans and consumers to refine the web-based interface and improve user interaction with design tools.
5. Economic and environmental impact analysis by evaluate the economic, cost-benefit ratio, and energy efficiency of cloud-enabled production compared to traditional batik methods to assess sustainability.

This study contributes to the field of advanced manufacturing in several key ways:

1. Demonstrates the first real-world implementation and evaluation of a cloud-based manufacturing system in the SMEs traditional batik sector.
2. Introduces a fully integrated design-to-production pipeline using open web technologies and CNC batik automation.
3. Provides a performance benchmark—across similarity, accuracy, time, scheduling, and reliability—for future digital manufacturing systems in creative industries.
4. Offers a transferable framework for deploying low-cost, scalable Industry 4.0 solutions in high-variety, low-volume production settings.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

References

[1] UN Trade and Development (UNCTAD), 2024. "Creative Economy Outlook 2024," United Nations, New York,

[2] D. Andansari, K. H. Bin Kamarudin, D. Shyafary, and H. Pristanti, 2023. "Innovation of craft and batik products in the industrial revolution 4.0 era in Indonesia," in *AIP Conference Proceedings*, American Institute of Physics Inc., DOI: 10.1063/5.0120511.

[3] S. I. Syed Shaharuddin *et al.*, 2021, "A Review on the Malaysian and Indonesian Batik Production, Challenges, and Innovations in the 21st Century," *Sage Open*, 11(3): 1–19. DOI: 10.1177/21582440211040128.

[4] Y. A. Rochman, A. Sudiarso, and M. K. Herliansyah, 2024, "Development of Lean Implementation Framework for Indonesian Batik Small and Medium-Sized Enterprises," *International Journal of Engineering, Transactions B: Applications*, 37(11): 2223–2238, DOI: 10.5829/ije.2024.37.11b.09.

[5] R. A. Rahadi, D. Rahmawati, N. Armelia Windasari, and P. Fajarinda Belgiawan, 2020, "The Analysis of Consumers' Preferences for Batik Products in Indonesia," *Review of Integrative Business and Economics Research*, 9(1): 278–287, DOI: https://doi.org/10.58745/riber.

[6] W. Wibawanto, Triyanto, A. Cahyono, and T. R. Rohendi, 2020, "Digital Innovation for Traditional Batik Crafter," *PEOPLE: International Journal of Social Sciences*, 6(2): 568–574, DOI: 10.20319/pijss.2020.62.568574.

[7] E. E. Pujiastuti, H. S. Utomo, Suratna, and S. Haryono, 2023, "Breaking Down Consumer Preferences: What Drives the Millennial Generation's Choices in Batik Clothing?" in *International Conference on Advance Research in Social and Economic Science (ICARSE)*, 39–46. DOI: 10.2991/978-2-38476-048-0_5.

[8] A. Mekaniwati, A. T. Bon, B. Rainanto, and E. Lulaj, 2023, "Sustainable Performance for Batik Small and Medium Enterprises Viewed from Dynamic Capabilities, Marketing Orientation and Green Marketing," *Central European Management Journal*, 31(2): 639–652, DOI: 10.57030/23364890.cemj.31.2.66.

[9] A. Sudiarso and R. Kusumawardani, 2018. "Implementation of Batik Machine to Improve Hand - Drawn Batik Production Time," *International Conference on Community Engagement and Education for Sustainable Development (ICCEESD)*, 24: 150–157

[10] D. S. E. Atmaja, H. Herianto, M. K. Herliansyah, and A. Sudiarso, 2023, “Bibliometric Analysis: Research on Batik in International Publications,” *International Journal of Innovation in Enterprise System*, 7(02): 134–144. DOI: 10.25124/ijies.v7i02.226.

[11] D. Wu, D. W. Rosen, L. Wang, and D. Schaefer, 2015, “Cloud-based design and manufacturing: A new paradigm in digital manufacturing and design innovation,” *CAD Computer Aided Design*, 59: 1–14, DOI: 10.1016/j.cad.2014.07.006.

[12] D. Schaefer, 2014. *Cloud-Based Design and Manufacturing (CBDM): A service-oriented product development paradigm for the 21st century*, Springer International Publishing, DOI: 10.1007/978-3-319-07398-9.

[13] Y. Wu, F. He, D. Zhang, and X. Li, 2018, “Service-Oriented Feature-Based Data Exchange for Cloud-Based Design and Manufacturing,” *IEEE Transactions On Services Computing* 11(2): 341–353, DOI: 10.1109/TSC.2015.2501981.

[14] D. Wu, D. W. Rosen, and D. Schaefer, 2014, “Cloud-based design and manufacturing: Status and promise,” in *Cloud-Based Design and Manufacturing (CBDM): A Service-Oriented Product Development Paradigm for the 21st Century*, 1–24. Springer International Publishing. DOI: 10.1007/978-3-319-07398-9_1.

[15] K. Cheng and R. J. Bateman, 2008, “e-Manufacturing: Characteristics, applications and potentials,” *Progress in Natural Science*, 18(11): 1323–1328, DOI: 10.1016/j.pnsc.2008.03.027.

[16] M. A. Rahman *et al.*, 2022, “A Cloud-Based Cyber-Physical System with Industry 4.0: Remote and Digitized Additive Manufacturing,” *Automation*, 3(3): 400–425. DOI: 10.3390/automation3030021.

[17] P. K. Fergiawan, P. W. Anggoro, A. T. Yuniarto, K. B. Purwanto, and O. D. W. Widyanarka, 2020, “Ceramic Jewelry with Texture and Ornament Islamic Pattern and Batik Indonesia—Design, Manufacturing, and Fabrication,” in *Lecture Notes in Mechanical Engineering*, 723–733 Springer Science and Business Media Deutschland GmbH. DOI: 10.1007/978-981-15-4481-1_69.

[18] S. Rianmora and C. Raksiri, 2022, “A Development of Computer Aided Program for Aluminium Die-Casting Mold Design,” *Engineering Journal*, 26(3): 51–69. DOI: 10.4186/ej.2022.26.3.51.

[19] S. Rianmora, N. Samorhom, and W. Chaidilok, 2024, “Utilizing CNC Router Machine to Construct a Prototype Incorporation Principles of Solid-based Rapid Prototyping Process and Interlocking Brick Design,” *Engineering Journal*, 28(8): 13–31, DOI: 10.4186/ej.2024.28.8.13.

[20] D. Wu, M. J. Greer, D. W. Rosen, and D. Schaefer, 2013. “Cloud manufacturing: Strategic vision and state-of-the-art, *Journal of Manufacturing Systems*, 32(4): 564-579, DOI: 10.1016/j.jmsy.2013.04.008.

[21] R. Henzel and G. Herzwurm, 2018, “Cloud Manufacturing: A state-of-the-art survey of current issues,” in *Procedia CIRP*, 947–952.Elsevier B.V. DOI: 10.1016/j.procir.2018.03.055.

[22] I. Jacob, Y. Lu, and X. Xu, 2022, “Cloud Manufacturing - An Overview of Developments In Critical Areas, Prototypes, and Future Perspectives,” in *IFAC-PapersOnLine*, 643–648. Elsevier B.V. DOI: 10.1016/j.ifacol.2022.09.474.

[23] K. Mubarok and M. K. Umami, 2020, “Cloud Manufacturing: An Approach to Strengthen Global Competitiveness of the Indonesian Small and Medium Manufacturing Enterprises,” in *Proceedings of the International Conference on Culture Heritage, Education, Sustainable Tourism, and Innovation Technologies (CESIT 2020)*, 185–192. DOI: 10.5220/0010305900003051.

[24] C. Ellwein, S. Neff, and A. Verl, 2020, “Cloud manufacturing: An automated literature review,” in *Procedia CIRP*, 251–256. Elsevier B.V. DOI: 10.1016/j.procir.2020.01.006.

[25] X. Vincent Wang, L. Wang, and M. Givehchi, 2015, “ICMS: A Cloud-Based System for Production Management,” n Advances in Production Management Systems: Innovative Production Management Towards Sustainable Growth (APMS), 460: 444–451, Springer International Publishing, DOI: 10.1007/978-3-319-22759-7_52.

[26] L. Zeballos and O. Quiroga, 2017. “From Computer Integrated Manufacturing to Cloud Manufacturing,” *International Journal of Computer Integrated Manufacturing,* 30(6): 501–515, DOI: 10.1080/0951192X.2014.902105.

[27] N. Suparmanto, A. Maria, S. Asih, A. Sudiarso, and I. Santoso, 2024. “The Design and Evaluation of CAD Custom Batik User Interface,” *International Journal on Advanced Sciences Engineering Information Technology* 14(2): 439–450. DOI: 10.18517/ijaseit.14.2.18807.

[28] N. Suparmanto, A. M. Sri Asih, A. Sudiarso, and E. Permanasari, 2024, “Pricing Decision System for Custom Design Batik,” *International Journal on Informatics Visualization (JOIV)*, 8(1): 123–133, DOI: 10.62527/joiv.8.1.2000.

[29] N. Suparmanto, A. M. S. Asih, A. Sudiarso, and P. I. Santosa, 2024, “Interface design features and evaluation of batik 4.0 mobile application,” *Indonesian Journal of Electrical Engineering and Computer Science*, 33(3): 1604–1619, DOI: 10.11591/ijeecs.v33.i3.pp1604-1619

[30] ISO/IEC 25010. 2023. “Systems and software engineering-Systems and software Quality Requirements and Evaluation (SQuaRE)-Product quality model,” Switzerland, 23AD.