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ANALYSIS OF THE NEEDS FOR A SMART WAREHOUSE MANAGEMENT SYSTEM MODEL BASED ON MICROSERVICES ARCHITECTURE: A CASE STUDY OF LEARNING MATERIAL DISTRIBUTION AT THE UNIVERSITAS TERBUKA

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Abstract

As a higher education institution with an open and distance learning system, Universitas Terbuka (UT) faces a major challenge in distributing Printed Teaching Materials (BAC) as the number of students reaches 671,000 by the end of 2024. This growth has led to increasingly complex supply chain management needs, including forecasting, production, warehousing, distribution, and SLA monitoring processes. This study aims to analyze the need to develop a microservices-based Smart Warehouse Management System (SWMS) in the PARAMITA program to improve the efficiency, transparency, and security of BAC distribution. The research method used a qualitative case study, incorporating observation, semi-structured interviews, focus group discussions, and data analysis through thematic coding using Atlas.ti. The results of the study show that the main challenges include forecasting risks, multi-vendor system integration, differences in SLA definitions, limited monitoring transparency, student data security, and system scalability towards the target of 1 million students. The conceptualization of the resulting SWMS model emphasizes real-time data integration, predictive planning modules, delivery orchestration with providers, and an integrated customer service hub. These findings are expected to strengthen data-driven decision-making, improve operational efficiency, and support UT's digital learning ecosystem.

Keywords: Smart Warehouse Management System, Microservices Architecture, Logistics Management

1 INTRODUCTION

As a university that implements an open and distance learning system, Universitas Terbuka (UT) has a strategic role in providing broad access to higher education. With a total of 671,000 students at the end of 2024, UT is among the top five universities with the highest number of students in the world (detik.com, 2024). This situation requires UT to develop a digital-based education ecosystem to ensure the quality of academic services and achieve international standards (Tapscot, 2015; RPJP UT 2021–2035). The digitisation of the education system has proven to be an important factor in expanding access, improving quality, and strengthening the governance of cyber university-based higher education institutions (Pudhail & Baihaqi, 2020).

The growth in the number of students directly impacts the increasing need for Printed Teaching Materials (BAC). In 2023 alone, UT recorded the distribution of more than 6.8 million copies of BAC, while also obtaining a MURI record as the largest provider of teaching materials (MURI, 2023). This volume is expected to increase in line with the target of 1 million students in 2025. The main challenge faced is the management of the supply chain and distribution of BAC on a national scale to ensure timely, accurate, and efficient delivery (Osterwalder & Pigneur, 2010).

The high scale of BAC distribution without an adaptive logistics management system has the potential to cause delays, cost inefficiencies, and a decline in academic service quality. This is further complicated by Indonesia's vast geographical conditions and the need for real-time distribution monitoring. Previous studies have shown that without technology-based innovation, warehouse and supply chain management tends to face obstacles regarding efficiency, sustainability, and limitations in predictive analytics (Fatimatuh Zahroh et al., 2025; Wen Ding, 2013). Thus, the fundamental cause lies in the limitations of conventional distribution systems that are not yet integrated with big data analytics, the Internet of Things (IoT), or artificial intelligence (AI) (Wang et al., 2019; Sharma & Singh, 2020).

To address these challenges, UT developed the PARAMITA (Pengiriman Bahan Ajar ke Mahasiswa Tepat dan Akurat or Precise and Accurate Delivery of Teaching Materials to Students) Programme as a form of Smart Warehouse Management System (SWMS) innovation. This system is based on Service Oriented Architecture (SOA) and microservices architecture to support scalability, reliability, and integration with various academic and non-academic applications (Papazoglou & van den Heuvel, 2007; Faber, 2013). Microservices have been proven to increase system flexibility compared to monolithic models, as shown in case studies of implementation in smart campuses and digital marketplaces (Suryotrisongko, 2017; Sinambela et al., 2021). With the support of this technology, UT is not only able to ensure the accuracy of BAC distribution, but also optimise space, time, and operational costs while supporting the principle of sustainability (Zailani et al., 2012).

1.1 Supply Chain Theory

The supply chain is defined as a network of organisations that manages the flow of goods, information, and resources from suppliers to end consumers (Chopra & Meindl, 2016). In the context of UT, the supply chain includes the process of printing Printed Teaching Materials (BAC), storage in warehouses, and distribution to students throughout Indonesia as end customers. The complexity of UT's supply chain is very high because the scale of distribution reaches millions of copies per year, requiring an efficient, integrated, and adaptive management system.

SCM theory emphasises six drivers of the supply chain, namely facilities, inventory, transportation, information, sourcing, and pricing (Chopra & Meindl, 2016). In the case of UT, facilities consist of central warehouses and regional units, inventory consists of BAC, and transportation is carried out through national logistics partners. Information is key, as the PARAMITA system, a Smart Warehouse Management System, functions to monitor the distribution flow in real time. Thus, the integration of these drivers through a microservices architecture can support more responsive supply chain management. Additionally, the theories of Lean Supply Chain (Womack & Jones, 2003) and Green Supply Chain (Zailani et al., 2012) are relevant for improving efficiency and sustainability. Lean emphasises reducing waste in the form of delays, excessive distribution costs, or inappropriate stock levels. Meanwhile, Green SCM emphasises sustainability, such as reducing print waste, minimising redistribution due to errors, and optimising distribution routes to save energy. With this approach, UT can ensure cost efficiency while supporting environmentally friendly practices.

Furthermore, the concept of Digital Supply Chain in the Industry 4.0 era (Wang et al., 2019) emphasises the integration of technologies such as big data analytics, IoT, and AI to create an adaptive and data-driven supply chain. The implementation of PARAMITA with a microservices architecture supports this transformation, as it enables the UT system to manage BAC distribution in a flexible, measurable, and integrated manner with the digital learning ecosystem. Thus, SCM theory not only explains the supply chain framework but also provides a conceptual basis for digital innovation in supporting academic services at UT.

2 METHOD

This study utilised a qualitative case study approach. Data collection was conducted through observation, semi-structured interviews, and focus group discussions. Respondents in this study were leaders of service providers in the PARAMITA programme. The collected data were then triangulated to ensure validity and subsequently analysed using thematic coding techniques. Data processing was carried out with the help of Atlas.ti software, which supports the coding and categorisation of themes. The analysis included identifying word frequency to find patterns in the emergence of key concepts, as well as exploring the relationships between codes to

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understand the connections between themes that emerged from the empirical data. In this way, qualitative data can be processed systematically to produce more in-depth findings.

3 FINDINGS AND DISCUSSION

Based on the results of the collection and analysis, the dimensions used for the development of microservice architecture-based SWMS are as follows:

3.1 System Requirements & Integration

Both Respondents agreed that integration between systems is necessary in the distribution of teaching materials. This distribution is carried out between all data on the provider in the API to make it more efficient.

"Kita pengennya itu semua data itu kita satukan di satu rumah… Cukup lewat satu sistem dengan API (We want to consolidate all the data in one place... Just through one system with an API)" (Respondent 1)

However, implementation in the field is still hampered by manual distribution via delivery/shipping services with various obstacles, such as SLAs, unclear addresses, and geographical factors. Meanwhile, Respondent 2 stated that they are more advanced, having developed the SIMBA system, a microservices-based system connected to 3PL via API that provides real-time monitoring of production, stock, and distribution.

"Kami kembangkan sistem SIMBA (Sistem Informasi Manajemen Bahan Ajar), tujuannya monitoring progress produksi, stok, paket, hingga status pengiriman ke mahasiswa (We developed the SIMBA (Teaching Material Management Information System) system, which aims to monitor the progress of production, stock, packages, and delivery status to students)" (Respondent 2)

3.2 Production & Forecasting

Forecasting is both a strategic and problematic issue. Respondent 1 stated that the risk of overprinting or underprinting is borne entirely by the provider. In the event of overprinting, the provider cannot sell the books because the copyright belongs to UT. Similarly, underprinting

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can result in delivery delays because the provider must reprint when there is a shortage of books, which will inevitably increase costs.

"Forecasting ini yang paling penting. Kalau lebih atau kurang, risikonya di penyedia. Padahal buku ini hak ciptanya UT, jadi tidak bisa dijual lagi (This forecast is the most important thing. If it is more or less, the risk lies with the provider. However, the copyright for this book belongs to UT, so it cannot be sold again)" (Respondent 1)

This situation means that suppliers really have to recalculate during the negotiation process because they feel they are bearing risks that cannot be fully controlled. On the Respondent 2 side, the production process has been digitised, although it is still in its early stages and is developing according to user needs. They stated that

"Proses create-nya masih development… kebutuhan user di lapangan seperti apa itu juga masih, ya sambil jalan kita lihat (The creation process is still under development... user requirements in the field are still unclear, so we will see as we go along)"
This means that an adaptive forecasting and demand planning system integrated with real-time student data is urgently needed by both parties.

3.3 Distribution & SLA

Distribution via delivery/shipping services poses a major challenge for providers. Differences in expectations regarding Service Level Agreements (SLAs) often cause tension, as UT calculates SLAs from the moment the Delivery Order (DO) is issued, while providers feel that the time required to prepare goods has not been taken into account.

"Yang terkait SLA jadi atas SLA yang H0 nya atau H1 nya itu dihitung ketika DO sudah turun. Padahal kita belum tau nih kapan untuk menyiapkannya (The SLA is related to the SLA, so the H0 or H1 is calculated when the DO has decreased. However, we do not yet know when to prepare it)" (Respondent 1)

In addition, field conditions such as flooding and unclear student addresses further complicate the distribution. Respondent 2 stated that they had integrated the system with 3PL and implemented a penalty mechanism if the SLA was violated.

"Kita ada monitoring SLA… Kalau terlambat, kita kenakan denda ke 3PL (We monitor SLAs... If there are delays, we impose fines on 3PLs)."

However, coordination with 3PLs continues to face obstacles due to differences in the technical readiness of each shipping company's information systems. Some 3PLs are already familiar with system integration, but others are not yet accustomed to it.

"Ada beberapa 3PL yang mungkin juga baru… jadi masih ada penyesuaian di API-nya waktu itu (There are several 3PLs that may also be new... so there are still adjustments to be made to the API at that time)"

3.4 Technology & Infrastructure

Respondent 1 has used the internal PROTEUS system for inventory and quality control, despite initially encountering server overload issues.

"Awal-awal kita memang, servernya gak kuat, Tapi akhirnya investasi (At first, our server wasn't powerful enough, but eventually we invested in it)" (Respondent 1)

Respondent 2 stated that their system was more stable with a Linux-based server and SQL Server database, which enabled real-time data updates and API integration.

"Servernya kita basenya Linux… Untuk database kita pake Microsoft SQL Server… Update data real-time (Our server is Linux-based... For the database, we use Microsoft SQL Server... Real-time data updates)" (Respondent 2)

With more established infrastructure, Respondent 2 stated that they were able to provide more transparent services for UT, while Respondent 1 still needed to strengthen their technological capacity.

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3.5 Data Security

Data security is an important and crucial area in communications between UT and providers. Respondent 1 relies on SOPs for data protection, document destruction, and access restrictions to critical or data-related processes.,

"Untuk keamanan data… Harus ada pemusnahannya… PIC tertentu saja yang boleh akses (For data security... It must be destroyed... Only certain PICs are allowed access)" (Respondent 1)

Meanwhile, Respondent 2 placed greater emphasis on technical aspects such as user authentication, API keys, firewalls, and role-based access.

"Keamanan data dijaga lewat autentikasi user, firewall, role access API… Data tidak boleh dimanipulasi (Data security is maintained through user authentication, firewalls, role access APIs, etc. Data must not be manipulated)" (Respondent 2)

Nevertheless, both Respondents faced demands from UT to comply with ISO standards and the Personal Data Protection Act. Respondent 2 noted differences in understanding the details regarding the level of security required by UT.

"UT kan sekarang menerapkan ISO… Jadi aplikasi yang dikembangkan partner harus sampai ke sana… Isunya sampai ke keamanan dan dokumentasi (UT is now implementing ISO... So applications developed by partners must comply with it... The issue is security and documentation)" (Respondent 2)

3.6 Experience & Benchmark

In terms of experience, Respondent 1 said that his party had handled large projects such as procurement based on SIPLah (School Procurement Information System) and the distribution of general election ballots, but they admitted that the virtual warehouse model used for UT was something new.

"Sebenarnya kalau yang seperti UT kita belum pernah, cuma kalau yang semacam gudang virtual terus terang ini hal yang baru buat kami (Actually, we have never had anything like UT before, but virtual warehouses are something new for us, to be honest)" (Respondent 1)

In contrast, Respondent 2 has a longer track record in school book distribution, and SIMBA is specifically designed for UT.

"Buku kami memang PT Gramedia juga mencetak buku sekolah… SIMBA dibuat khusus untuk UT (Our books are indeed printed by PT Gramedia, which also prints school books... SIMBA was created specifically for UT)" (Respondent 2)

3.7 Quality Control (QC)

Quality control is also a concern. Respondent 1 highlighted the need for strict supervision to ensure that the printed results meet UT standards in terms of binding and finishing.

"Buku kami memang sudah diupayakan mengikuti kualitas yang diinginkan UT (We have endeavoured to ensure that our book meets the quality standards required by UT)" (Respondent 1)

Meanwhile, Respondent 2 has integrated production data with stock and delivery orders, thereby minimising quality gaps.

"Produksi & racikan sudah digital, data produksi terintegrasi dengan stok dan DO (Production and formulation are digitalised, with production data integrated with stock and delivery orders)" (Respondent 2)

3.8 Monitoring & Transparency

Monitoring of distribution by Respondent 1 is still manual and multi-layered. The student complaint process is often lengthy because it must go through UT before being forwarded to the provider or shipping company.

"Selama ini kita laporan ke mahasiswa diteruskan ke UT, baru dari UT ke Temprina, Temprina lagi ekspedisi lagi… Jadi muter terus padahal harusnya bisa dipangkas (Until now, we have

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been reporting to students, then forwarding it to UT, then from UT to Temprina, then Temprina sends it on again... So it keeps going round and round when it should be cut short)" (Respondent 1)

Conversely, Respondent 2 have provided a real-time dashboard through SIMBA, which makes it easier for UT to directly monitor delivery status and warehouse stock.

"Hasil produksi kami yang sudah siap kirim dapat dipantau secara real-time pada dashboard terintegrasi kami (Our ready-to-ship production results can be monitored in real time on our integrated dashboard)" (Respondent 2)

3.9 Communication

Communication is a central challenge. Respondent 1 said that his party faced a long and layered communication flow, as well as disagreements regarding SLAs and forecasting, which made providers feel burdened.

"Kami memang pada tahap awal menghadapi tantangan komunikasi yang panjang dan memakan waktu (We are indeed in the early stages of facing a long and time-consuming communication challenge)" (Respondent 1)

On the other hand, Respondent 2 stated that they faced communication challenges in the form of UT requirements that were often not well defined from the outset. In addition, both Respondents experienced coordination issues with shipping/delivery services, adding to the complexity, and data security standards also became a strategic communication issue.

"Kadang user juga masih samar-samar nih, dia butuhnya apa sih… Setelah jadi kelihatan, baru masukan tambahan muncul (Sometimes users are still vague about what they need... Once it becomes clear, additional input will appear)" (Respondent 2)

3.10 Conceptual Framework

The factors that are necessary for SWMS development in the previous section are organised into a conceptual framework, which involves stakeholders, processes, main tasks and functions, and challenges faced in the distribution of teaching materials at the UT.

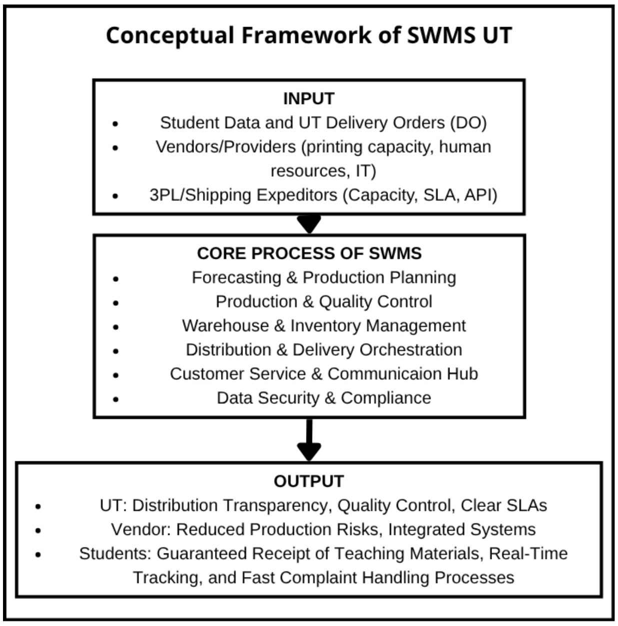

Figure 1. Conceptual framework related to needs and challenges, and analysis

This framework was also developed to address the main challenges identified from interviews with UT teaching material providers. These challenges include differences in expectations regarding SLA calculations, inaccurate forecasting, and lengthy communication processes. The distribution process also faces external obstacles such as flooding, unclear addresses, or students not being at home at the time of delivery. In addition, UT's system requirements are often dynamic and change midway, requiring providers to constantly adapt. The framework in Figure 1 is outlined in Table 1 below:

Table 1. UT SWMS requirements framework

Stages	Process and Data Details	Explanation
Input	- Student Data and Delivery Orders from UT - Student registration, - Delivery order list, address, telephone number, - Number of teaching materials to be printed. - Vendor/Provider	The SWMS development process stems from three main sources of requirements. 1) Student data and order documents (OD) generated by UT as the basis for planning the number of teaching materials to be printed and their distribution addresses. 2) Providers with printing capacity, internal systems, and IT infrastructure to support production and distribution.

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Stages	Process and Data Details	Explanation
	- Printing capacity, internal human resource system, and IT infrastructure. - 3PL/Shipping, delivery capacity, SLA, API integration.	3) Shipping partners or 3PLs that play a role in delivering teaching materials to students with service capacity, SLA, and 4) The readiness of various API integration systems.
Core Process	- Forecasting & Production Planning - Production & Quality Control - Warehouse & Inventory Management - Distribution & Delivery Orchestration - Customer Service & Communication Hub - Data Security & Compliance	1) Forecasting and production planning, namely a forecasting module that uses real-time data from UT to reduce the risk of over- or under-printing that has been borne by vendors. 2) A digital production and quality control (QC) module enables automatic recording of binding, finishing, and print results to ensure quality. 3) The printed results are then entered into the warehouse and inventory management module to monitor stock and link production data with order documents. 4) The process continues to distribution and delivery orchestration, which manages shipments through API integration with various delivery services, calculates SLAs based on goods ready for shipment, and provides real-time tracking. 5) A customer service and communication hub is required to serve as a single portal between UT, production providers, delivery providers, and students, thereby expediting the complaint process. 6) The entire process is reinforced by a data security and compliance module that ensures user authentication, firewalls, role-based access, and compliance with ISO 27001 standards and the Personal Data Protection Act.
Output	- UT: Transparency of the distribution process, clear SLAs, and print quality control. - Providers: more accurate forecasting, reduced production risks, lighter communication load, smoother system integration,	The development and implementation of SWMS is expected to provide broad benefits for student services at UT. 1) UT, as the owner, will obtain a production and distribution process with good governance and good product quality. 2) Providers will be assisted with more accurate planning, reduced risks in production and delivery, and faster communication and reporting.

Stages	Process and Data Details	Explanation
	clear SLAs, and automatic penalty monitoring. - Students: certainty of when teaching materials will be received, real-time information, and faster complaint channels.	3) Students will receive certainty regarding the timing of instructional materials, accompanied by real-time information and faster complaint channels.

Source: Processed data, 2025

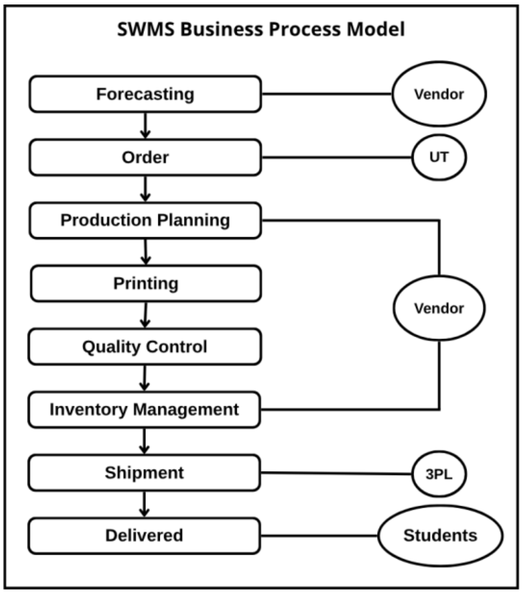

Figure 2. SWMS Business Process Model

4 CONCLUSION

This study concludes that BAC distribution at the Universitas Terbuka requires an integrated smart warehouse management system to address the increasing complexity of the supply chain. The main challenges identified are accurate forecasting, integration between provider systems, differences in SLA expectations, monitoring that is not yet transparent, protection of sensitive student data, and system scalability in the face of surges in demand. By utilising a microservices architecture, SWMS PARAMITA can provide real-time data-based forecasting modules, digital quality control, API integration with providers, a customer service hub for one-stop communication, and data security systems compliant with ISO 27001 and the Personal Data Protection Act. The implementation of this model is expected to improve efficiency, distribution speed, student satisfaction, and the competitiveness of UT.

5 CONTRIBUTIONS

5.1 Theoretical Contributions

- Expanding the application of Supply Chain Management, Lean SCM, and Digital Supply Chain theories in the context of open higher education.
- Providing a conceptual framework for the integration of microservices in the distribution system of teaching materials in the higher education sector.

5.2 Practical Contribution

- Providing a microservices-based SWMS design blueprint for UT.
- Providing technical recommendations for predictive forecasting, multi-vendor integration, digital SLAs, and data security.

6 RESEARCH LIMITATIONS

This study has limitations in terms of the number of respondents, which only involved primary providers, so it does not represent all UT distribution partners. In addition, the analysis is still descriptive and qualitative in nature, without direct operational testing of the SWMS system. The generalisation of findings is also limited to the UT context, so its application to other educational institutions requires further adjustment. Future research could expand the number of respondents, conduct a pilot project on SWMS implementation, and measure the quantitative impact on cost efficiency, SLA, and student satisfaction.

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